**BACHELOR THESIS & COLLOQUIUM – ME141502**

# EXPERIMENTAL STUDY OF CHARCOAL FILTER AND UV RADIATION AS BALLAST WATER TREATMENT SYSTEM

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DEPARTMENT OF MARINE ENGINEERING

FACULTY OF MARINE TECHNOLOGY

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**SKRIPSI – ME 141502**

# STUDI EKSPERIMEN PADA FILTER ARANG DAN RADIASI SINAR UV SEBAGAI SISTEM PENGOLAH AIR BALLAS

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**APPROVAL FORM**

**EXPERIMENTAL STUDY OF CHARCOAL FILTER AND UV RADIATION AS BALLAST WATER TREATMENT SYSTEM**

**BACHELOR THESIS**

Submitted in fulfillment of the requirement for the degree of Bachelor in Engineering
at
Marine Operation and Maintenance (MOM) Laboratory
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

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Himawan Abrarri Sutanto

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**Experimental Study of Charcoal Filter and UV Radiation as Ballast Water Treatment System**


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## Abstract

Ship are widely used by means of transportation, especially in areas or region that has surrounded by sea. Ships moves over 80% of the world's commodities and transfers approximately 3 to 5 billion tonnes of *ballast water* internationally annually. Ballast Water is water carried by ships to ensure stability, trim and structural integrity. When a ship loads cargo, the *ballast water* is discharged. When a ship is empty of cargo, it fills its tanks with *ballast water*. *Ballast water* contains many microorganisms such as: phytoplankton, zooplankton, etc. When introduced to new marine environments, they pose a threat to the local marine ecological system. To solve and overcome this problem *IMO (International Maritime Organization)* on 2004 has been issued a regulation on *ballast water treatment management* written in *IMO Ballast Water Management Convention* in which if the ballast water about to be discharged into the sea it must be processed first to meet IMO standards.

This project will aim to study ballast water treatment method using a *Charcoal Filter* and combining it with *UV radiation* using method of filtering the microbial content at a variation flow rates of *10 Lpm*, *20 lpm*, and *30 lpm* with a maximum UV dose of *120 watts*. Microbial observation in this study used *Total Plate Count* (TPC) method by using specific media of growth of *Escherichia coli* bacteria in the form of *Eosin Methylene Blue* (EMB) and sterilizied salinity where the salinity has the same as sea water sample. From the results of this observation will be known whether the prototype of ballast water treatment that has been made are working as intended and effectively in killing microbial water pathogens contained in sea water. Based on the results experiment of Charcoal Filter and UV Radiation as Ballast Water Treatment System, where the analysis of microbial content on

Kenjeran's seawater samples in the existing condition done by using *Total Plate Count* (TPC) method, Kenjeran's seawater samples prior to the treatment were carried out microbial content of $9x10^8$ CFU/ml.

From data results of the experiment that has been done, it shows that difference in variation of flow rates can effect the quality performance of a filter media. In this case *Charcoal Filter* without use of UV Radiation in flow rates of *10 lpm* has microbial content of $1.4x10^3$ CFU/ml, while at *20 lpm* has microbial content of $6.3x10^3$ CFU/ml, and then at *30 lpm* has microbial content of $7.0x10^4$ CFU/ml. While from data when using *Charcoal Filter* with flow rates of *10 lpm* and UV dossage power of *120 watts* has microbial content of $1.1x10^3$ CFU/ml, while at *20 lpm* has microbial content of $1.6x10^3$ CFU/ml and then at *30 lpm* has microbial content of $5.5x10^3$ CFU/ml. Then by using *Carbon Block Filter* with flow rates of *10 lpm* and UV dossage power of *120 watts* has microbial content of $1.4x10^4$ CFU/ml, while at *20 lpm* has microbial content of $1.8x10^4$ CFU/ml and then at *30 lpm* has microbial content of $2.1x10^8$ CFU/ml, this data proves that Charcoal Filter provides more effective and efficient way to filter microbial content inside of the water samples more than Carbon Block Filter can provide, where in flow rates of 10 lpm and with UV Radiation of 120 watts, Charcoal Filtration method has less Microbial Content of $1.1x10^3$ CFU/ml in comparison with Carbon Block Filtertration method that has more microbial content of $1.4x10^4$ CFU/ml.

By using Charcoal Filtration with flow rate of 10 lpm and UV Radiation of 120 watts that has amount microbial content of $1.1x10^3$ CFU/ml, compared to previous experiment has amount microbial content of $1.0x10^4$ CFU/ml, proves that Charcoal Filtration method can possibly use as alternative media to treat ballast water, and also possibly have a better result if the Charcoal media have been activated before. While on Carbon Block Filter with flow rate of 10 lpm and UV Radiation of 120 watts has amount microbial content of $1.4x10^4$ CFU/ml, compared to previous experiment has amount microbial content of $2.0x10^4$ CFU/ml, that proves that by using Carbon Block Filter also has advantage of better performance overall than using ordinary Carbon Filter.

Keywords: *Charcoal Filter*, *UV Radiation*, Ballast Water Treatment system, Experimental, Study

**Studi Experimen Pada Filter Arang dan Radiasi Sinar UV Sebagai Alat Pengolah Air Ballas**


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**Abstrak**

Kapal secara luas digunakan sebagai alat modal transportasi, terutama di daerah atau wilayah yang dikelilingi oleh laut. Kapal-kapal ini bergerak lebih dari 80% dari komoditas transportasi dunia dan mentransfer sekitar 3 hingga 5 milyar ton air ballas ke seluruh pelosok dunia per-tahunnya. Ballas adalah air yang ditampung di tangki ballas kapal pada kapal untuk memastikan stabilitas, trim dan integritas kapal. Ketika kapal memuat beban kargo, air ballas akan di lepaskan ke laut lalu ketika kapal sedang akan tidak memuat kargo tangki ballas kapal akan memuat air dari laut. Air ballas yang berasal dari air laut ini mengandung banyak mikroorganisme, contohnya: fitoplankton, zooplankton, dll. ketika diperkenalkan kepada lingkungan laut yang baru, mikroorganisme ini akan menimbulkan ancaman bagi sistem ekologi laut tersebut. Untuk memecahkan dan mengatasi masalah ini IMO (International Maritime Organitation) pada tahun 2004 telah mengeluarkan peraturan tentang sistem pengolahan air ballas pada kapal yang di tetapkan dalam IMO Ballast Water Management Convention untuk mengatur air ballas yang akan dibuang ke laut harus diproses terlebih dahulu dimana air ballas harus memenuhi standar IMO yang sudah di tetapkan.

Eksperimen ini akan bertujuan untuk mempelajari metode pengolahan air balas menggunakan Filter Arang yang dikombinasikan dengan radiasi sinar UV sebagai metode penyaringan mikroba pada air ballas dengan variasi aliran 10 Lpm, 20 lpm, dan 30 lpm dan dosis UV maksimum yaitu 120 watt. Pengamatan mikroba dalam penelitian ini meggunakan metode Total Plate Count (TPC) yaitu dengan menggunakan media spesifik penumbuh bakteri Escherichia coli dalam bentuk Eosin Methylene Blue (EMB) dan salinitas yang sudah di sterilisasi di mana nilai salinitasnya akan sama dengan sampel air laut. Dari hasil pengamatan ini akan diketahui apakah prototipe pengolahan air ballas yang telah dibuat dapat

berfungsi sebagaimana mestinya dan efektif dalam membunuh mikroba patogen yang terkandung pada air laut. Berdasarkan hasil percobaan Filter Arang dengan Radiasi Sinar UV sebagai system pengolahan air ballas, yang dimana analisis kandungan mikroba pada sampel air laut Kenjeran dalam kondisi eksisting dilakukan dengan menggunakan metode Total Plate Count (TPC). Pada sampel air laut Kenjeran sebelum dilakukanya eksperimen, kandungan mikroba yang didapatkan adalah sebesar $9x10^8$ CFU/ml.

Dari hasil data percobaan yang telah dilakukan, menunjukkan bahwa perbedaan variasi laju aliran dapat mempengaruhi kualitas kinerja media filter. Dalam kasus ini dengan menggunakan Filter Arang tanpa radiasi sinar UV dalam laju aliran 10 lpm memiliki kandungan mikroba sebanyak $1.4x10^3$ CFU/ml, lalu pada laju aliran 20 lpm memiliki kandungan mikroba sebanyak $6.3x10^3$ CFU/ml, dan pada laju aliran 30 lpm yang memiliki kandungan mikroba sebanyak $7.0x10^4$ CFU/ml. Sedangkan dari hasil data ketika menggunakan Filter Arang dengan laju aliran 10 lpm dan dengan daya radiasi sinar UV 120 watt memiliki kandungan mikroba sebanyak $1.1x10^3$ CFU/ml, lalu pada laju aliran 20 lpm yaitu sebanyak $1.6x10^3$ CFU/ml, dan pada laju aliran 30 lpm yaitu sebanyak $5.5x10^3$ CFU/ml. Kemudian jika menggunakan Carbon Block Filter dengan laju aliran 10 lpm dan daya radiasi sinar UV 120 watt memiliki kandungan mikroba sebanyak $1.4x10^4$ CFU/ml, lalu pada laju aliran 20 lpm memiliki kandungan mikroba yaitu sebanyak $1.8x10^4$ CFU/ml, dan pada laju aliran 30 lpm yang memiliki kandungan mikroba sebanyak $2.1x10^8$ CFU/ml. Data ini membuktikan bahwa Filter Arang mempunyai nilai guna yang lebih efektif dan efisien untuk menyaring konten mikroba di dalam sampel air laut dibandingkan dengan menggunakan Carbon Block Filter, di mana pada laju aliran 10 lpm dan dengan radiasi sinar UV 120 watt, metode Filtrasi Arang memiliki kandungan Mikroba yang lebih sedikit yaitu sebanyak $1.1x10^3$ CFU/ml, dibandingkan dengan Carbon Block Filter yang memiliki kandungan mikroba sebanyak $1.4x10^4$ CFU/ml.

Dengan menggunakan Filtrasi Arang pada laju aliran 10 lpm dan dengan menggunakan daya radiasi sinar UV 120 watt yang memiliki kandungan mikroba sebanyak $1.1x10^3$ CFU/ml, dibandingkan dengan menggunakan Carbon Block Filter yang memiliki kandungan mikroba sebanyak $1.4x10^4$ CFU/ml, membuktikan bahwa Filter Arang dapat digunakan sebagai media alternatif untuk sistem pengoalahan air ballas dan akan mungkinkan memiliki hasil yang lebih baik jika media Arang telah melalui proses pengaktifkan sebelumnya. Sedangkan pada Carbon Block Filter dengan laju aliran 10 lpm dan radiasi sinar UV 120 watt memiliki kandungan mikroba sebesar $1.4 \times 10^4$ CFU/ml, dibandingkan dengan percobaan sebelumnya yang memiliki jumlah mikroba sebanyak $2.0 \times 10^4$ CFU/ml, dimana data ini membuktikan bahwa dengan menggunakan media Carbon Block Filter memiliki keunggulan kinerja yang lebih baik secara keseluruhan daripada menggunakan Carbon Filter biasa.

Kata Kunci: Filter Arang, Radiasi Sinar UV, Sistem Pengolahan Air Ballas, Eksperimen, Studi

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## PREFACE

All praise into the presence of Allah SWT who has provided his grace, so author can complete this Thesis entitled "**Experimental Study of Charcoal Filter and UV Radiation as Ballast Water Treatment System"** well and timely. Where this final project is proposed as one of the requirements of graduation of undergraduate study program in the Department of Marine Engineering, Faculty of Maritime Technology, Insitut Teknologi Sepuluh Nopember.

Author realizes completion of this Thesis cannot be separated from the help and support from many different forms, and because of that author express his deeply gratitude to all different kind of parties of:

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Author realizes that this thesis is far from perfect, therefore every constructive suggestion and idea from all parties is highly expected by author for the correction and improvement of this thesis in the future. And on final words, author hope that what is written in this thesis can provide benefits for author in particular and all readers in general.

Surabaya, July 2018

Author

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# CHAPTER I

# INTRODUCTION

## 1.1 Background

Ships are widely used by means of transportation, especially in areas or region that has surrounded by sea. Ships moves over 80% of the world's commodities and transfers approximately 3 to 5 billion tonnes of *ballast water* internationally annually. Ballast Water is water carried by ships to ensure stability, trim and structural integrity. When a ship loads cargo, the *ballast water* is discharged. When a ship is empty of cargo, it fills its tanks with *ballast water*. *Ballast water* contains many microorganisms such as: *phytoplankton, zooplankton, etc*. When introduced to newmarine environments, they pose a threat to the local marine ecological system. Invasive aquatic species is one of the four greatest threats to the world's oceans, the others being: land-based sources ofmarine pollution, over-exploitation of living marine resources, physical alteration and destruction of coastal and marine habitat. Most species carried in ships' ballast water do not survive the voyage. Most of those that do, do not survive when discharged into the new environment (Llyod's Register, 2014) However, under certain circumstances some species do survive to form viable populations, and may become serious pests. The impacts can be divided into three main categories according to the *International Maritime Organization (IMO)*.

- *Ecological*: when the native biodiversity and/or ecological processes may disrupted by the invading species. It is estimated that introduced marine species invade new environments somewhere in the world on a weekly to daily basis.

- *Economical:* when fisheries, coastal industry and other commercial activities and resources are disrupted by the invading species.

- *Human health:* when toxic organisms, diseases and pathogens are introduced through ballast water, potentially causing illness and even death in humans.

To solve and overcome this problem *IMO (International Maritime Organization)* on 2004 has been issued a regulation on *ballast water treatment management* written in *IMO Ballast Water Management Convention*. According to the regulation, ballast water which are about to be discharged into the sea must be processed first to meet IMO standards. Indonesia as an elected state became the council of *IMO Category C* recognized by the *International Maritime Organization (IM*O) 29th Assembly in London on November 27, 2015. *Indonesia* has a great responsibility to protect the marine environment and prevent pollution from ship operations. Indonesia's commitment in preserving the sea is demonstrated by the Indonesia's policy that will ratify the *IMO Ballast Water Management Convention* in 2017. With this ratification it will bring legal certainty to protect the Indonesian sea from *Invasive Alien Species (IAS)* and *Harmful Aquatic Organism and Pathogens (HAOP).*

To comply with this *IMO Ballast Water Management Convention*, Based on **Figure 1.1** there are some development methods to treat the ballast water system aboard a ship such as using *Filtration (Physical Separation)*, *Mechanical*, *Chemical* or with Combining the treatments that already stated applied to the ballast system.

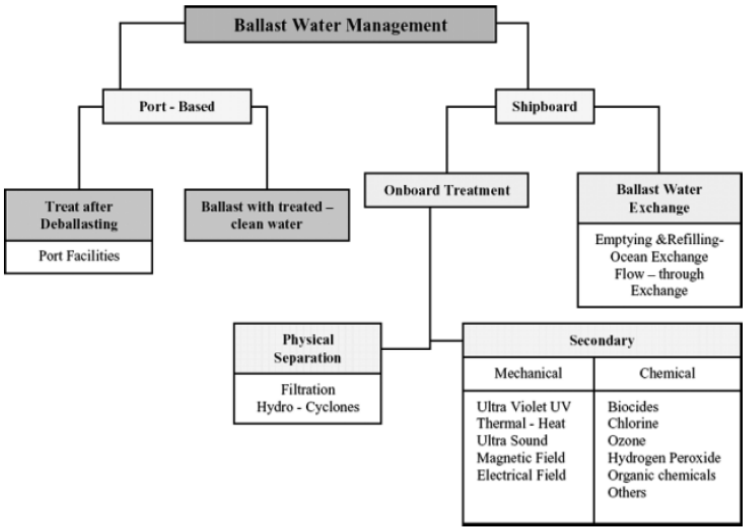


Figure 1.1 Treatment technologies for ballast water

(Source: American Bureau of Shipping )

There is no one piece of treatment equipment can completely inactivate all contaminants. All treatment methods have limitations and often a combination of treatment process is required to efficiently treat the water (Dvorak, 2008). Recently, many approaches combine two or three methods together. *Filtration* and *UV Radiation* are two widely used ones (Clarke, 2004) and are evaluated to have highest benefits/costs ratio (Rustom, 2007).

This project will aim to study ballast water treatment method using a *Charcoal Filter* and combine it with *UV radiation*. This treatment has a different impact to a treated ballast water system, Since *Charcoal* is used for water filtration because of it adsorptive (pores) properties. In these absorbance process which contaminant is attracted to and held (absorbed) onto the surface of the charcoal particles (Dvorak, 2008). This filtration method of treatment is supposed to have a better performance in combination with *UV Treatment.* Since *Charcoal* will filter the contaminant (bacteria) that contained in sea water, then the *UV Radiation* will partake in the process to inactivate remaining contaminant of the sea water, since *UV Rays* has the ability to affect the function of living cells by altering the material of the cell nucleus or can be called DNA, so that living creature can be killed (Eccleston, 1998).

Since ballast water mainly carries with various *phytoplankton, zooplankton and bacteria, Total Plate Count* (TPC) method is use in this project to evaluate the microorganisms that will multiply and form colonies can be seen directly and counted with the eyes without using a microscope of the *Charcoal Filter and UV Radiation treatment* during the experiment (Prescott, 2002). *Charcoal Filter with* combination of *UV radiation* method of treatment were also subject to be study in this project, with an objectives to comparing it performance with pre-existing *Crumb Rubber* and *UV radiation* method of ballast water treatment.

### 1.2 Problem Identifications

In order for the research process to run as expected, it is necessary to note the problems that arise during the process of this research, namely are:

a. What is the effective dose of UV usage and the efficient flow rate variation that uses *Charcoal Filter and UV Radiation* as it ballast water treatment system?

b. How is the analysis of microbial content of treated water in this experiment resulted by using *Charcoal Filter and UV Radiation*?
c. How is the prototype performance compared to pre-existing prototypes that uses *crumb rubber, carbon filter, and UV Radiation* methods of treatment

**1.3 Research Limitations**

In order for the research to run effectively and the objectives are achieved it is necessary to limit the problem, such as:

a. The location of water retrieval and sampling is done in the Kenjeran Coast.
b. On this project experiment of ballast water treatment prototype author is focusing this research to develop *Charcoal Filter and UV Radiation* method of treatment.
c. On this project experiment, author will limit the criteria of flow rates and UV radiation power dossage that are used by this experiment of ballast water treatment prototype and will further study regarding it effectiveness.

**1.4 Research Objectives**

Based on problem identification above, the objectives of this project are as follows:

a. To create a prototype experiment of ballast water treatment system alternative by using the *Charcoal Filter and UV Radiation* as mean of treatment method.
b. To determine the effective dose of UV usage and also to determine the efficient flow rate of the prototype experiment, that inactivate the microorganisms contained inside the sample of water by using *Charcoal Filter and UV Radiation* as it methods of ballast water treatment system.
c. To analyze the microorganisms content that exist in pre-existing ballast water treatment prototype and comparing it performance with the *Charcoal Filter and UV Radiation* method of treatment that this project will develop.

**1.5 Research Deliverable**

To create a prototype experiment of ballast water treatment system as a viable alternative method to treat a ballast water by using the *Charcoal Filter and UV Radiation* as mean treatment and to be a viable option to treat ballast water.

### 1.6 Research Benefits

The benefits of research that will be done is:

a. To produce a ballast water treatment system prototype using *Charcoal Filter and UV Radiation* that can be used as learning materials and to further develop this project.
b. To validate information on results of the *pre-existing prototype* and comparing it with prototype that uses *Charcoal Filter and UV Radiation* ballast water treatment system that this project will develop.
c. Knowing the difference performance in prototype that this project will develop and comparing it with the *pre-existing prototype*.

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# CHAPTER II

# LITERATURE STUDY

## 2.1 Problem Overview

*Ballast water system* is a system on the ship when water stored in ballast tank of a vessel to improve ship's stability, balance and trim. The *suction* and *discharge* of ballast water on the vessel is carried out when the vessel is undergo a *loading-unloading* activities or when the vessel needs an extra stability during bad weather. Ship's ballast water system also serves as a system to maintain stability of the ship and maintain ship's draft to remain safe for sailing perpouses. In addition that ship's ballast water system have a positive impact for a ship, this ballast water system also has a negative impact on the environment, health and economy point of view *(European Maritime Safety Agency, 2013)*.

When a ship is empty of cargo, it fills its tanks with *ballast water*. *Ballast water* contains many *microorganisms, phytoplankton, zooplankton, etc.* When it introduced to newmarine environments, they *pose a threat* to the local marine ecological system. *Invasive aquatic species* is one of the four greatest threats to the world's oceans, the others being: *land-based sources of marine pollution, over-exploitation of living marine resources, physical alteration* and *destruction of coastal and marine habitat*. This statement also strengthened by evidence on the ballast water that discharged by foreign ships that contains an *Invasive Alien Species* (IAS) or *Harmful Aquatic Organism and Pathogens* (HAOP). If the *IAS* and *HAOP* are released in an environment where these microbes can breed, it can lead to the extinction of an asili species that cause economic and health damage problem to the surrounding environment (IMO Ballast Water Management Convention, 2004).

On **Figure 2.1** below, it shows the process of *ballast water system* where the *ballast system* is divided into two, namely the *suction/ballasting* process of ballast system, where the ballast water replenished into the ballast tanks located on the ship. During the ballasting procees, ballast water contain bacteria from the sea. This process take place during the loading of the ship. The second process is *deballasting/discharge* procedure, where the water is discharged into the sea from ballast tank. Within this process of ballast water, the ballast water has already been contaminated by bacteria from ballsting process before. This procees take place during ship's loading procedure. In addition to *suction* and *discharge* process of the ballast system, there is a system where *ballast water* is transferred from one tank to another tank to maintain ship stability. This procees also occur during *transit* procedure.


Figure 2.1 Ship's Ballast Water System

(Source: damengreen.com)

To solve and overcome this problem *IMO (International Maritime Organization)* on 2004 has been issued a regulation on *ballast water treatment management* written in *IMO Ballast Water Management Convention*. According to the regulation, ballast water which are about to be discharged into the sea must be processed first to meet IMO standards. Indonesia as an elected state became the council of *IMO Category C* recognized by the *International Maritime Organization (IM*O) 29th Assembly in London on November 27, 2015. *Indonesia* has a great responsibility to protect the marine environment and prevent pollution from ship operations. Indonesia's commitment in preserving the sea is demonstrated by the Indonesia's policy that will ratify the *IMO Ballast Water Management Convention* in 2017. With this ratification it will bring legal certainty to protect the Indonesian sea from *Invasive Alien Species (IAS)* and *Harmful Aquatic Organism and Pathogens (HAOP)*.

To comply with this *IMO Ballast Water Management Convention*, there are some development methods to treat the ballast water system aboard a ship such as using *Filtration (Physical Separation)*, *Mechanical*, *Chemical* or with Combining the treatments that already stated applied to the ballast system. Recently, many approaches combine two or three methods together. *Filtration* and *UV radiation* are two widely used ones (Clarke, 2004) and are evaluated to have highest benefits/costs ratio (Rustom, 2007).

On the 1st research development and prototype on *the ballast water treatment system using crumb rubber and UV radiation* have been done by (Fauzi, et al, 2016) as can be seen on **Table 2.1** and **Table 2.2** which resulted in an effective and efficient *Ballast Water Treatment Prototype to eliminate the pathogenic water microbes found in the water.* The result of this research is 99% microbial in marine water samples inactivation when prototype is run using *carbon filtration* or *crumb rubber* with maximum water discharge of ***20 lpm** and UV radiation* with minimum dose of ***7.10 mW/cm2***. But the *carbon* filter has better performance in water filtration compared to the *crumb rubber filter*. There was also no effect caused by the addition of ballast water flow rates in the *UV reactor* to the UV doses required for the *inactivation of pathogenic microbial in water*. In the results of this study, ***99%*** of inactivated microbes were obtained, where flow rates should also have an effect on the ballast water treatment results in the *UV reactor*.

Table 2.1 Table Comparison of Prototype Result Performance Using Carbon Filter With Different UV Dosage and Flow Rate Ratio

(Source: Fauzi et al, 2016)

| No | Debit (lpm) | Lamp Capacities (watt) | UV Dossage (mW/cm2 | Number of Living Microbes (Cfu/ml) |
|---|---|---|---|---|
| 1 | 5 | 30 | 7,10 | 0 |
| 2 | 10 | 30 | 7,10 | 0 |
| 3 | 20 | 30 | 7,10 | 0 |
| 4 | 5 | 60 | 14,20 | 0 |
| 5 | 10 | 60 | 14,20 | 0 |
| 6 | 20 | 60 | 14,20 | 0 |
| 7 | 5 | 70 | 16,58 | 0 |
| 8 | 10 | 70 | 16,58 | 0 |
| 9 | 20 | 70 | 16,58 | 0 |

Table 2.2 Table Comparison of Prototype Result Performance Using Crumb Rubber with Different UV Dosage and Flow Rate Ratio

(Source: Fauzi et al, 2016)

| No | Debit (lpm) | Lamp Capacities (watt) | UV Dossage (mW/cm2 | Number of Living Microbes (Cfu/ml) |
|---|---|---|---|---|
| 1 | 5 | 30 | 7,10 | 0 |
| 2 | 10 | 30 | 7,10 | 10 |
| 3 | 20 | 30 | 7,10 | 0 |
| 4 | 5 | 60 | 14,20 | 0 |
| 5 | 10 | 60 | 14,20 | 0 |
| 6 | 20 | 60 | 14,20 | 0 |
| 7 | 5 | 70 | 16,58 | 0 |
| 8 | 10 | 70 | 16,58 | 0 |
| 9 | 20 | 70 | 16,58 | 0 |

On 2nd research prototype development that have been done in 2017 by (Puspitasari et al, 2017) with method of *scalling up* the 1st prototype standard by 2x then experiment it with, different *UV Power Dossage* and different *flow rate* variation of ballast system treatment prototype to find *performance comparation* between 1st and 2nd experiment prototype.

Table 2.3 Table Comparison of Prototype Result Performance Using Different UV Dosage and Different Flow Rate Ratio

(Source: Puspitasari et al, 2017)

| UV Dossage (Watt) | $10^6$ | | | | | |
|---|---|---|---|---|---|---|
| | Crumb Rubber | | | Carbon | | |
| | Flow Rates (LPM) | | | | | |
| | **10** | **30** | **50** | **10** | **30** | **50** |
| 30 | 10 | 0 | 11 | 23 | 0 | 2 |
| 60 | 7 | 2 | 1 | 6 | 2 | 0 |
| 90 | 1 | 0 | 9 | 2 | 11 | 1 |
| 120 | 0 | 1 | 7 | 1 | 1 | 1 |

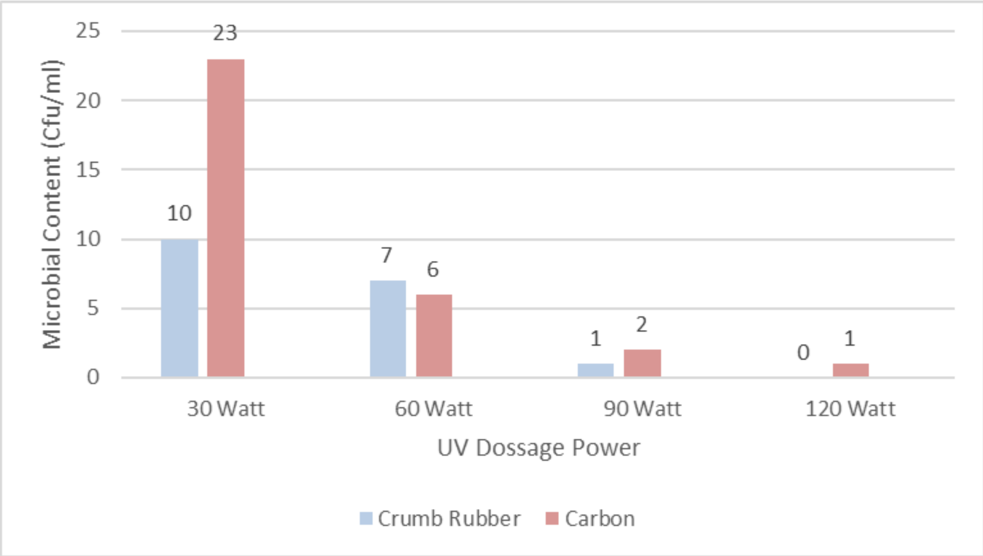



Figure 2.2 Graphic Comparison of Crumb Rubber Filter and Carbon Filter At 10 Lpm Flow Rate

(Source: Puspitasari et al, 2017)

Based on **Table 2.3** and **Figure 2.2** (Puspitasari et al, 2017), which resulted in the most effective and efficient flow rate in filtering the microbial content is at a flow rate of ***10 Lpm*** with a UV dose of ***120 watts*** with less microbial content overall whether it using *crumb rubber* or using *carbon* as it filter treatment.

However, the data results from this pre-existing experiments that resulted in ***0 Cfu/ml*** can be caused by the occurrence of microbial hemolysis inside the water sample itself before the experiments taking place. This microbial hemolysis may occur due to its lower water salinity levels compared with sea water samples, since microbes will not live and are presumably already been dead at first, so this results at delution stage of $10^6$ are not considered as a valid data because by the time this experiments are conducted the delution stage also still reaching at high rate delution level of $10^6$.

From the result of prototype experiment that has been run, it proves that filtration can remove large amount of particles or organism, and combining it with *UV radiation* can also *inactivate the residual bacteria, viruses and small organisms* inside ballast system itself for discharge perpouses and comply it with *IMO Convention*.

But currently applied filtration methods including *sand, crumb rubber, membrane* and *disc filters* may *suffer low efficiency,* or *short lifespan* (Tang, 2006). So an alternative solution is needed due to this *lack of efficiency, flow rate variation and short lifespan* of a materials caused by using the *crumb* as it filter.

This project will aim to study ballast water treatment method using a *Charcoal Filter* and combine it with *UV radiation* using method of filtering the microbial content at a variation flow rates of ***10 Lpm***, ***20 lpm***, and ***30 lpm*** with a maximum UV power dossage of ***120 watts***. This treatment has a different impact to a treated ballast water system, Since *Charcoal* is used for water filtration because of it adsorptive (pores) properties. In these absorbance process which contaminant is attracted to and held (absorbed) onto the surface of the charcoal particles. (Dvorak, 2008). This filtration method of treatment is supposed to have a better performance in combination with *UV Treatment*. Since *Charcoal* will filter the contaminant (bacteria) that contained in sea water, then the UV Radiation will partake in the process to inactivate remaining contaminant of the sea water, since *UV Rays* has the ability to affect the function of living cells by altering the material of the cell nucleus or can be called DNA, so that living creature can be killed ( Eccleston, 1998).

This project also aims the effectiveness and performance of *Charcoal Filtration* with combination of *UV Radiation*, then comparing it with existing prototype to better understand the technologies of ballast water treatment aboard a ship.

Since ballast water mainly carries with various *phytoplankton, zooplankton and bacteria, Total Plate Count* (TPC) method is use in this project to evaluate the microorganisms that will multiply and form colonies can be seen directly and counted with the eyes without using a microscope of the *Charcoal Filter and UV Radiation treatment* during the experiment (Prescott, 2002).

### 2.2 Microbial Water Patogen on Ballast Water

*Pathogen microorganisms* are microorganisms that can cause disease inside the host of these microorganisms. Sea water is one of the intermediaries that can spread the pathogen microorganisms. These microorganisms can cause harm directly or indirectly to the environment contaminated by it.

If humans are contacted directly with these microrganisms then humans will have a chance to be infected as well and can cause an interferece to the health of the food that has been consumed by humans. This disease will also spread over and disturbed indigestion system inside human's body causing it to not function properly as intended. The dangers if this disease contacted indirectly can be caused when humans consume seafood that has been contaminated or infected by microbial water pathogens. Microbes contained in the food will move into the human body and will reproduce periodically so it will cause health problems in humans infected by it.

Some of the microbes of water pathogens are often found in the water are bacteria that can cause *gastrointestinal infections* such as: *Entrobacter, Salmonella, Shigella, Escherichia Coli,* or *Proteus, Providencia* (Cliver, 1984).

### 2.2.1 Vibrio Cholerae

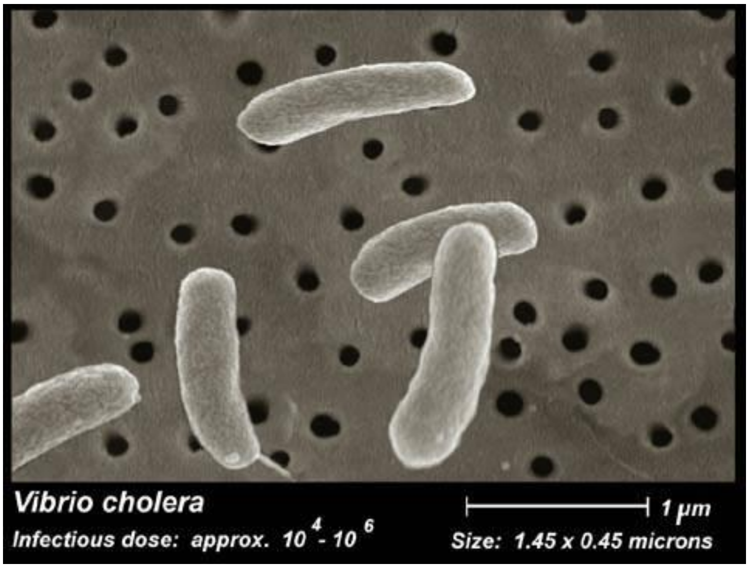



Figure 2.3 Vibrio Cholerae

(Source: The World Health Organization [Cholera])

As seen on **Figure 2.3**, and in accordance to (Rizka et al, 2017) *Vibrio Cholerae* is a gram-negative bacterium in which the size of this bacterium is 1-3 x 0.4 - 0.6 µm and has one flagel. In addition, these bacteria do not have spores and do not have a sheath. These bacteria are halophilic which are not acid resistant so that the vibrio can grow at 4-9 pH and grow optimally between 6.5 - 8.5 pH. It also can grow at 20-40% of salinity. *Vibrio Cholerae* also having characteristic as bacteria that are not invasive, and never entered into human's blood circulation. But infesting the intestine that can cause gastritis to human.

### 2.2.2 Enterobacter Cloacae


Figure 2.4 Enterobacter Cloacae

(Source: [H.N.] MICROBIOLOGYINPICTURES.COM)

As **Figure 2.4** described, *Enterobacter Cloacae* is a gram-negative bacteria in the form of bacilli, with a size between 0.6 - 1.0 µm to 1.2 - 3.0 µm. *Enterobacter Cloacae* does not form spores, it encapsulated and has a flagellum, these bacteria are often found with *Escherichia Coli* that live freely in nature especially on water or soil and also the digestive tract of humans and animals (Wulandari, 2013). Other characteristics are they growing aerobically and anaerobically or more often ferment than oxidize glucose that sometimes also produce gas, showing positive catalase, negative oxidation and reducing nitrate tonitrite.

### 2.2.3 Escherichia Coli

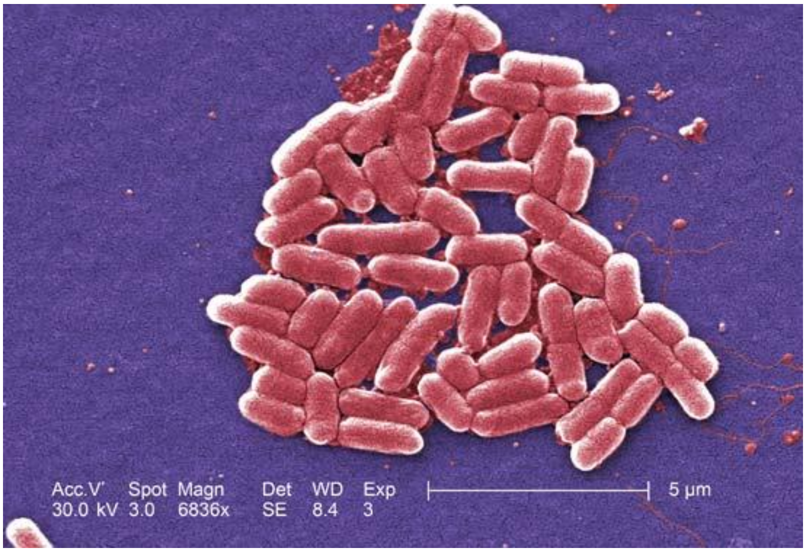



Figure 2.5 Escherichia Coli

(Source: Janice Haney Carr/CDC, 2017)

As seen on **Figure 2.5**, *Escherichia coli* is a bacteria that can be pathogenic, also acting as the leading cause of morbidity and mortality worldwide (Tenailon et al, 2010). This bacterium is a short stem-shaped gram-negative bacterium that has a length of about 2 µm diameter of 0.7 µm, width of 0.4 to 0.7 µm and is anaerobic facultative. In general, bacteria require high humidity around 85% (Madigan & Martinko, 2006). This bacterium is a class of mesophilic bacteria ie bacteria that have optimum growth temperature is 15-45 ° C and can live at between 5.5 – 8 pH. *Escherichia Coli* bacteria will grow optimally at 27 ° C, but according to research this bacteria will undergo grwoth inactivation at a maximum temperature of above 40-45°C.

#### 2.2.3.1 The Effect Caused by Escherichia Coli and Enterobacter To Sea Water Environment

*Enterobacter* in the ocean waters have been stud by scientists for decades. Supported by public health problems and with wider efforts to study the bacterial effect to environmental aspects. Many studies have explored *Escherichia coli* and other bacteria in their exposure to seawater, all of these efforts are motivated to evaluate the risks posed by microorganisms when it released into the sea, also cause a sea pollution or damaging marine environment. When *Entericbacter* exposed to a seawater they are simultaneously causing pollution at sea environment and also causing disturbance in sea's *pH, temperature, salinity, nutrient availability and light radiation.* But when the sea salinity has sufficient organic nutrients it has less significant impact (Yael, 2001).

### 2.3 IMO Regulation Regarding Ballast Water Management on The Ship

The transfer of invasive marine species into new environments via ballast water has been identified as one of the major threats to the world's oceans. In response, the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, in its Agenda 21, called on the International Maritime Organization (IMO) and other international bodies to take action to address the problem. By this time, the IMO had been seeking a solution for over 10 years. In 1991, it published Guidelines for Preventing the Introduction of Unwanted Organisms and Pathogens from Ship's Ballast Waters and Sediment Discharges. These were updated in 1993. In 1997, the IMO published Guidelines for Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens (IMO Ballast Water Management Convention, Resolution A.868(20)).

In February 2004, the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (the Ballast Water Management or BWM Convention) to regulate discharges of ballast water and reduce the risk of introducing non-native species from ships' ballast water. To complement the BWM Convention, the IMO has adopted guidelines contained in its Marine Environmental Protection Committee (MEPC) resolutions and circulars. The BWM Convention imposes a challenging ballast water discharge standard. In response to this, a number of technologies have been developed and commercialised by different vendors. Many have their origins in land-based applications for municipal and industrial water and effluent treatment, and have been adapted to meet the requirements of the BWM Convention and shipboard operation. These systems must be tested and approved in accordance with the relevant IMO Guidelines.

By the effective date of the convention (8 September 2017), all ships of 400 gross tonnage and above to which the BWM Convention applies (including existing ships, except floating platform, FSUs and FPSOs) are required to possess International Ballast Water Management Certificate. Under the Convention, all ships engaged on international voyages will be required to manage their ballast water and sediments to a certain standard,according to a ship-specific BWM plan,approved by the Member's Flag Administration. All ships will also have to carry a ballast water record book and an international BWM certificate. The BWM standards will be phased in over a period of time. Eventually,most ships will need to install an on-board ballast water treatment system meeting the IMO's standards by the date of a ship's first renewal of its International Oil Pollution Prevention (IOPP) certificate after the Convention enters into force on 8th September 2017 (as prescribed in IMO Assembly Resolution A.1088 (28)). As an example, a ship that completes her IOPP renewal survey on 7th September 2017 may then have until 7th September 2022 before the ship will be required to comply with Regulation D-2 of the Convention and thereby fit a type-approved BWM system.

States Parties to the Convention are given the option to take additional measures which are subject to criteria set out both in the Convention and agreed IMO guidelines.Members should contact their Flag States,if they are States Parties to the Convention,to determine whether any such additional measures will be taken. Once the Convention enters into force, ship's ballast water record books must record when ballast water is taken on board;circulated or treated for BWM purposes,and discharged into the sea.It should also record when ballast water is discharged to a reception facility as well as accidental or other exceptional discharges of ballast water.

From this convention, there are variety of regulations regarding the processing of ballast water on the ship. This provision then known as ANNEX, which consists of five parts, namely ANNEX A to ANNEX E.

- ANNEX section A discusses general terms.

- ANNEX section B discusses the requirements for water repellent management and control on ships. The rules that must be comply with this ANNEX are as follows:

- Ships must have a water treatment system approved by the authorities.
- The vessel must have a log book to record the retrieval, handling, and disposal water
- Ships that built before 2009 with a water tank capacity equivalent to 1500 and 5000 m3 shall meet the standards of water handling by means of water exchange methods or water reply performance standards until 2014. Ships built before 2009 with a capacity of water tanks counting less than 1500 or more than 500 m3 must meet the standards of water treatment by using reply water exchange method or water reply performance standards until 2016.
- Ships that built in 2009 or thereafter with a water tank capacity of less than 5000 m3 shall comply with the standard performance rules of water reply.
- Ships built between 2009 - 2012, with a water tank capacity of more than 5000 m3 or more must meet the standard performance rules of water reply.
- Ships built in 2012 or thereafter with a water tank capacity of less than 5000 m3 shall meet the standard performance rules of water reply.
- Ships that uses a ballast water exchange system must reply water exchange at least 200 nautical miles from the nearest island and at sea depths of at least 200 m.
- In cases when the ship is unable to exchange ballast water such as stated in above rules, the ballast water exchange should be made as far as possible from the nearest island, which is at least 50 nautical miles from the nearest island and at least within 200 m depth.

- ANNEX section C discusses about the additional regulations. At this ANNEX it is stated that "A state or a union of several cooperating States, may be possible to impose additional rules to achieve the objective of reducing harmful microorganisms due to water retaliation and its sediment. In this case, the State or a combination of several States working together must coordinate with the nearest neighboring country which may be affected by enforcement of these additional rules and must communicate with IMO to obtain approval from imposition of additional rules for at least six months"

- As for ANNEX section D, it discusses the standard for ballast water treatment system. The terms of this ANNEX are as follows:
    - In regulation D-1, that the standard of the ballast water exchange in ship should meet with an efficiency of 95% of the volume of water exchange. For vessels that exchange ballast water using the pumping-through method, pumping-through must at three times the volume of each ballast water tank and should be considered to meet approved standards. For pumping-through less than three times the volume of ballast water tank as long it meets the required standards then it is allowed.
    - In regulation D-2, it is mentioned that vessels using a ballast water tretment systems may only dispose of less than 10 living organisms of a size greater than or equal to 50 micrometers per 1 m3, and for microorganisms measuring that are between 10 and 50 micrometres, only 10 microorganisms per 1 millimeter allowed to be removed. As for the type of microbes, it should not exceed the concentration that has been set. For vibrio cholerae less than 1 cfu per 100 ml. For Escherichia coli less than 250 cfu per 100 ml. for intestinalentercocci less than 100 cfu per 100 ml can be seen on this **Table 2.4** and **Table 2.5** that stated:

Table 2.4 Regulation of IMO Ballast Water Management Convention

(Source: Llyod's Register)

| Ballast Capacity ($m^3$) | Construction Date | First Intermediate or Renewal Survey, which ever occurs first after anniversary date in the year indicated below | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| <1500 | <2009 | D1 or D2 | | | | | | | | D2 |
| | >2009 | D2 | | | | | | | | |
| >1500 | <2009 | D1 or D2 | | | | | | D2 | | |
| <5000 | >2009 | D2 | | | | | | | | |
| >5000 | <2012 | D1 or D2 | | | | | | | | D2 |
| | >2012 | D2 | | | | | | | | |

Table 2.5 Approved Number of Microbial Content Ballast Water According IMO Convention

(Source: Llyod's Register)

| Organism Category | Regulation |
|---|---|
| **Plankton, >10-50 µm In minimum dimention** | <10 cells / $m^3$ |
| **Plankton, 10-50 µm** | <10 cells / ml |
| ***Toxicogenic Vibrio Cholera* (O1 and O139)** | <1 CFU / 100 ml or less than 1 CFU / gr |
| ***Escherichia coli*** | <250 CFU / 100 ml |
| ***Intestinal Enterococci*** | <100 CFU / 100 ml |

- ANNEX section E is about survey and certification requirements for ballast water treatment systems. At this ANNEX, it has regulates and approving conditions for various surveys and certifications. In addition, it also provides a form for the water treatment management certificate, and a water record ball form.

## 2.4 Ballast Water Treatment Systems Onboard a Ship

With the regulation of *IMO International Convention for the Control and Management of Ships Ballast Water and Sediments*, it is necessary to treatment the ballast water in order to comply with the regulation. According Suroso (2006), in outline there are two methods of ballast water treatment namely, ballast water processing treatment at the port and ballast water processing treatment on the ship.

Processing on the ship is divided into 3 types of physical methods, mechanical methods and chemical methods. For physics methods using filtration and cyclonic methods, for mechanical methods using *UV rays, heating, ultrasonic, magnetic fields and electric fields*. As for chemical methods using chemicals such as *chlorine, hydrogen peroxide, organic chemistry and others* as can be seen on **Figure 1.1**

On March of 28 - 30 2001, entitled as "IMO International Ballast Water Treatment Standards Workshop" IMO sets out the criteria of water treatment implemented in London as follows:

- *Safety* is the safety of ships and crews on the top priority, so existing safety standards may have to be developed to cover the issue of ballast water treatment.
- *Environmental* Acceptability is a new processing system that will not cause greater environmental problems than before.
- *Practicability* of a new processing system must be compatible with ship design and operational limits to be practical for existing vessels or new buildings.
- *Cost Effectiveness* is a new processing system that does not require a high cost.
- *Effectiveness* is the effectiveness of a technology that can kill or dispose of microorganisms is important.

**2.5 Result Study of The Previous Research**

(Lin et al, 2017) has conducted a research on the performance regarding *Charcoal Filter* as a water filter. In his research, the charcoal that used are bamboo charcoal in regarding to where the project is taken place is in Taiwan and from aspect the availability of resources, according to the annual statistics of the Forestry Bureau reports (2015) from 1998 to 2013 the average percent of various bamboos in Taiwan's total bamboo forest area accounted for about 6%. The average number of various bamboos harvested amounted to about 1.24 billion pieces.

Bamboo occupy an important relation to the practicality of life, and have significant economic value in Taiwan. However, the 921 earthquake in 1999 seriously impacted the local traditional bamboo industries. For the recovery of the bamboo industries and to achieve Taiwan bamboo resource utilization, since 2002, the Forestry Bureau has scheduled the project "Promotion and Transformation of Bamboo Industries" to develop new types of bamboo products, especial for bamboo charcoal.

In general, Carbon Material is a good adsorbent for gaseous and liquid adsorption and is widely applied in the purification, de–colorization, and removal of toxic substances, as well as the treatment of waste water (Manocha, 2003) (Yorgun et al, 2009) (Sun & Jiang, 2010)

On previous study (Lin et al, 2015) showed that the Carbon/Charcoal with multiple micro/mesopores can be used as functional water purifying material. As Carbon/Charcoal has a developed pore structure, that can adsorb the trace amounts of organic contaminants in water (Kihn et al, 2000) (Andersson et al, 2001) it also significantly reduce the chemical oxygen demand and total organic carbon in water (Kunio et al, 2001) (Seyed et al, 2004) (Omri et al, 2013) and as an inhibitory effect on total bacterial count and coliform contain in water (Ogawa et al, 2011).

According to (Lin et al, 2017) the results of his research on multiple range test of the multi–layer filtration method treatment with different filtration flow velocities had significant difference, indicating that the decrease of turbidity is influenced by the multi–layer filtration method at a flow velocity of 5-10 mL/min.

Table 2.6 Coliform and total bacterial count and its percent removal of water specimens after treating by the multi–layer filtration method

(Soruce: H.C Lin, 2017)

| Purification Method, water specimen and flow felocity | | | Coliform (CFU/mL) | PR (%) | Total Bacterial Count (CFU/mL) | PR (%) |
|---|---|---|---|---|---|---|
| Source Water | | | 158.50 (61.5) | - | 1688.18 (9.09) | - |
| Multi-layer filtration method | T700 | 5 mL/min | 7.00 (0.00) | 95.58 | 144.00 (16.00) | 91.47 |
| | | | | | | |
| | | 10 mL/min | 4.00 (1.00) | 97.48 | 161.00 (9.00) | 90.46 |
| | T800 | 5 mL/min | 10.5 (2.50) | 93.38 | 124.52 (9.98) | 92.54 |
| | | | | | | |
| | | 10 mL/min | 5.00 (4.00) | 96.85 | 145.00 (3.00) | 91.31 |
| | T900 | 5 mL/min | 1.50 (0.50) | 99.05 | 26.00 (1.00) | 98.44 |
| | | | | | | |
| | | | 0.00 (0.00) | 100.00 | 73.25 (1.25) | 95.63 |

As seen on **Table 2.6** resulting in The AC with the strongly alkaline solution condition can cause bacterial death and/or the bacteria to be adsorbed (Uraki et al, 2008). The coliform of the source water was ***158.50 CFU/mL***, and the treated water after purifying with the multi–layer filtration method was ***1.50–10.50 CFU/mL*** with the flow velocity of ***5mL/min***, on T800 source of water which resulting that some of it aren't meet the standard D-2 of *IMO Convention of Ballast Water Treatment* ***(<10 cells/ml)***.

Table 2.7 Efficiency Results of Suspended Solid Removal Under Various Design and Operational Conditions

(Source: Tang, 2006)

| Target Meter | Filter Depth m3/h.m2 | Filtration Rate m3/h.m2 | Removal Efficiency % | | |
|---|---|---|---|---|---|
| | | | 0.66 mm Media | 1.2 mm Media | 1.9 mm Media |
| Phytoplankton | 0.6 | 24.4 | 58±10 | 58 8 | 50 7 |
| | | 48.9 | 50±3 | 40 5 | 34 3 |
| | | 73.3 | 46±5 | 42 7 | 31 9 |
| | 0.9 | 24.4 | 69±4 | 63 5 | 58 3 |
| | | 48.9 | 70±3 | 62 3 | 59 6 |
| | | 73.3 | 62±4 | 54 3 | 50 6 |
| | 1.2 | 24.4 | 71±3 | 68 3 | 61 5 |
| | | 48.9 | 63±2 | 56 4 | 52 7 |
| | | 73.3 | 62±3 | 57 3 | 49 8 |

Based on (Tang, 2006) results also prove that *Charcoal Filtration treatment* shows a better performance than other applied filtration methods as seen on **Table 2.7**, that a *Crumb Rubber Filter* removed up to ***70.7%*** phytoplankton when initial alga density ranged from ***1.04×10$^3$*** to ***5.31×10$^3$ ea/mL*** and velocity changed from ***24.4*** to ***73.3 m$^3$/(m2•h)***.

This proves that *Charcoal Filter* has a significant benefits to a treated water aside the use of multi-layered filtration method that (H. C. Lin, 2017) has been conducted.

*Charcoal Filtration with* combination of *UV radiation* method of treatment were also subject to be study in this project, with an objectives to comparing it performance with pre-existing *Crumb Rubber* and *UV radiation* method of ballast water treatment and will be further disscussed.

## 2.6 Pre-Existing Prototype Model and Results

(Puspitasari et al, 2017) on her experiment by *Scalling Up The Pre-Existing Prototype of Ballast Water Treatment System Using Crumb Rubber Filtration and Radiation of UV* has undertake the development of ballast water treatment system by using Crumb Rubber filtration and UV radiation. In this study produce a prorotype with a lab scale where the main component of this system is Suction Tank 1, Pump, Ball Valve, Flow Meter, Crumb Rubber Filter, Carbon Filter, UV Reactor and Discharge Tank 2. Where the prototype process of work as a ballast water treatment system can be seen on **Figure 2.6**.

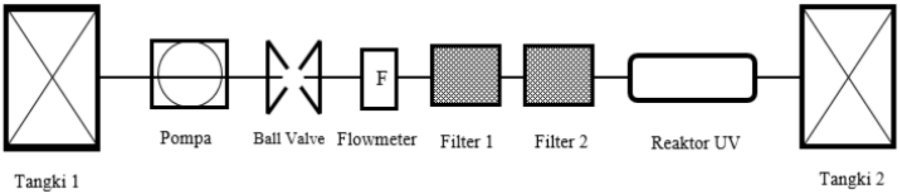



Figure 2.6 Work-Flow System of The Pre-Existing Prototype That Has Been Scalled Up

(Source: Puspitasari et al, 2016)

In **Figure 2.6** shows the work-flow process diagram of a ballast water treatment prototype system in which seawater derived from kenjeran coast and still contains many microorganisms will be accommodated in tank 1 and will be pumped at different rate of variation. The seawater arrangement will be regulated by the valve and will be monitored about the flow rate using a flowmeter. Once the seawater is pumped, then the sea water will go into filter 1 to filtered the microbial content. After that the sea water will re-enter into filter 2 to do re-filtering the microbial content. In this test system will use 2 filters that use *crumb rubber* and use *carbon filter*. Furthermore, from the filtration results, the seawater will enter the UV reactor to conduct the inactivation of the microbe. Inside the UV reactor will also be set the dose of UV light irradiation. Because the prototype uses 4 UV lamps with 30 watts of power, the maximum of UV lamp irradiation dose is 120 watts. After the inactivation of microorganisms, the processed seawater will enter the tank 2 to test the content of microorganisms contained in the sea water that has been done processing.

On the recent pre-existing research experiment prototype development that have been done by (Puspitasari et al, 2017) with method of *scalling up* the 1st prototype (Fauzi et al, 2016) standard by 2x, and then experiment it with different *UV power dossage* and also by adding *flow rate* variation to the ballast system treatment prototype.

Table 2.8 Result of Microbial Content By Using Crumb Rubber Filters (CFU)

(Source: Puspitasari et al, 2017)

| UV Dossage (Watt) | $10^4$ | | | |
|---|---|---|---|---|
| | Flow Rates (LPM) | | | |
| | **10** | **30** | **50** | **70** |
| 30 | 7 | 40 | 27 | 27 |
| 60 | 5 | 21 | 12 | 12 |
| 90 | 2 | 4 | 8 | 8 |
| 120 | 1 | 3 | 5 | 15 |

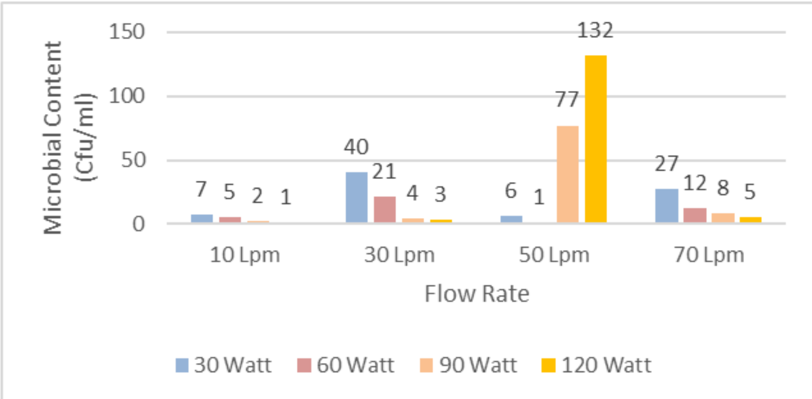



Figure 2.7 Graph of TPC Results Using Crumb Rubber Filters

(Source: Puspitasari et al, 2017)

As can be seen in **Table 2.8** and **Figure 2.7** that the most effective flow rate in inactivating microbial content amounts is at a flow rate of ***10 Lpm*** and in UV radiation at ***120 watts***. This is because at the time of the test using a flow rate of ***10 Lpm*** and the same dose of ***120 watts*** the amount of microbial content is at ***1x10⁴ CFU***.

Based on results of tests that have been done, it can support the theory by using method of ballast water treatment with *filtration* and *UV radiation*. With the implementation of *filtration method* and in combination with *UV radiation*, can reduce the amount of microbial content contained in the ballast water.

Table 2.9 Result of Microbial Content By Using Carbon Filters (CFU)

(Source: Puspitasari et al, 2017)

| UV Dossage (Watt) | $10^4$ | | | |
|---|---|---|---|---|
| | Flow Rates (LPM) | | | |
| | **10** | **30** | **50** | **70** |
| 30 | 30 | 16 | 14 | 3 |
| 60 | 19 | 3 | 7 | 19 |
| 90 | 4 | 1 | 5 | 0 |
| 120 | 2 | 1 | 3 | 7 |

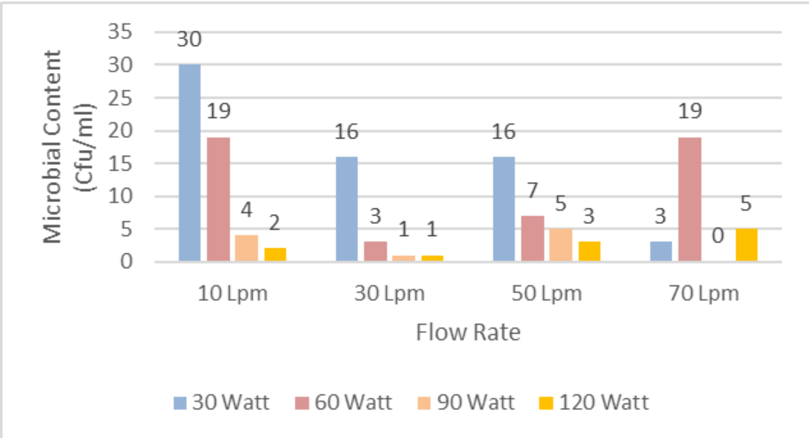



Figure 2.8 Graph of TPC Results Using Carbon Filters

(Source: Puspitasari et al, 2017)

*Functional Groups* can be formed on activated carbon if activated carbon activation caused by interaction on carbon surface. This *Functional Groups* will cause the surface of the activated carbon to become chemically reactive and can affect the nature of the adsorption. One activator that can affect the adsorption power of activated carbon is temperature, contact time and physical activation. (Bhatnagar et al, 2016).

Based on the above data, can be seen that the most effective and efficient flow rate in filtering the microbial content is at a flow rate of ***10 Lpm*** with a UV dose of ***120 watts*** with amount of microbial content is ***$2x10^4$ CFU***.

As from the data stated above in regard of performances with existing prototype the optimal *UV Power Dossages* of ***120 watts***, Due to above statements author will choose to experiment with different variation of flow rate at ***10 lpm***, ***20 lpm***, and ***30 lpm*** with maximum capacity of UV Power Radiation always will be at ***120 watts***.

But currently applied filtration methods including sand, crumb rubber, membrane and disc filters may suffer low efficiency, low flow rate or short lifespan (Tang, 2006). So, an alternative solution is needed due to this lack of efficiency, flow rate variation and short lifespan of a materials caused by using the crumb as it filter.

On the development of this project, the treatment that will be used is *Charcoal Filter with* combination of *UV radiation* method of treatment as ballast water treatment system. This comparison is prioritized to determine the effectiveness and efficiency of *Charcoal filters* and *UV Radiation* compared to the *crumb rubber filters* and *carbon filters* in treating the microbes contained in seawater.

## 2.7 Charcoal Filter

Indonesia as a rich country with both conventional and biomass energy sources. Woodfuels are still in use and it is account for 29% of total energy consumption in Indonesia. Almost all rural households use woodfuels, mainly for cooking, and also a substantial amount of urban households are woodfuel users, indicating a sizeable flow of traded woodfuels from rural areas to cities. In addition, village industries such as charcoal, brick, ceramics and tile making, and lime burning use fuelwood.

According to Regional Wood Energy Development Programme (RWEDP) Indonesia is still has large forest areas - 60% of the total land area. This large scale logging of natural forests takes place for the pulp and paper industry and for timber. The Government is committed to implementing sustainable forest management by the year 2000. On the populated island of Java, about two-thirds of woodfuels does not come from the forests, and on West-Java as much as 93% of all fuelwood comes from village lands, mainly from mixed home-gardens.

Forest Products and Socio-economics Research and Development Centre (in Bogor), under the Kementrian Perhutani Indonesia, has been engaged in studies on woodfuel utilization. It is reported that the demand for fuelwood is higher than the amount it produced, and it is projected to increase by another 5% in the period 1995-2000, particularly in industry. There is probably still substantial scope for putting waste from the logging and wood industries to good use as fuel, for instance in Kalimantan. This would at the same time alleviate environmental burdens resulting from the waste.

In this experiment, charcoal that used are tree charcoal in regarding to Indonesia's Government plan to utilize more waste from charcoal usage and from aspect the availability of resources in Indonesia itself. *Charcoal Filter* are mostly used to improve the taste and odor of water. Their removal efficiency depends on the quality and amount of charcoal used in the filter and the length of time that the filter has been in use. Higher water turbidity and flow rate also decrease removal efficiency. If these filters become saturated, the trapped contaminants can be released back into the filtered water. Also, the particles that accumulate within the filters may serve as food for bacteria, resulting in high concentrations of bacteria within the filter that can eventually be released into the treated water. These filters typically do not have the problem of bacteria growth and may be able to filter out coliforms and pathogens (Meridian Institute, 2005)

*Charcoal* is characterized as a carbonaceous material with a highly porous internal structure, which is usually derived from the pyrolysis and chemical treatment of sources including wood, coal, nutshells, bamboo and other organic materials in accordance of article from (Ando. N, 2010). Procces to produce a *Charcoal* usually performed at high temperature by chemical or steam treatment, to generates an extensive porous network within the carbonaceous material (Yahya M.A, 2015). The adsorptive properties of *Charcoal* towards organic contaminants have been widely recognized and studied for many years, with this material well suited for removing contaminant species from water (Sweetman, 2017).

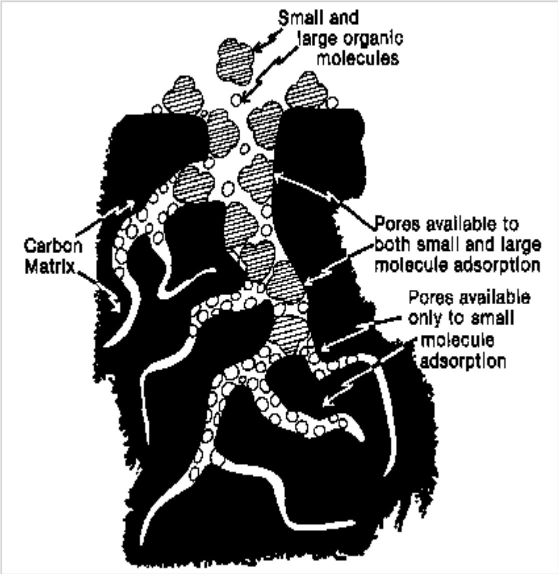



Figure 2.9 Charcoal Adsorbtion of Contaminants

(Source: Shinsan, 2016)

This project will use wood charcoal that has been trimmed and sieved to a pallets size of **2 mm** and contained in the filter cartridge as seen on **Figure 2.10**.

Figure 2.10 Charcoal Filter Cartridge

Steps of producing this pallets of *Charcoal* are as follows:

1. Crushing the coal with a hammer into a smaller size as seen on **Figure 2.11**

Figure 2.11 Preperation Step to Crushing the Coal

2. Filtering and sievering the crushed coal with filter that have size of **2 mm** , with intention of reducing powder like material as can be seen on **Figure 2.12** and **Figure 2.13**.

Figure 2.12 Filtering the Crushed Coal

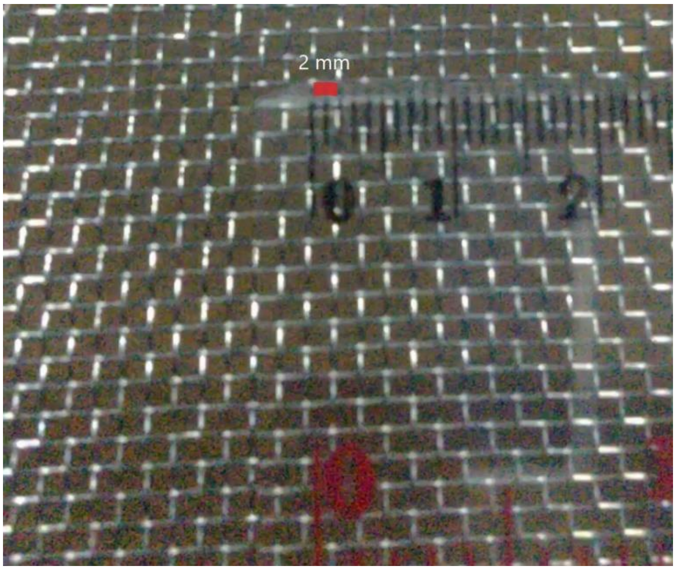



Figure 2.13 Diameter of Sievered Filter

3. The end-result of this step will produced pallet like coal that has been sieved to meet the writer standard of this project as material of filter.

## 2.8 Carbon Filter Cartridge

In accordance with (Puspitasari, et al 2017) and to meet apple to apple standard of comparison from her project, this project will also compare the usage of carbon filter cartridge and compare it to an alternative filtration that this project will undergo.

Carbon block is mainly comprised from activated carbon granules and a binding agent that allows the carbon granules to maintain a static position relative to each other, so water can flow through the loose column of carbon, taking the path of least resistance. Carbon block is formed into a cartridge of predetermined dimensions. The use of end caps forces water to flow through the carbon block's static pores. The uniform pore structure between the individual granules of carbon can enable carbon block to achieve higher effectiveness in contaminant reduction. The uniform pore structure of carbon block also increases the contact time with the filter media, further increasing the block's ability to remove contaminants.


Figure 2.14 Carbon Block Filter Cartridge

**2.9 UV Rays**

Ultraviolet light has the ability to affect the function of living cells by altering the material of the cell nucleus or can be called DNA, so that living creature can be killed (Eccleston, 1998). The ultraviolet rays in this project are generated from UV lamps which are essentially similar to fluorescent lamps where inside tubes are filled with inert gas usually argon or mercury. UV doses used in this water treatment process should be considered when conducting the water ballast treatment processing.

Spesification:

- Brand : RoHS and Germacidal Lamp Electronic Ballast
- Type : ESS –A39T5UV and RW5-425-40
- Ampere : 0.37 - 0.16 A and 0.39 – 0.43A
- Voltage : 115 – 227 Volt and 230 - 300 Volt
- Frequency : 50 – 60 Hz

Spesification:

- Brand : Germacidal Lamp Electronic Ballast
- Type : RW5-425-40
- Ampere : 0.39 – 0.43A
- Voltage : 230 - 300 Volt

Figure 2.15 UV Light Adapter

## 2.10 Total Plate Count (TPC) Method on Microbial Testing

The principle of the Total Plate Count (TPC) method is to grow cells of living microorganisms on agar media, so that microorganisms will multiply and form colonies that can be seen directly and counted with the eye without using a microscope. In this method, the dilution technique should be properly addressed. The purpose of this dilution is to reduce the amount of microbial content in the sample so that later can be observed and known the number of microorganisms specifically to get the exact calculation.

On **Figure 2.15** shows that the dilution stage starting from making a 10 ml sample solution (mixture 1 ml / 1gr sample with 9 ml diluent solution). From the solution then take 1 ml and mix it into 9 ml diluent solution to obtain dilution of $10^{-2}$. Then dilution of $10^{-2}$ is taken again 1 ml and inserted into a reaction tube containing 9 ml physiological solution to obtain dilution of $10^{-3}$, and so on until it reaches the dilution that this project will aim. After the dilution process is done, then it this planted on plates of agar media. After the incubation, each colony is observed and calculated Colonies are a collected from the microorganisms that share the same properties of shape, structure, surface, and so on.

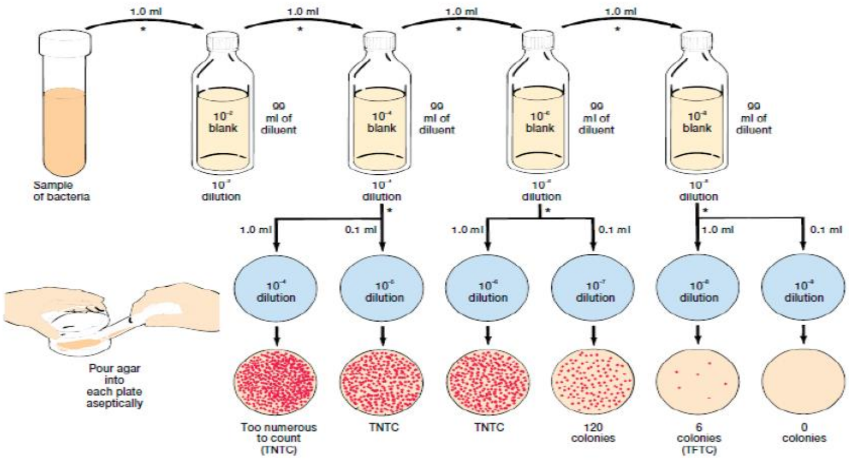



Figure 2.16 TPC Method of Experiment

(Source: Prescott, 2002)

In order for this test to be more validated, continuous research is required by using a *comparative analyis study* method on pre-existing prototype and comparing it with *Charcoal Filtration* to know whether the result and performance of this experiment will consistent and comply within requirement given by *IMO Convention*.

## 2.10 Technology Readiness Level (TRL)

According to (Mankins, 1995) Technology Readiness Levels (TRL) are a systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology. The TRL approach has been used on-and-off in NASA space technology planning for many years and was recently incorporated in the NASA Management Instruction (NMI 7100) addressing integrated technology planning at NASA.

Shown in **Figure 2.15** it provides a summary view of the technology maturation process model for NASA space activities for which the TRL's were originally conceived, other process models may be used. However, to be most useful the general model must include:

- 'Basic' research in new technologies and concepts (targeting identified goals, but not necessary specific systems)
- A focused technology development addressing specific technologies for one or more potential identified applications,
- Technology development and demonstration for each specific application before the beginning of full system development of that application
- System development (through first unit fabrication)
- System 'Launch' and operations.

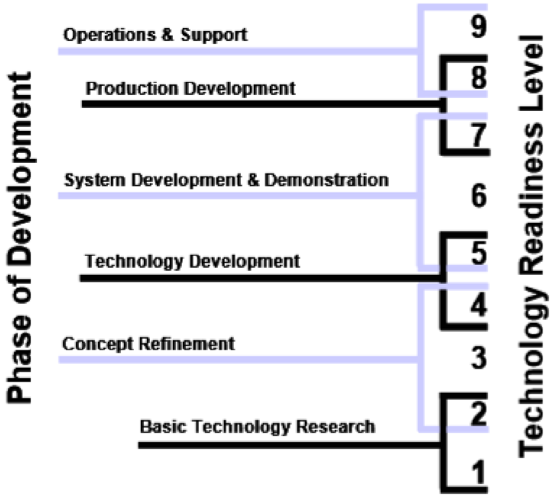



Figure 2.17 System Phases of Development and TRL on Parallel Paths

(Source: Sauser, 2006)

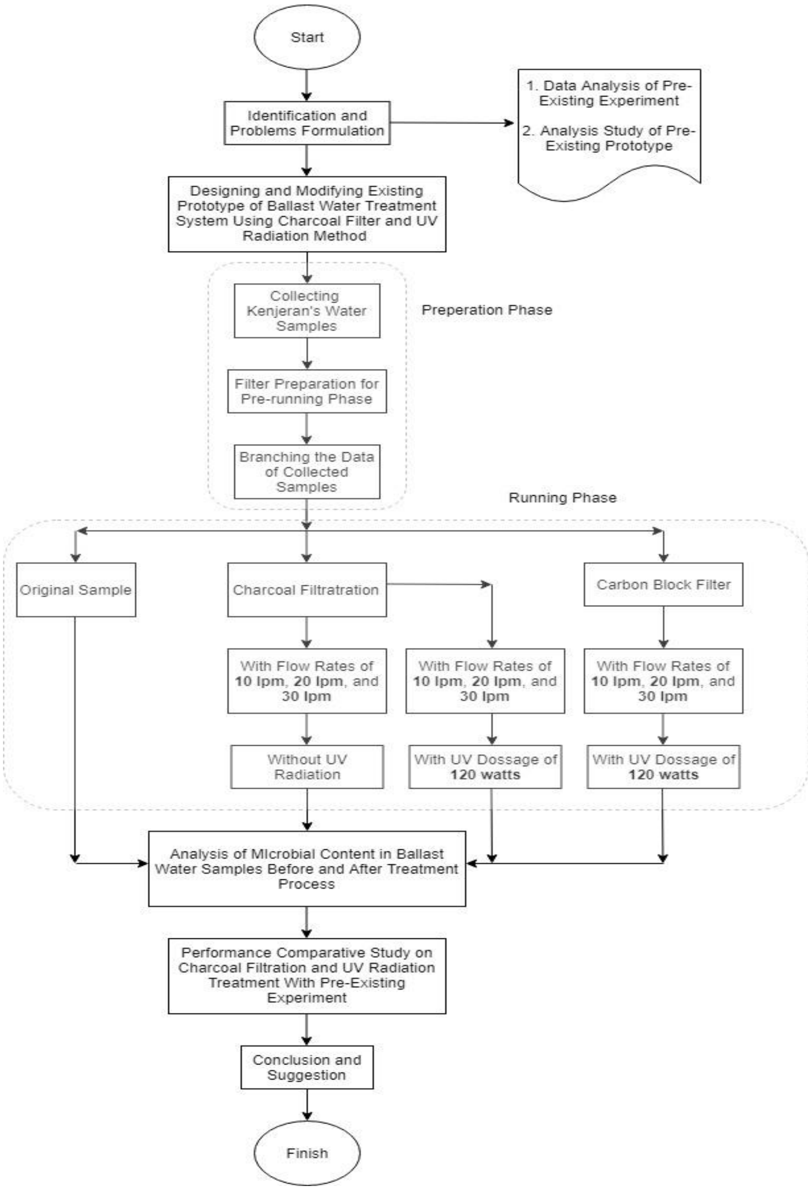
Based on the Technology Readiness Level (TRL) that has been stated above, this project will undergo on first phase of **TRL 1** on **Basic Technology Research**.

# CHAPTER III

# METHODOLOGY

## 3.1 Methodology Flow Chart

The following issues are attached Work Flow Chart that this project will conduct are:



### 3.2 Identification and Problems Formulation Regarding Results and Performance of Pre-existing Ballast Water Treatment Prototype

At this stage, the formulation of problem concerning the performance and results on the *pre-existing prototype* are subject to be studied. Since the results of pre-exsisting ballast water treatment are reached the effectiveness of *10 lpm* and with *UV Power Dossage of 120 watts*, This project will aim to study ballast water treatment method using a *Charcoal Filter* and combine it with *UV Radiation* using method of filtering the microbial content at a variation flow rates of ***10 Lpm***, ***20 lpm***, and ***30 lpm*** with a maximum UV dossage power of ***120 watts***. Further validation are required to evaluate the different results from the limitation given.

### 3.3 Designing and Modifying Existing Prototype of Ballast Water Treatment System Using Charcoal Filter and UV Radiation Method of Treatment

At this stage, the development prototype of ballast water treatment system are on *Designing and Modifying Phase*. In this experiment, filter that to be used are using *Charcoal Filtration* and *UV Radiation* treatment. In this designing steps, this prototype must undergo designing process using autocad, then material selection, and an final check of installation assembly.

#### 3.3.1 Existing Design Prototype of Ballast Water Treatment System

The first step to modify the current system is starting from observing the existing prototype and analyze how the system works. Regarding the results of existing prototype, it is to study the design of ballast water treatment management and know how it works, as can be seen on **Figure 3.2**.

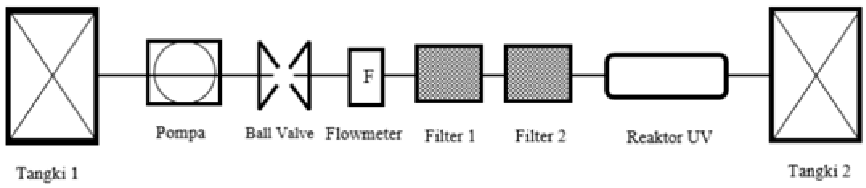



Figure 3.1 Existing BWTS Prototype

(Source: Puspitasari et al, 2017)

From **Figure 3.1**, pre-existing ballast water treatment system prototype that already built are consisted parts of:

1. Tank 1: That works as a container to store seawater on existing condition.
2. Pump: Seawater that contains on Tank 1 will be pump through and transfer it to the filter with different debit variation.
3. Ball Valve: The variation on this system will be matched with configuration using Ball Valve that located in discharge of the pump.
4. Flow Metere: When variating the ballast water debit with the ball valve, it also monitor on the flow metere that located between ball valve and filter.
5. Filter 1: Crumb Rubber Filter
6. Filter 2: Carbon Filter
7. UV Reactor: After filtration process ballast water will entering UV Treatment Reactor and will be process again to inactivate the micro-organism inside ballast water. On this UV Reactor there was 2 UV lamps with capacities of 30 watts each of the lamps. Dossage power of the UV Radiation will be variated.
8. Tank 2: Discharge tank to store treated water

### 3.3.2 Modifying Exsiting Prototype of Ballast Water Treatment System

In this modifying step this project will undertake a design process as can be seen on below **Figure 3.2**, **3.3**, **3.4**, **3.5**, and **3,6**.

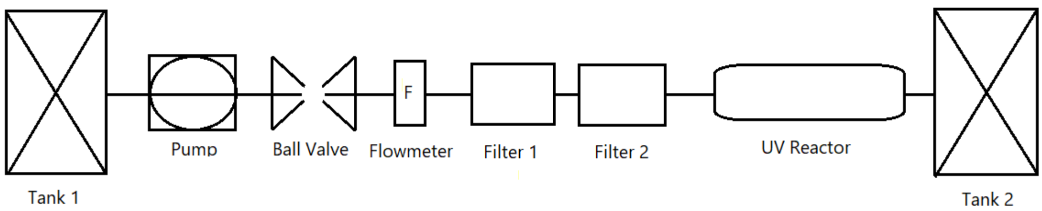



Figure 3.2 Simple Design of Modifying the Prorotype

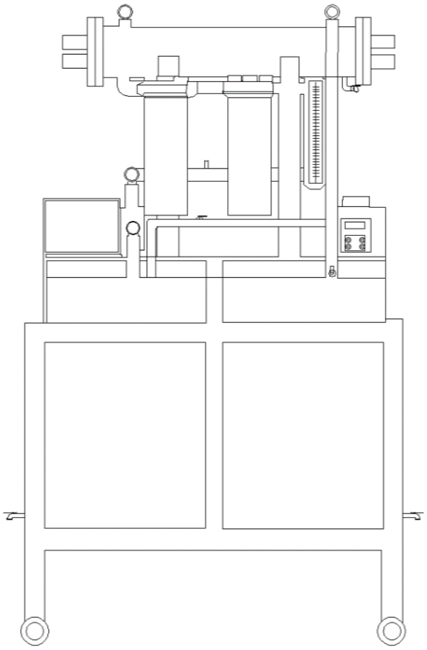


Figure 3.3 Modifying and Designing Prototype on Autocad

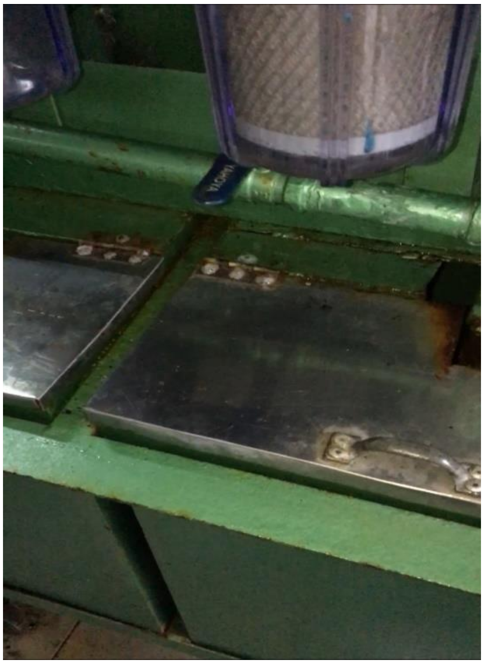


Figure 3.4 Connecting Pipe

The next step of this project is to modify the the existing prototype, first is by adding new flow lines of pipes that connected from discharge tank (Tank 2) to Suction Tank (Tank 1) as can be seen on **Figure 3.4**. This cross section of pipes allows the flow of water to cycle and imitates the real situation aboard a ship, that utilize ballast water distribution across different ballast tank to maintain stability at sea and to make sure the seawater are properly treated by ballast water management system.

Figure 3.5 UV Reactor Water Tap

After adding the pipes the next step is by adding a water tap on UV reactor as can bee seen on **Figure 3.5**. By adding a water tap on UV Reactor, it allows the writer to clean by means of emptying the treated water that traped inside UV reactor to maintain the prototype performance as long this project will undergo.

Next, are changing the *Filter Material* inside *Filter Housing* to match the writer's criteria, Filter that will be used in this project are *Charcoal Filter* and *Carbon filter* as can be seen on **Figure 2.10** and **Figure 2.14**. And the last step of this modifying step are repainting it to eliminate some rust outside and inside tank of the prototype and adding 4 wheels on bottom of the prototype to make it mobile and easy to drain because the height of the prototype is also increase because of it.

The end-result of this modifying step will be prototype that meet the writer's standard and are meet this project objectives, that can be seen on **Figure 3.6**.


Figure 3.6 End-Result of the Modifying Proces

### 3.4 Collecting Kenjeran's Water Samples

Before the running process of the prototype can take place, first step that author will undergo, is to collect kenjeran's water as experimental samples. This sample will serve as media of study to determine quality standard of an original sample and samples after going through different treatment. Information and data below achived from author when collecting samples from Kenjeran's Coast as can be seen on **Figure 3.7**.

| | |
|---|---|
| Date | : Thursday, June 21st 2018 |
| Location | : Kenjeran Coast |
| Time | : 13.00 WIB |
| Temperature | : 26°C |


Figure 3.7 Collecting Spot for Kenjeran's Sea Water Samples

(Source: Google Earth 3D)

### 3.5 Filter Preperation for Pre-running Phase

To make sure the filtration system ***(Charcoal Filter)*** work as intended, first step that will be take is to **Pressure Test** the charcoal itself inside the cartridge using a simple pressure device is called ***Digital Luggage Scale*** as can be seen on **Figure 3.8** that attached with piece of custom wood that already been cutted and shaped like inside the diameter of filter cartridge that will work as press machine, this method is intended to read how much force that will generate when this device are pulled upside down and the stick will push inside cartridge itself pushing the filter material in.

This standard of method is to make sure the filter does not dissolve from different variation of the flow rates this filter will undergo, and to count how long does it takes the water from input ***(Tank 1)*** to travel between treatment process from the ballast water management prototype itself to end-procces that will end up in ***(Tank 2)***.

The **Pressure Test** which this filter will undergo are consisted in 3 variations with pressure point of ***5 kg***, ***10 kg***, and ***15 kg***, which every ***20 grams*** of charcoal inserted into the filter cartridge and pressed with variations of *Pressure Point* stated above, in with exception if any of the variations stated above are dissolved either with flow rates of ***10 lpm***, ***20 lpm***, and ***30 lpm*** will automatically be considered as *failed* with an objective to choose which *Filter* with an optimal *Pressure Point* that are not dissolved and viable to carry this research through ***Running State***.

Table 3.1 Pre-Running Pressure Test Result

| **Filter Pressure Point *(Kg)*** | **Total Time of Ballast Water Travel from Input to Output *(t)*** |
|---|---|
| **5** | ***Dissolved*** |
| **10** | ***0.50,00 seconds*** on max flow rates of ***30 lpm*** |
| **15** | ***Dissolved*** |

Figure 3.8 Digital Luggage Scale


Figure 3.9 Charcoal Filter with Pressure Point of 10 kg

From this pre-running experiment with all variations of *Pressure Point* the best and most viable option to choose is ***10 kg*** of pressure as can be seen on **Table 3.1**. This filter does not dissolve and provide most fast Total Time of Ballast Water Travel from Input to Output *(t)* which takes about ***0.50,00 seconds*** to finish, and from author's criteria with maximum time of ***5.00,00 minutes***, that the water must finish travelling from input to output with maximum flow rates of ***30 lpm*** in consideration if filter can handle the greatest flow rates then which means this filter can also handle below maximum flow rates that already has given neither is ***10 lpm*** or ***20 lpm***.

This ***Charcoal Filter*** with pressure point of ***10 kg*** has a total weight of ***417 grams***. An empty *Cartridge filter* is weighted around ***199 grams***, then adding it with ***Charcoal*** material weighted at ***218 grams*** by pressing the material inside its cartridge with pressure point of ***10 kg*** every ***20 grams***.

### 3.6 Branching the Data of Collected Samples

In this step author will devide and branched the samples to collect data that will be needed to compare, for example:

1. **Original Sample**: This sample will contain the original kenjeran's water unprocessed, with intention to comparing it with the sample that will undergo a treatment process.

2. **1st Branch (Sample 1, Sample 2, and Sample 3)**: This first branch of 3 different samples will undergo some criteria of a process which will use ***Charcoal Filtration*** without ***UV Radiation*** as it treatment, and deviding it into 3 variation with flow rates of ***10 lpm***, ***20 lpm***, and ***30 lpm***.
3. **2nd Branch (Sample 4, Sample 5, and Sample 6)**: The second branch of the samples will use criteria of process using ***Charcoal Filter*** with ***UV Radiation*** as it treatment, and deviding it into 3 variation with flow rates of ***10 lpm***, ***20 lpm***, and ***30 lpm*** then combining it with ***120 watts*** of UV Radiation.
4. **3rd Branch (Sample 7, Sample 8, and Sample 9)**: The third and last branch of the samples will use criteria of process using ***Carbon Block Filter*** with ***UV Radiation*** as it treatment, and deviding it into 3 variation with flow rates of ***10 lpm***, ***20 lpm***, and ***30 lpm*** then combining it with ***120 watts*** of UV Radiation.

### 3.7 Analysis of Microbial Content in Ballast Water Samples Before and After Treatment Process

At this stage, an analysis amount of microbial content in pathogenic water before the ballast water treated and after the ballast water has been treated are taking place. This process was conducted to find out how the performance of Charcoal Treatment prototype is compared with pre-existing prototype. Whether the data generated from this experiment has the consistency as the past method were being compared. The method use to analyze the microbial content of this pathogenic water is by using Total Plate Count (TPC) method, in which the microorganism cell was stimulates using Sodium Agar (Na) so that living microbes will reproduce and form colonies that can be calculated directly without using a microscope (Prescott, 2002).

According to **Figure 3.10**, the dilution stage starts from making a 10 ml sample solution (mixture of 1 ml of water sample with 9 ml of sterile seawater solution). From the solution it will be mixed and will be recovered as much as 1 ml and put into 9 ml sterile seawater solution on the second tube to obtain dilution $10^{-2}$. From the $10^{-2}$ dilution it will be recovered as much as 1 ml and inserted into a third reaction tube containing 9 ml of sterile seawater solution and obtained $10^{-3}$ dilution.

After the dilution process, the sample will be plant to the agar plate media and after that it will be incubated. The number of colonies of each cup will be observed and counted. Colonies are a collection of microorganisms that have the same properties of shape, form, surface and so on. The advantage of this TPC method is to know the number of microbes that are dominant in the water content of the sample and can know the existence of other types of microbes contained in the water sample.

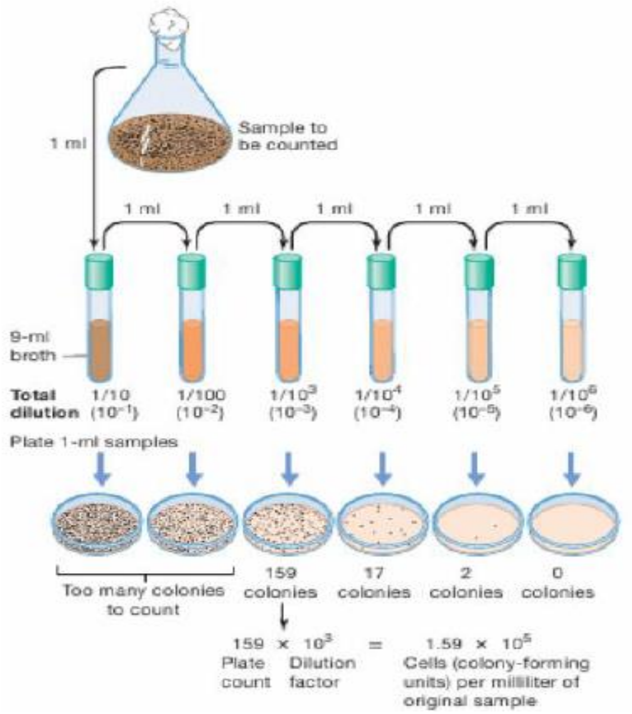



Figure 3.10 Total Plate Count (TPC)

(Source: Prescott, 2002)

To calculate the number of colonies contained in the cup, there are some requirements that must be considered, are:

1. The plate that will selected and calculated is the plate that have a number of colonies between 25 to 250.

2. Some colonies that merge into one are a large collection of colonies, where the number of colonies is in doubt, and can be calculated as a one colony.

3. A row or chain of colonies that looks like a thick line is counted as a colony.

4. Plate that need to be choose are from dilution that showing the number of colonies between 25-250 colonies.

### 3.8 Performance Comparative Studies on Charcoal Filtration and UV Radiation Treatment with Pre-Existing Prototype

At this phase, the performance analysis of the *Charcoal prototype* are compared with the *pre-existing prototype*. In addition, the results also a subject to be studied and compared between *Charcoal prototype* and *pre-existing* prototype. If the results of the tests have consistent results with the results of testing in the first stage, it can be stated that the water treatment system using UV filtration and irradiation can comply with the standard given by *IMO Ballast Water Management Convention*.

### 3.9 Conclusion and Suggestion

At this stage, the conclusion and suggestion from this ballast water treatment using *Charcoal Filter* will be stated and as subject to be studied for the next experiment or project. The ultimate goal of this project are to validate and as an alternative method of treatment from the pre-existing prototype.

# Chapter IV

# DATA ANALYSIS

## 4.1 General

In this chapter will be explained about the data analysis and discussion of the preparation phase, pre-running phase, running phase and results of sea water treatment experiments using *Charcoal Filter* and *UV Radiation* prototype of water ballast processing prototype that has been conducted. Then the results of this study are compared with recent study by (Puspitasari et al, 2017) to determine how the performance and viability of *Charcoal Filter* and *UV Radiation* as an alternative treatment system. This data analysis was obtained from laboratory observation from amount of microbes that contained in sea water with the water conditions that have been processed in the prototype of ballast water treatment and sea water that has not been processed by the prototype. Microbial observation in this study used *Total Plate Count* (TPC) method by using specific media of growth of *Escherichia coli* bacteria in the form of *Eosin Methylene Blue* (EMB) and sterilized salinity where the salinity has the same amount as sea water sample. From the results of this observation will be known whether the prototype of ballast water treatment that has been made are working as intended and effectively in killing microbial water pathogens contained in sea water.

## 4.2 Running and Collecting Data

Table 4.1 *(Charcoal Filter without UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Charcoal Filter Without UV Radiation** | | | |
|---|---|---|---|
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.50,77 minutes* | *1.12,95 minutes* | *1.02,99 minutes* |

Table 4.2 *(Charcoal Filter with UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Charcoal Filter with UV Radiation** | | | |
|---|---|---|---|
| **UV Dossage** | **120 watts** | | |
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.54,68 minutes* | *1.17,15 minutes* | *1.05,97 minutes* |

Table 4.3 *(Carbon Block Filter with UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Carbon Block Filter with UV Radiation** | | | |
|---|---|---|---|
| **UV Dossage** | **120 watts** | | |
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.36,31 minutes* | *1.11,20 minutes* | *1.01,12 minutes* |

Analytical data that has been collected through running procedure according to author's step of work of will be presented in this sub chapter. First of is the analysis of *Total Time of Ballast Water Travel from Input to Output (t)* after Kenjeran's Sea Water going thourgh *Charcoal Filter* on pressure point of ***10 kg*** using variation of flow rates in ***10 lpm***, ***20 lpm***, and ***30 lpm*** with **120 watts** *UV Radiation* or without *UV Radiation* method of treatment.

This results then will further studied using method of *Total Plate Count* (TPC) by using specific media of growth of *Escherichia coli* bacteria in the form of *Eosin Methylene Blue* (EMB) and sterilized salinity with amount of $25^{o}/_{oo}$ acted as diluent of *Escherichia Coli*.

## 4.3 Microbial Content of Kenjeran's Sea Water in Existing Condition

Analysis of microbial content of Kenjeran's seawater samples in the existing condition is done by using *Total Plate Count* (TPC) method by using a specific medium of growth of *Escherichia coli* bacteria in the form of *Eosin Methylene Blue* (EMB) and by using salinated diluent. After being observed, Kenjeran's seawater samples prior to the treatment were carried out microbial content of ***$9x10^8$ CFU/ml*** as can be seen on data stated with **Table 4.4**.

Table 4.4 Kenjeran's Seawater Sample on Existing Condition

| **Kenjeran's Seawater Sample on Existing Condition** | **CFU/ml** |
|---|---|
| | $9.0 \times 10^8$ |

## 4.2 Filtration and UV Radiation Effect on Kenjeran 's Sea Water Microbial Content

*Escherichia coli* is a bacteria that can be pathogenic, also acting as the leading cause of morbidity and mortality worldwide (Tenailon et al, 2010). This bacterium is a short stem-shaped gram-negative bacterium that has a length of about 2 µm diameter of 0.7 µm, width of 0.4 to 0.7 µm and is anaerobic facultative. In general, bacteria require high humidity around 85% (Madigan & Martinko, 2006). This bacterium is a class of mesophilic bacteria ie bacteria that have optimum growth temperature is 15-45 ° C and can live at between 5.5 – 8 pH. *Escherichia Coli* bacteria will grow optimally at 27 ° C, but according to research this bacteria will undergo grwoth inactivation at a maximum temperature of above 40-45 ° C.

*Escherichia Coli* belong to different categories of *Enterobacteriaceae*. In this experiment author will conduct observations on the number of *coliform Enterobacteriaceae* (CFU) contained in the collected sample of water and will be further discussed.

### 4.2.1 Analysis of Microbial Content in Charcoal Filtration Method

Table 4.5 Microbial Content (CFU/ml) in *Charcoal Filtration* Method without Using *UV Radiation*

| UV Dossage (watts) | Charcoal Filtration | | |
|---|---|---|---|
| | Flow Rates (lpm) | | |
| | 10 | 20 | 30 |
| - | $1.4 \times 10^3$ | $6.3 \times 10^3$ | $7.0 \times 10^4$ |

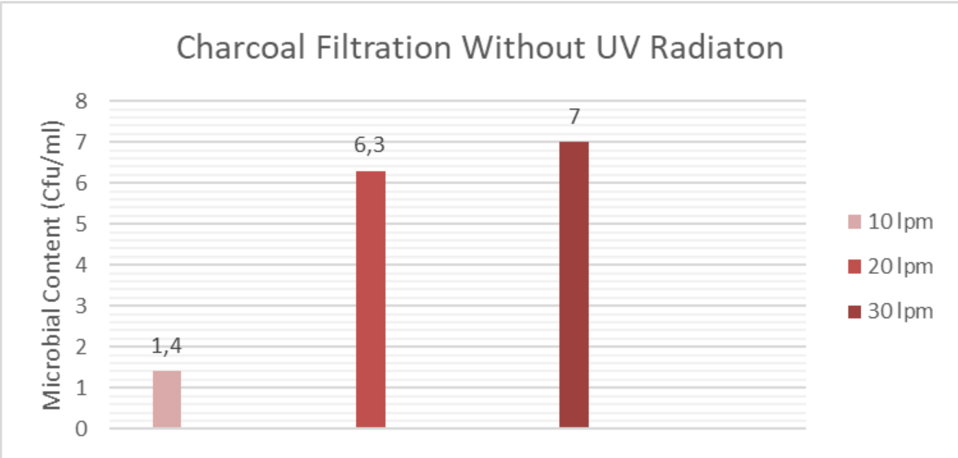



Figure 4.1 Microbial Content (Cfu/ml) in *Charcoal Filtration* Method without *UV Radiation*

From observations that have been conducted by using *Total Plate Count* (TPC) method, the obtained results of Microbial Content in *Charcoal Filtration* without using *UV Radiation* can be seen on **Table 4.5** and **Figure 4.1** shows the quantitative results of microbial content contained in each test sample.

From the data results given above, it shows that difference in variation of flow rates can effect the quality performance of a filter media. In this case *Charcoal Filter* without *UV Radiation* in flow rates of ***10 lpm*** has microbial content of **$1.4\text{x}10^3$** CFU/ml, while at ***20 lpm*** has microbial content of **$6.3\text{x}10^3$** CFU/ml and then at ***30 lpm*** has microbial content of **$7.0\text{x}10^4$** CFU/ml.

Which supported the statement in accordance with article from (Meridian Institute, 2005) are stated with higher water turbidity and higher use of flow rate can also decrease the removal efficiency of a filter media.

The most efficient and effective treatment for Kenjeran's seawater samples prior to the treatment, were carried out microbial content is ***$9.0x10^8$*** CFU/ml, Then compared after using ***10 lpm*** variation of flow rate that has microbial content of **$1.4x10^3$** CFU/ml by use of *Charcoal Filtration* method of treatment.

### 4.2.2 Analysis of Microbial Content on Charcoal Filtration and UV Radiation Method

Table 4.6 Microbial Content in *Charcoal Filtration* Method with *UV Radiation* of 120 watts

| **UV Dossage (watts)** | **Charcoal Filtration** | | |
|---|---|---|---|
| | **Flow Rates (lpm)** | | |
| | **10** | **20** | **30** |
| **120 watts** | $1.1 \times 10^3$ | $1.6 \times 10^3$ | $5.5 \times 10^3$ |

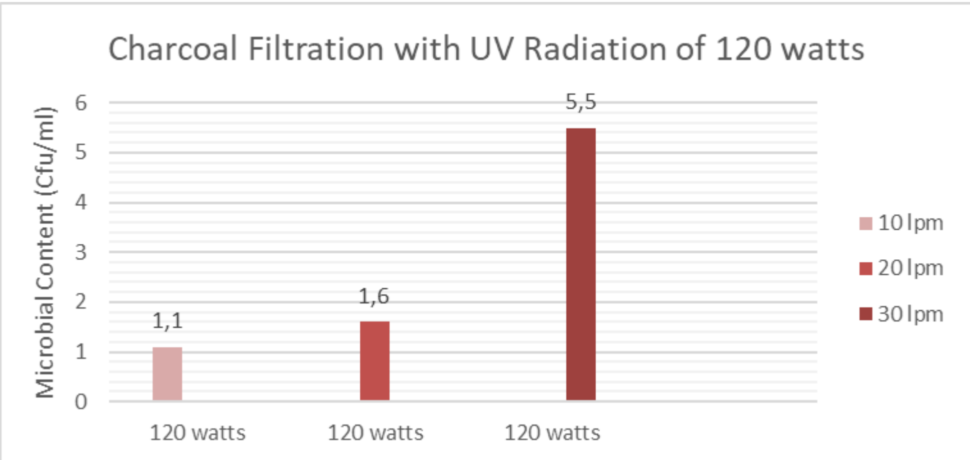



Figure 4.2 Microbial Content (CFU/ml) in *Charcoal Filtration* Method with *UV Radiation* of 120 watts

From observations that have been conducted by using *Total Plate Count* (TPC) method, the obtained results of Microbial Content in *Charcoal Filtration* with *UV Radiation* of **120 watts** can be seen on **Table 4.6** and **Figure 4.2** shows the quantitative results of microbial content contained in each test sample.

From the data results given above, in use of *Charcoal Filter* with flow rates of ***10 lpm*** and UV dossage power of ***120 watts*** has microbial content of $\mathbf{1.1x10^3}$ CFU/ml, while at ***20 lpm*** with UV dosage power of ***120 watts*** has microbial content of $\mathbf{1.6x10^3}$ CFU/ml and then at ***30 lpm*** with UV dosage power of ***120 watts*** has microbial content of $\mathbf{5.5x10^3}$ CFU/ml.

This different result from before and after is caused by *Charcoal*. *Charcoal Filter* is used for water filtration because of it adsorptive (pores) properties. In these absorbance process which contaminant is attracted to and held (absorbed) onto the surface of the charcoal particles (Dvorak, 2008). From observations that have been conducted by using *Total Plate Count* (TPC) method, the obtained results of Microbial Content in *Charcoal Filtration* with *UV Radiation* of **120 watts** can be seen on **Table 4.6** and **Figure 4.2** shows the quantitative results of microbial content contained in each test sample.

The most efficient and effective treatment for Kenjeran's seawater samples prior to the treatment, were carried out microbial content is $\boldsymbol{9.0x10^8}$CFU/ml, Then compared after using ***10 lpm*** variation of flow rate and in combination with *UV Dossage Power* of ***120 watts*** that has microbial content of $\mathbf{1.1x10^3}$ CFU/ml by use of *Charcoal Filtration* and *UV Radiation* method of treatment.

### 4.2.3 Analysis of Microbial Content on Carbon Block Filtration and UV Radiation Method

Carbon Filter is a water filteration method that has been widely used in world as a tool to filter microbial content on a daily usage of water. This filter uses activated carbon that can act as a absorbent and can contain and filter microbial contaminants. In this experiment and in the pre-existing experiment, the performance comparison between Experimental *(Charcoal Filter)* filter with carbon filter.

From observations that have been conducted by using *Total Plate Count* (TPC) method, the obtained results of Microbial Content in *Carbon Block Filtration* with *UV Radiation* of **120 watts** can be seen on **Table 4.7** and **Figure 4.3** shows the quantitative results of microbial content contained in each test sample.

Table 4.7 Microbial Content (CFU/ml) in *Carbon Block Filtration* Method with *UV Radiation* of 120 watts

| **UV Dosage (watts)** | **Carbon Block Filtration** | | |
|---|---|---|---|
| | **Flow Rates (lpm)** | | |
| | **10** | **20** | **30** |
| **120 watts** | $1.4 \times 10^4$ | $1.8 \times 10^4$ | $2.1 \times 10^8$ |

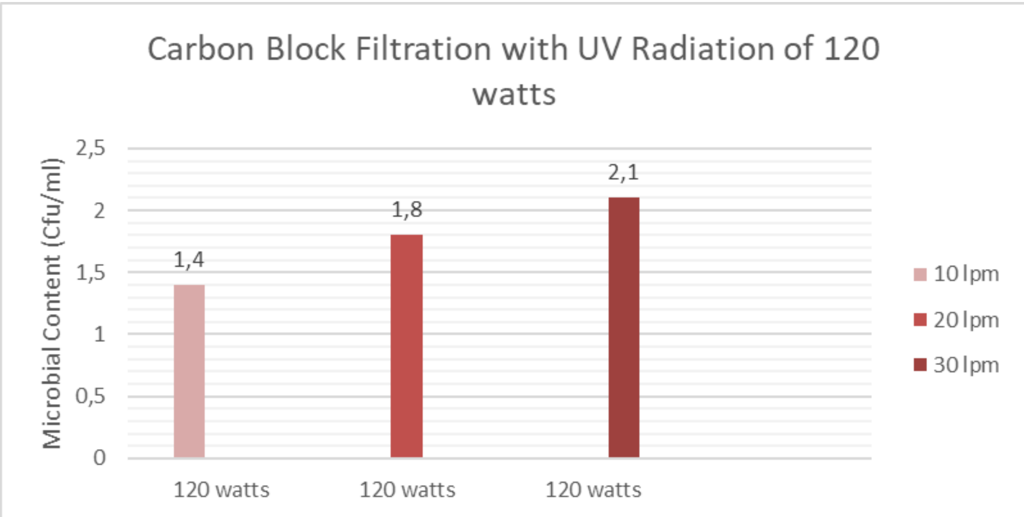



Figure 4.3 Microbial Content (CFU/ml) in *Carbon Block Filtration* Method with *UV Radiation* of 120 watts

From the data results given above, in use of *Carbon Block Filter* with flow rates of ***10 lpm*** and UV dosage power of ***120 watts*** has microbial content of **$1.4 \times 10^4$** CFU/ml, while at ***20 lpm*** with UV dosage power of ***120 watts*** has microbial content of **$1.8 \times 10^4$** CFU/ml and then at ***30 lpm*** and UV dosage power of ***120 watts*** has microbial content of **$2.1 \times 10^8$** CFU/ml.

The most efficient and effective treatment for Kenjeran's seawater samples prior to the treatment, were carried out microbial content is **$9.0x10^8$** CFU/ml, Then compared after using ***10 lpm*** variation of flow rate and in combination with *UV Dossage Power* of ***120 watts*** that has microbial content of **$1.4x10^4$** CFU/ml by use of *Carbon Block Filtration* and *UV Radiation*.

### 4.2.4 Analysis Comparation Study Performance of Charcoal Filter and Carbon Block Filter

In this comparation analysis study author will present and compare the data that already stated above to know it consistency, efficiency, and effectiveness of *Charcoal Filter*. This method is done to ensure and increase the validity in determining type of filter that has the most effective and efficient way in filtering microbial content.

Table 4.8 Microbial Content (CFU/ml) in *Charcoal Filtration* and *Carbon Block Filtration* Method with *UV Radiation* of 120 watts

| UV Dossage (watts) | Charcoal Filtration | | | UV Dossage (watts) | Charcoal Filtration | | | UV Dossage (watts) | Carbon Block Filtration | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Rates (lpm) | | | | Flow Rates (lpm) | | | | Flow Rates (lpm) | | |
| | 10 | 20 | 30 | | 10 | 20 | 30 | | 10 | 20 | 30 |
| - | $1.4 \times 10^3$ | $6.3 \times 10^3$ | $7.0 \times 10^4$ | 120 watts | $1.1 \times 10^3$ | $1.6 \times 10^3$ | $5.5 \times 10^3$ | 120 watts | $1.4 \times 10^4$ | $1.8 \times 10^4$ | $2.1 \times 10^8$ |

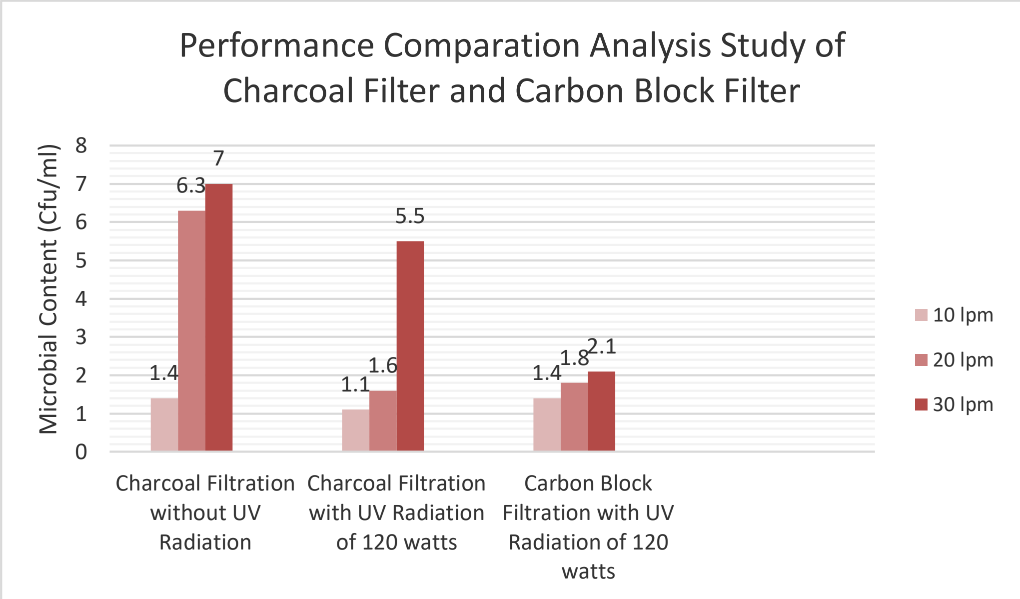



Figure 4.4 Performance Comparation Analysis Study of *Charcoal Filter* and *Carbon Block Filter*

As can be seen on **Table 4.8** and **Figure 4.4** *Charcoal Filter* provides more effective and efficient way to filter microbial content inside of the water samples more than *Carbon Block Filter* can provide. This statement is supported by the data given on **Table 4.8** and **Figure 4.4** where in flow rates of ***10 lpm*** and with *UV Radiation* of ***120 watts***, *Charcoal Filtration* method has less Microbial Content of $\mathbf{1.1x10^3}$ CFU/ml in comparison with *Carbon Block Filtertration* method that has more microbial content of $\mathbf{1.4x10^4}$ CFU/ml. In **Table 4.8** and **Figure 4.4** there are also data form Charcoal Filtration without the use of UV Radiation as it treatment that has amount of $\mathbf{1.4x10^3}$ CFU/ml.

This data proves that This treatment has a different impact to a treated ballast water system, Since *Charcoal* is used for water filtration because of it adsorptive (pores) properties. In these absorbance process which contaminant is attracted to and held (absorbed) onto the surface of the charcoal particles (Dvorak, 2008). Filtration method of treatment is supposed to have a better performance in combination with *UV Treatment*. Since *Charcoal* will filter the contaminant (bacteria) that contained in sea water, then the *UV Radiation* will partake in the process to inactivate remaining contaminant of the sea water, since *UV Rays* has the ability to affect the function of living cells by altering the material of the cell nucleus or can be called DNA, so that living creature can be killed (Eccleston, 1998).

The majority of water purification devices that are currently in use are comprised of material that has the appropriate balance between performance and cost. Many filtration devices operate under mains of water pressure and flow water through a formed particle or carbon block, where the density of packed particles results in maximum internal pore sizes that range from 0.5–10 μm and then operates by gravity mechanism, where water passes over larger media particles to enable contaminant adsorption according to (Sweetman, 2017).

The typical elemental composition of *Charcoal* is around 80% carbon, with other elements including oxygen and nitrogen accounting for the remaining material according to article from (Dabrowski, 2005). Both the physical and chemical properties of *Charcoal* will affect the pore distribution capacities to different organic and inorganic species (Ebie, 2001).

*Charcoal* that used in this expirement are tree charcoal in regarding to Indonesia's Government plan to utilize more waste from charcoal usage and from aspect the availability of resources in Indonesia itself.

In this experiment author used crushed *Charcoal* with particle size of **2 mm**, with pressure point of ***10 kg*** and has a total weight of ***417 grams***. An empty *Cartridge filter* is weighted around ***199 grams***, then adding it with ***Charcoal*** material weighted at ***218 grams*** by pressing the material inside its cartridge with pressure point of ***10 kg*** every ***20 grams*** to ensure that this filter will not dissolved during this experiment.

### 4.3 Performances Analysis and Comparation Study of Existing Experiment With *Charcoal Filter and UV Radiation* Method of Treatment

To validate the test result on Ballast Water Treatment System using *Charcoal Filter* and *Carbon Block Filter*, Performance Analysis and Comparation Study will be conducted to compare the performance differences between existing method of treatment from using *Crumb Rubber Filter* and *Carbon Filter* to current study by using *Charcoal Filtration* and *Carbon Block Filtration* with *UV Radiation* of ***120 watts*** and by using variation flow rates in ***10 lpm***.

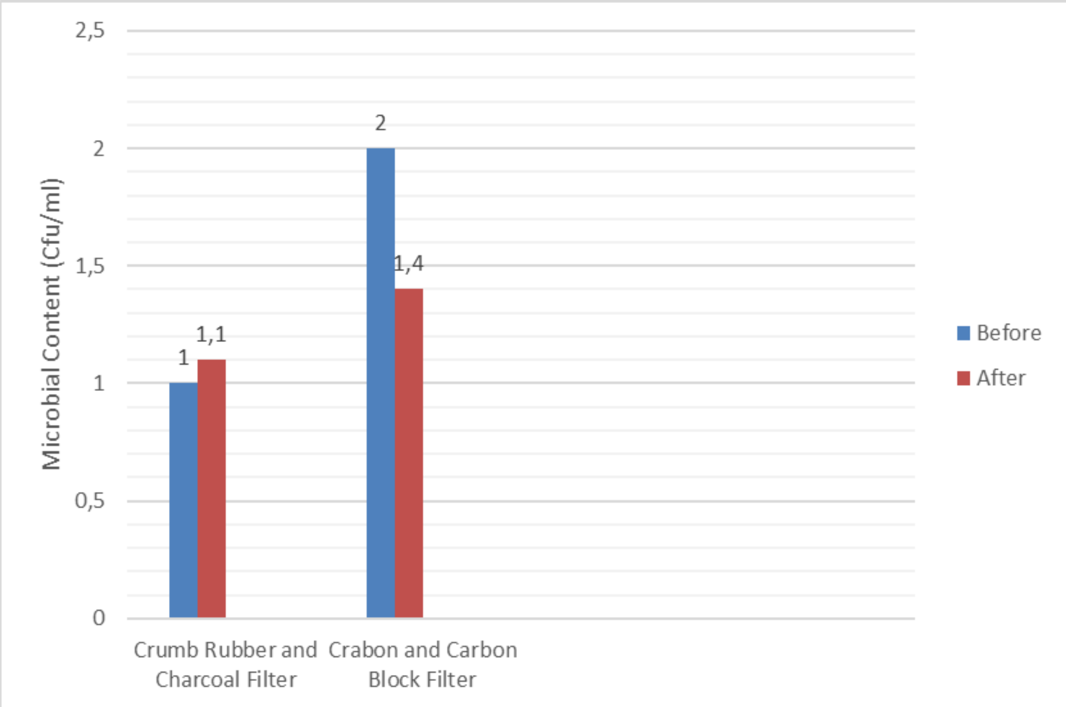



Figure 4.5 Performance Analysis and Comparation Study from Existing Experiment to *Charcoal Filtration* and *Carbon Block Filtration*

As can be seen on **Figure 4.5** by using *Charcoal Filtration* with flow rate of ***10 lpm*** and *UV Radiation* of ***120 watts*** has amount microbial content of $\mathbf{1.1x10^3}$ CFU/ml, while on previous experiment has amount microbial content of $\mathbf{1.0x10^4}$ CFU/ml. This data proves that *Charcoal Filtration* method can possibly use as alternative media to filter ballast water, and also possibly have a better result if the Charcoal media have been activated before. The activation process, usually performed at high temperature by chemical or steam treatment, generates an extensive porous network within the carbonaceous material (Yahya, 2015).

On **Figure 4.5** also stated that by using *Carbon Block Filter* flow rate of ***10 lpm*** and *UV Radiation* of ***120 watts*** has amount microbial content of **$1.4 x 10^4$** CFU/ml, while on previous experiment has amount microbial content of **$2.0 x 10^4$** CFU/ml. Using *Carbon Block Filter* has advantage of better performance overall than using ordinary *Carbon Filter*.

# CHAPTER V

# CONCLUSION AND SUGGESTION

## 5.1 Conclusion

The final conclusion from author perspective on this Experimental Study of *Charcoal Filter* and *UV Radiation* as Ballast Water Treatment System are as follows:

1. This prototype of ballast water treatment can perform the most effective to inactivate microbial content in seawater by using a ***10 Lpm*** flow rate and with maximum UV dose of ***120 watts*** when using *Charcoal Filtration* as its method of treatment.
2. The test results using *Charcoal Filtration* method with combination of *UV Radiation* as method to treating ballast water proves has effective and efficient value as an alternative to filter and inactivate the microbial content in Ballast Water. *Flow rates* and *UV doses* also may affect the removal efficiency of microbial content. The greater the flow rate are given, then the greater the amount of microbial content are obtained. On the contrary, the greater the UV dose given the smaller the amount of microbial content present in the sample water.
3. From observations that have been conducted by using *Total Plate Count* (TPC) method, the most efficient and effective treatment for Kenjeran's seawater samples prior to the treatment, were carried out microbial content is $\mathbf{9.0 \times 10^{8}}$ CFU/ml, then compared by using ***10 lpm*** variation of flow rate and in combination with *UV Dossage Power* of ***120 watts*** that has microbial content of $\mathbf{1.1 \times 10^{3}}$ CFU/ml.

## 5.2 Suggestion

To further develop this experiment, there are some suggestions from author perspective that can be added for the next experiment, namely:

1. Additional method of treatment can be added such as adding additional filter or dual filtration method of treatment using *Charcoal Filter*.

2. *Charcoal Filter* can be further developed and produced as an activated carbon. The activation process, usually performed at high temperature by chemical such as or steam treatment, generates an extensive porous network within the carbonaceous material (Yahya, 2015) to increase its effectivity and efficiency perfoming filtration process of microbial content in Ballast Water.
3. Scalling measurement between model prototype and on board of ship that has scale of 1/1 need to be taken into consideration because how it will be beneficial and relevant if the current prototype can also implemented directly into the ship.
4. Additional analysis of cycling process in ballast water treatment system need to be further studied and discussed in the next experiment, to maximixe the treatment efficiency of ballast.
5. Further study of *UV Radiation* light is needed to further develop the most effective and efficient way to build an *UV Reactor* for Ballast Water Management System.

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# Attachment 1
# Results Data of Microbial Content Using Total Plate Count (TPC) Method

## 1.1 Amount of Microbial Content Before the Experiment

Table 1.1 Kenjeran's Seawater Sample on Existing Condition

| Kenjeran's Seawater Sample on Existing Condition | CFU/ml |
|---|---|
| | $9.0 \times 10^8$ |

## 1.2 Amount of Microbial Content Using Charcoal Filtration Without UV Radiation

Table 1.2 Microbial Content (CFU/ml) in *Charcoal Filtration* Method without Using *UV Radiation*

| UV Dossage (watts) | Charcoal Filtration | | |
|---|---|---|---|
| | Flow Rates (lpm) | | |
| | 10 | 20 | 30 |
| - | $1.4 \times 10^3$ | $6.3 \times 10^3$ | $7.0 \times 10^4$ |

## 1.3 Amount of Microbial Content Using Charcoal Filtration and UV Radiation

Table 1.3 Microbial Content in *Charcoal Filtration* Method with *UV Radiation* of 120 watts

| UV Dossage (watts) | Charcoal Filtration | | |
|---|---|---|---|
| | Flow Rates (lpm) | | |
| | 10 | 20 | 30 |
| 120 watts | $1.1 \times 10^3$ | $1.6 \times 10^3$ | $5.5 \times 10^3$ |

## 1.4 Amount of Microbial Content Using Carbon Block Filtration and UV Radiation

Table 1.4 Microbial Content (CFU/ml) in *Carbon Block Filtration* Method with *UV Radiation* of 120 watts

| UV Dosage (watts) | Carbon Block Filtration | | |
|---|---|---|---|
| | Flow Rates (lpm) | | |
| | 10 | 20 | 30 |
| 120 watts | $1.4 \times 10^4$ | $1.8 \times 10^4$ | $2.1 \times 10^8$ |

## 1.5 Analysis Comparation Study Usage of Charcoal Filter and Carbon Block Filter

Table 1.5 Microbial Content (CFU/ml) in *Carbon Block Filtration* Method with *UV Radiation* of 120 watts

| UV Dosage (watts) | Charcoal Filtration | | | UV Dosage (watts) | Charcoal Filtration | | | UV Dosage (watts) | Carbon Block Filtration | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Rates (lpm) | | | | Flow Rates (lpm) | | | | Flow Rates (lpm) | | |
| | 10 | 20 | 30 | | 10 | 20 | 30 | | 10 | 20 | 30 |
| - | $1.4 \times 10^3$ | $6.3 \times 10^3$ | $7.0 \times 10^4$ | 120 watts | $1.1 \times 10^3$ | $1.6 \times 10^3$ | $5.5 \times 10^3$ | 120 watts | $1.4 \times 10^4$ | $1.8 \times 10^4$ | $2.1 \times 10^8$ |

## 1.6 Laboratorium Data from Angler Biochemlab Surabaya

Certificate No. 184324-3
July 11, 2018

5.10/F/2/2 Rev. 2/2
page 1 of 1

**REPORT OF ANALYSIS**

CLIENT : Himawan Abrarri Sutanto
Ketintang Regency Blok I / 26 RT 009 RW 006
Kel. Ketintang, Kec. Gayungan, Surabaya

RECEIVED ON : July 06, 2018

TEST REQUIRED : Total Plate Count Analysis

VOLUME RECEIVED : 100 mililiters sample liquid in package was submitted by client

TYPE OF SAMPLE : Water

DESCRIPTION of SAMPLE : Air Laut 30 LPM

METHOD & EQUIPMENT :
Bacteriological Analytical Manual Chapter 3, 2001.

TEST RESULT :

| Measurand | Unit | Result |
|---|---|---|
| Total Plate Count | cfu/mL | **$7.0 \times 10^2$** |

Note :
Precision of the analysis batch had been checked and fulfilled the declared Laboratory Quality Control Criteria
(x.xx) : ( . ) as character indicates decimal notation

Pharma Testing & RND Manager

KJU 18070129#3
#CA-180711#24-WTR

This result related to the samples submitted only.

Diah Intan Purwanti, S.Si

Figure 1.1 Microbial Analysis Data from Angler Biochem Lab Surabaya on ***30 lpm***

Certificate No. 184324-2
July 11, 2018

5.10/F/2/2 Rev. 2/2
page 1 of 1

## REPORT OF ANALYSIS

CLIENT : Himawan Abrarri Sutanto
Ketintang Regency Blok I / 26 RT 009 RW 006
Kel. Ketintang, Kec. Gayungan, Surabaya

RECEIVED ON : July 06, 2018

TEST REQUIRED : Total Plate Count Analysis

VOLUME RECEIVED : 100 mililiters sample liquid in package was submitted by client

TYPE OF SAMPLE : Water

DESCRIPTION of SAMPLE : Air Laut 20 LPM

METHOD & EQUIPMENT :
Bacteriological Analytical Manual Chapter 3, 2001.

TEST RESULT :

| Measurand | Unit | Result |
|---|---|---|
| Total Plate Count | cfu/mL | **$6.3 \times 10^3$** |

Note :
Precision of the analysis batch had been checked and fulfilled the declared Laboratory Quality Control Criteria
(x.xx) : ( . ) as character indicates decimal notation

Pharma Testing & RND Manager

KJU 18070129#2
#CA-180711#23-WTR

This result related to the samples submitted only.

Diah Intan Purwanti, S.Si

Figure 1.2 Microbial Analysis Data from Angler Biochem Lab Surabaya on ***20 lpm***

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**REPORT OF ANALYSIS**

CLIENT : Himawan Abrarri Sutanto
Ketintang Regency Blok I / 26 RT 009 RW 006
Kel. Ketintang, Kec. Gayungan, Surabaya

RECEIVED ON : July 06, 2018

TEST REQUIRED : Total Plate Count Analysis

VOLUME RECEIVED : 100 mililiters sample liquid in package was submitted by client

TYPE OF SAMPLE : Water

DESCRIPTION of SAMPLE : Air Laut 10 LPM

METHOD & EQUIPMENT :
Bacteriological Analytical Manual Chapter 3, 2001.

TEST RESULT :

| Measurand | Unit | Result |
|---|---|---|
| Total Plate Count | cfu/mL | **$1.4 \times 10^3$** |

Note :
Precision of the analysis batch had been checked and fulfilled the declared Laboratory Quality Control Criteria
(x.xx) : ( . ) as character indicates decimal notation

Pharma Testing & RND Manager

KJU 18070129#1
#CA-180711#22-WTR

This result related to the samples submitted only.

Diah Intan Purwanti, S.Si

Figure 1.3 Microbial Analysis Data from Angler Biochem Lab Surabaya on ***30 lpm***

## 1.7 Laboratorium Data from Balai Riset dan Standarisasi Industri Surabaya

**LAPORAN HASIL UJI**

No. 4601~4609/18/LHU/2/VII/2018

| | | | |
|---|---|---|---|
| Nomor Analisa : | 2018P4601 s/d 2018P4609 | Nama Pengirim : | HIMAWAN ABRARRI S. |
| Contoh : | Air Laut | Alamat : | Jl. Royal Ketintang Regency Blok I No. 26 Surabaya |
| Merk : | Terlampir | | |
| Diterima Tanggal : | 28 Juni 2018 | | |
| Catatan Sampel : | 500 ml air laut dalam botol | | |

| Nomor Analisa | Kode | Satuan | Hasil Uji Angka Lempeng Total (ALT) | Metode Uji |
|---|---|---|---|---|
| P. 4601 | 10 Charcoal Filter | koloni/mL | $1.1x10^3$ | SNI 01-2897-1992 |
| P. 4602 | 20 Charcoal Filter | koloni/mL | $1.6x10^3$ | SNI 01-2897-1992 |
| P. 4603 | 30 Charcoal Filter | koloni/mL | $5.5x10^3$ | SNI 01-2897-1992 |
| P. 4604 | 40 Charcoal Filter | koloni/mL | $7.0x10^7$ | SNI 01-2897-1992 |
| P. 4605 | 10 Block Charcoal Filter | koloni/mL | $1.4x10^4$ | SNI 01-2897-1992 |
| P. 4606 | 20 Block Charcoal Filter | koloni/mL | $1.8x10^4$ | SNI 01-2897-1992 |
| P. 4607 | 30 Block Charcoal Filter | koloni/mL | $2.1x10^8$ | SNI 01-2897-1992 |
| P. 4608 | 40 Block Charcoal Filter | koloni/mL | $8.9x10^3$ | SNI 01-2897-1992 |
| P. 4609 | X = Sampel Ori | koloni/mL | $9.0x10^8$ | SNI 01-2897-1992 |

Figure 1.4 Microbial Analysis Data from Badan Riset dan Standarisasi Industri Surabaya

## 1.8 Total Time of Ballast Water Travel from Input to Output

Table 1.6 *(Charcoal Filter without UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Charcoal Filter Without UV Radiation** | | | |
|---|---|---|---|
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.50,77 minutes* | *1.12,95 minutes* | *1.02,99 minutes* |

Table 1.6 *(Charcoal Filter with UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Charcoal Filter with UV Radiation** | | | |
|---|---|---|---|
| **UV Dossage** | **120 watts** | | |
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.54,68 minutes* | *1.17,15 minutes* | *1.05,97 minutes* |

Table 1.7 *(Carbon Block Filter with UV Radiation)* Total Time of Ballast Water Travel from Input to Output (t)

| **Carbon Block Filter with UV Radiation** | | | |
|---|---|---|---|
| **UV Dossage** | **120 watts** | | |
| **Flow Rates (lpm)** | **10** | **20** | **30** |
| **Total Time of Ballast Water Travel from Input to Output *(t)*** | *1.36,31 minutes* | *1.11,20 minutes* | *1.01,12 minutes* |

# Attachment 2
# Prototype Modification and All Used Equipments Spesification in the Experiment

## 2.1 Modifying the Prototype

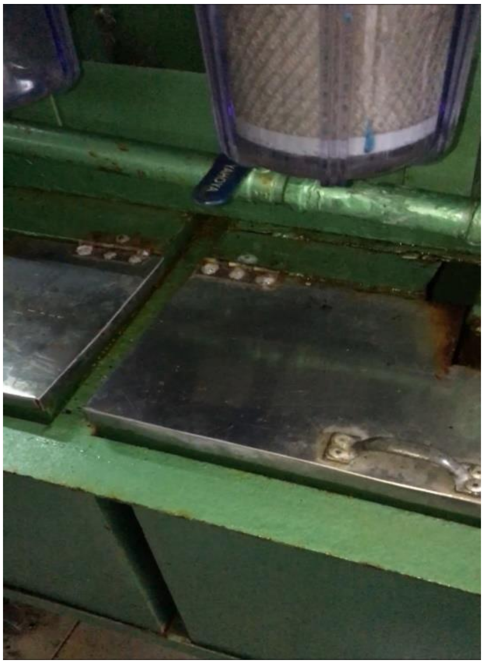

Figure 2.1 Adding a Connected Pipe from Tank 1 to Tank 2

Figure 2.2 Adding a water tap on UV reactor


Figure 2.3 Changging the Filter Material inside Filter Housing


Figure 2.4 Repainted and by adding 4 wheels

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**AUTHOR BIOGRAPHY**

The Author’s name is Himawan Abrarri Sutanto, born on 15 April 1995 in Klaten, Central Java. As the only son from Father Sutanto Danukarta and Mother Susmindah Junita Rinanengtyas. Author derived from an ordinary family with a formal education at SDN Jetis 06 Lamongan, then continued his study at SMP Negeri 1 Lamongan, and further to SMA Muhammadiyah 2 Surabaya. In 2014, author proceed to pursue bachelor degree at Department of Marine Engineering (Double Degree Program with Hochschule Wismar), Faculty of Marine Engineering, Institut Teknologi Sepuluh Nopember Surabaya. Author was member of Marine Operation and Maintenance (MOM) Laboratory during his last year (2017-2018). Author also taking part in campus organizations and event comittee such as: UKM MUSIK ITS (2014-2015) and Acco-Trans Committee Marine Icon (2016-2017). Author also participate on ITS International Geoscience Convention (2017) and participate as a finalist for Royal HaskoningDHV Innovation Challenge (2018).