GREEN TEA LEAVES AS NATURAL ADSORBENT TO REMOVE POLLUTANTS FROM SHRIMP FARM

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ABSTRAK

Di Malaysia dan negara lain, pencemaran sumber air, seperti ternakan udang, telah meningkat pada kadar yang membimbangkan. Eutrofikasi disebabkan oleh logam berat dan bahan pencemar lain yang dimasukkan ke dalam ladang udang, mengganggu ekosistem akuatik dan menyebabkan masalah kesihatan. Daun teh hijau, yang mempunyai kandungan katekin yang tinggi, kapasiti tinggi untuk penjerapan, dan mudah didapati di pasaran, merupakan salah satu bahan buangan yang menjanjikan yang boleh digunakan untuk menyerap bahan cemar daripada air. Oleh itu, matlamat kajian ini adalah untuk menentukan sejauh mana daun teh hijau yang dibuang berfungsi untuk membuang bahan cemar daripada air sisa ladang udang. Kajian ini melibatkan penyediaan bahan, satu siri eksperimen kelompok, dan kajian isoterma penjerapan. Eksperimen menunjukkan bahawa masa sentuhan terbaik ialah pada 10, 20, 30, 40 dan 50 min, dan dos penjerap ialah 0.2, 0.4, 0.6, 0.8, 1.0 dan 1.2g. Secara keseluruhan, kajian ini menunjukkan bahawa sisa daun teh hijau merupakan penjerap alternatif yang menjanjikan untuk menyerap bahan pencemar daripada air sisa ladang udang.

ABSTRACT

In Malaysia and other nations, pollution of water resources, such as shrimp farms, has been escalating at an alarming rate. Eutrophication was caused by heavy metals and other pollutants that were introduced into shrimp farms, upsetting the aquatic ecosystem and causing health problems. Green tea leaves, which have a high catechin content, a high capacity for adsorption, and are readily available on the market, are one of the promising waste materials that can be utilised to adsorb contaminants from water. Therefore, the goal of this study is to determine how well discarded green tea leaves work to remove contaminants from shrimp farm wastewater. This study involves the preparation of materials, a series of batch experiments, and adsorption isotherm studies. The experiments show that the best contact time is at 10, 20, 30, 40 and 50 min, and the adsorbent dose is 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2g. In overall, this study indicates that waste green tea leaves are a promising alternative adsorbent to adsorb pollutant from shrimp farm wastewater.

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LIST OF SYMBOLS

°C	Degree Celcius
%	Percentage
g	Gram
m	Meter
min	Minutes
ml	Mililitre
pH	The concentration of Hydrogen Ion
ppm	Parts per Million
rpm	Rotation per Minute
mg/L	Miligram per Litre

LIST OF ABBREVIATIONS

TSS	Total Suspended Solid
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
OCPs	Organochlorine Pesticides
OPPs	Organophosphorus Pesticides
PCBs	Polychlorinated Biphenyls
BFRs	Brominated Flame Retardants
CO_2	Carbon Dioxide
Pb	Lead
Zn	Zinc
Hg	Mercury
Ni	Nickel
Cd	Cadmium
Cu	Copper
Cr	Chromium
As	Arsenic
Ag	Silver
Fe	Iron
Mn	Manganese
Mo	Molybdenum
B	Boron
Ca	Calcium
Sb	Antimony
Co	Cobalt

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water, is the most valuable natural resource. In today's society, appropriate wastewater treatment is a requirement, not a choice. pH is a vital limiting chemical component for aquatic life. The biological functions of aquatic organisms can be disrupted when the water in a stream is too acidic or basic, resulting in harm or death. The pH of the effluent is one of the factors that determine effective wastewater treatment. Suspended particles, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, and plankton and other microscopic organisms, cause turbidity in wastewater. Turbid water has a muddy or hazy appearance and is unpleasant to look at. As sewages get more powerful, turbidity rises. Turbidity is a major issue in waste water treatment. (Mohammed, 2015) Entire suspended solids, on the other hand, are a measurement of the total amount of solid material in a given volume of water. Total Suspended Solid (TSS) is a mass measurement of all suspended solids, organic and inorganic. TSS is a direct measurement of total solids in a water body that includes dissolved solids. As a result, whereas turbidity cannot be used to compute sedimentation rates, TSS could. The amount of sunshine that penetrates the water determines its clarity. While the amounts of suspended solids in water primarily determines this, other dissolved solids can also influence it. (Kusari, 2011) Heavy metals develop in aquatic habitats primarily through the food chain, and metals can harm humans when taken through contaminated aquatic foods.

Despite the fact that some metals are required by living organisms, they are exceedingly dangerous or deadly at high doses. In addition to their carcinogenic effects, heavy metals can cause serious problems such as liver disease, cardiovascular abnormalities, kidney failure, and death in extreme circumstances.

When heavy metal contamination levels reach the maximum acceptable limits, it not only endangers human health but also has a number of negative repercussions for ecological balance. Pollutants such as metals and heavy metals have become a serious problem in today's world due to their direct impact on living species, such as flora and fauna, as well as humans. During wastewater treatment, heavy metals and/or organic compounds are frequently removed from effluent streams. Modifying the pH of a wastewater treatment system with acidic/basic chemicals is crucial because it permits dissolved material to be removed from the water during the treatment process.

Researchers commonly use the adsorption method to remove heavy metals from waste discharges. Activated carbon has long been used as an adsorbent, although it is an expensive material. As a result, research into the development of low-cost and more effective activated carbon replacements is required. In terms of design and operation, the adsorption process is adaptable, and it provides high-quality treated effluent in a variety of situations. Adsorption has proven to be a good method for treating industrial waste effluents, offering significant cost, availability, profitability, ease of operation, and efficiency advantages over traditional procedures, especially in terms of economics and the environment. In the search for a low-cost and easily accessible adsorbent, biological materials have been studied as suitable metal biosorbents. Biosorption is becoming a feasible alternative to traditional technologies for the removal and/or recovery of toxic metals from wastewater. Adsorbent are occasionally reversable, they can be regenerated using an appropriate desorption method. Due to residual potential forces between the surface molecules, chemical adsorption forms a single carbon layer of the adsorbate on the surface. Physical adsorption occurs when molecules gather in the capillaries of a solid.

Shrimp are particularly vulnerable to heavy metal deposition from a range of sources, including water, sediments, and diets, because they are top trenchers in the aquatic food chain. Heavy metals are most commonly consumed through seafood, although other medium such as water, air, and soil can also be sources. As a result, heavy metal toxicity prevents shrimps from reaping the health benefits of their diet, while customers are increasingly concerned about food safety issues. As a result, it is necessary to determine the presence of heavy metal in commonly ingested farmed shrimps, as well as the potential health hazards.

Shrimp farm wastewater contains nutrients such as nitrogen and phosphate, as well as suspended particles and organic compounds Shrimp farms can be located largely near the shore, with many of them directly on the water's edge. When farmers start a production cycle, they usually fill their ponds with water from the ocean or wells. Water is returned to the environment via a water output channel throughout the production cycle and at the end. Once discharged, the wastewater with a high organic content will combine with the nearby water bodies. In recent decades, the shrimp aquaculture sector has expanded fast in developing nations, particularly in Asia and Latin America, allowing countries to produce cash and employ thousands of people. (2021)

Camellia Sinensis is a plant whose leaves and leaf buds are used to make tea, which really is a popular beverage. Tea has anticancer properties, decreases cholesterol levels, has antibacterial and anti-inflammatory properties, and aids in weight loss, according to a recent medical study. The high quantity of catechins, an antioxidant, is suggested to be the reason for this. (Prasanth et al., 2019) Green tea is made from leaves that have undergone minimal oxidation during processing. They are unfermented, pale-colored leaves with a slightly bitter taste. Its extracts can be found in a wide range of beverages, health foods, nutritional supplements, and cosmetics. Green tea has more flavonoids than meals that are thought to be helpful to one's health. Tea leaves are natural adsorbents that can bind to a wide range of heavy metal ions.

The experiment is repeated to produce an adsorption isotherm by altering the amount of solid, the initial concentration of the solution, or both. One of the most typical experiments used to determine adsorption equilibrium and kinetics from solutions is a batch adsorption experiment from the liquid phase, also known as an immersion experiment. It entails adding a known mass of sample to a specified volume of liquid at an initial concentration. To mix the liquid, either a stirrer or the entire cell is agitated. The liquid is sampled or circulated to a detector, and the variation of the liquid concentration over time is tracked until equilibrium is reached. (Brandani, 2020)

1.2 Problem Statement

Metals in wastewater have detrimental impacts on the environment and human health when they are present. In industrialized countries, poisonous heavy metals discharged from various industrial locations, as well as polluted liquid waste, have been successfully eliminated by high resolution and expensive treatment procedures. However, in developing nations, implementing such advanced wastewater treatment technology is technically difficult and costly.

Contaminants can be found in a variety of industrial effluent streams, including waste effluent from shrimp farm. Direct discharge into natural waters would pose a significant risk to the aquatic ecology, whereas direct discharge into the sewage system could have a severe impact on later biological wastewater treatment. They are known to have toxic effects on human health, including arthritis/rheumatoid arthritis, mental disorders, anaemia, insomnia, liver damage, and heart problems. When pollutant-containing wastewater is discharged directly into the environment, it has a negative impact on all kinds of life. (Biswas et al., 2021)

The high cost of activated carbon, which is used in most conventional adsorption systems and requires regeneration, has sparked interest in studying the potential of employing cheaper raw materials. Another substance has been discovered by the researchers that are less expensive and easier to obtain and can heavy metals from wastewater. One of the wastes that are almost as high in powerful antioxidants is green tea waste. It is the most cost-effective method for removing metals from shrimp farm wastewater.

1.3 Objective of Study

The objective of this study include:

1. To evaluate the applicability of the green tea leaves as adsorbent for the parameters characterizing the shrimp wastewater using the batch method.

1.4 Scope of Study

In order to achieve the objectives, there are some scopes that should be focused in which are in observation and investigation the effect of process condition for the removal of pollutants by using green tea leaves. In this study, the wastewater was collected from the Shrimp Farm in Kuantan, Pahang. Apart from this, the adsorbent that used was green tea leaves. This experiment was conducted to find out the determination of the removal percentage that can be obtain by analyse the result of the initial concentration of the shrimp farm water parameters which are pH, , Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO). The study was carried out using Batch Method.

1.5 Significant of study

The use of green tea leaves which contain high antioxidants is the best alternative for removing the pollutants in the shrimp ponds. Green tea has a greater flavonoid concentration to be beneficial to one's health. Tea leaves are natural adsorbents, capable of absorbing a variety of heavy metal ions. It is a new low-cost, naturally available adsorbent that can effectively remove hazardous metal ions even at trace levels. (Prasanth et al., 2019) Agricultural techniques, landfill erosion, embarkation and docking activities, industrial and domestic effluent, and natural processes are all sources of heavy metals in aquatic systems. Non-degradable heavy metals can produce toxicities in aquatic environments by assimilation, deposition, or integration at a certain concentration into abiotic components, and then bioaccumulation into aquatic species. (Wuana & Okieimen, 2011)

The food chain is the primary channel for heavy metal accumulation in aquatic environments, and metals can pose a health risk to humans when consumed through contaminated aquatic foods. From this study, it will prove that green tea leaves are very effective adsorbent for the removal of pollutants from the wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Wastewater

Water contamination caused by heavy metals released by industrial activity and industrialization is a major issue in today's globe, posing a threat to the environment and human health. There has been a focus on finding technologies to remove heavy metals from waste water before disposal since they will harm biological organisms that have the ability to absorb heavy metals from wastewater. (MP, 2018)

Sewage is a term that refers to any waste water that has been contaminated with faeces or urine. Sewage refers to liquid waste materials that are disposed of by a pipe, sewer, or other similar system, or in a pit emptier. Prior to release into the environment or reuse, industrial wastewater treatment refers to the procedures and processes that are utilised to remediate waters that have been contaminated in some way by organic industrial or commercial activity.

The makeup of wastewater is 99.9% water, with the remaining 0.1 percent being removed. Organic materials, bacteria, and inorganic chemicals make up 0.1 percent. Wastewater is water which has been contaminated by home, industrial, or commercial activities. As a result, the composition of all wastewaters is continually changing and highly varied, making it difficult to pin down a single definition of the term. Wastewater effluents are discharged into lakes, ponds, streams, rivers, estuaries, and seas, among other places. Storm runoff comprises dangerous elements that wash off roads, parking lots, and rooftops. (L. A, 2017)

2.1.1 Wastewater Pollution

Water pollution is the discharge of pollutants into underground groundwater or lakes, streams, rivers, coasts, and seas to the point when the substances obstruct beneficial water use or ecosystem function. Water pollution can include the discharge of energy, such as radiation or heat, into bodies of water in addition to the release of material like chemicals, debris, or microbes. Sewage can promote algae growth, resulting in low pH "dead zones" where aquatic life cannot survive due to a lack of oxygen. Oil spills, such as the Deepwater Horizon oil leak in 2010, strand and kill many marine species. Microplastics can accumulate in humans who consume seafood due to biomagnification (“Water Pollution,” 2022).

When harmful substances, often chemicals or microorganisms contaminate a stream, river, lake, ocean, aquifer, or other body of water, the water quality degrades and the water becomes toxic to humans or the environment. Water contamination occurs when toxic compounds from farms, towns, and factories dissolve and mix with it. Water is very susceptible to pollution. Water, also known as a "universal solvent," can dissolve more chemicals than any other liquid on the planet. It's also the reason why water is so easily contaminated (Denchak, 2022)

There are several types of wastewater pollution:

i. **Surface Water**: Surface water, which covers over 70% of the planet, is what fills the oceans, lakes, rivers, and other blue spots on the globe map. Almost half of the rivers and streams, as well as more than a third of the lakes, are filthy and unsafe to swim in, fish in, or drink from. The most common type of contamination in these freshwater sources is nutrient pollution, which includes nitrates and phosphates. While plants and animals require these minerals to develop, agriculture waste and fertilizer runoff have made them a serious contaminant. Municipal and industrial waste discharges also contribute to the toxic load. There is also all the trash that companies and individuals dump into waterways.

ii. **Groundwater**: Groundwater is formed when rain falls and seeps deep into the earth, filling the fractures, crevices, and porous areas of an aquifer (essentially an underground reservoir of water).

iii. **Point Source**: Point source pollution occurs when contamination comes from a single source. Contamination from leaking septic systems, chemical and oil spills, and illegal dumping are just a few examples of wastewater (also known as effluent) released legally or illegally by a company, oil refinery, or wastewater treatment plant. While point source pollution originates in a single location, it has the potential to pollute miles of streams and the ocean.

iv. **Nonpoint Source**: Pollution from diffuse sources is known as nonpoint source pollution. These may include agricultural or rainwater runoff, as well as rubbish blown into streams from land.

v. **Transboundary**: Water pollution cannot be limited by a line on a map, it goes without saying. Contaminated water from one country pouring into the waters of another is referred to as transboundary pollution. Contamination can occur as a result of a natural disaster, such as an oil spill, or as a result of the slow order to move up of industrial, agricultural, or municipal discharge downriver.

vi. **Ocean Water**: Chemicals, nutrients, and heavy metals are carried by streams and rivers from farms, industry, and towns into our bays and estuaries, where they flow out to sea. 80% of ocean pollution (also known as marine pollution) originates on land, whether along the coast or far inland. Meanwhile, air marine trash, especially plastic, gets washed into storm drains and sewers. The waters are also occasionally polluted by large and tiny oil spills and leaks, and they are constantly absorbing p carbon pollution from the air. The ocean absorbs up to a quarter of all carbon emissions produced by humans. (Denchak, 2021)

2.1.2 Effect of Wastewater to the Environment

The most the environment is when it contributes to the pollution and loss of natural immediate impact of wastewater on habitat and the wildlife that lives in those areas by exposing them to dangerous substances that would not otherwise be present in the natural course of things. Wastewater is one of the most lethal disease sources and carriers. More than 3.4 million people die each year from a waterborne disease, according to a World Health Organization. Heavy metals, pathogens, salts, toxic chemicals, oil and grease, sediments, nutrients, sludge, acids and bases, poisonous organic compound, organic and inorganic elements can all be found in wastewater. This wastewater is hazardous to humans, animals, and the environment. It's poisonous, corrosive, reactive, acidic, and flammable. (Zhao et al., 2012)

The effluent contains toxic chemicals that harm aquatic habitats. When a huge volume of biodegradable compounds winds up in water, organisms begin to break them down, using a lot of dissolved oxygen in the meantime. Dissolved oxygen is essential for marine life to thrive, and its depletion can put fish's lives at risk. A lot of dissolved oxygen is taken up when huge algae blooms die and decompose in freshwater habitats, putting fish and other aquatic species at risk. The extra plant material also suffocates the bottom, putting bottom-dwelling species under further stress. Furthermore, certain algae create chemicals that are hazardous to both the environment and human health. Nutrient pollution also has an impact on marine waters. Near the water's surface, excessive phytoplankton and huge forms of algae restrict light from reaching the seagrasses on the bottom. The bottom sediments are no longer stabilised as the grasses die, resulting in increased water turbidity and a loss of habitat for fish and other marine species. (G, 2016)

This is difficult to estimate the substantial environmental costs associated with municipal discharges because of the presence of many hazardous compounds in wastewater effluents and the uncertainty regarding how they affect live organisms separately and/or in combination. Impacts might be acute and occur fast, or they can be cumulative and occur over time. Municipal wastewater discharges, on the other hand, are well documented to pose a serious hazard to aquatic habitats life.

Ammonia is the most harmful component of wastewater, and municipal treatment plants are one of the most significant sources of ammonia contamination. Lower reproductive capacity and growth are two of the consequences. High ammonia levels might potentially cause acute effects. (Flushing Our Environment Down the Drain, 2019) Oil and grease in wastewater are more difficult to break down and might sit on the water's surface. This prevents the photosynthetic aquatic plants from receiving the light they require. It can also suffocate fish and become entangled in the feathers of birds. These are hazardous to humans and animals, just as heavy metals like lead and mercury. Water pollution is the discharge of pollutants into underground groundwater or lakes, streams, rivers, coasts, and seas to the point when the substances obstruct beneficial water use or ecosystem function.

2.1.3 Heavy Metals in Wastewater

The presence of heavy metals in wastewater has risen in conjunction with the growth of industry and human activities, such as plating and electroplating, batteries, pesticides, mining, rayon, metal rinse processes, tanning, fluidized bed bioreactors, textiles, metal smelting, petrochemicals, paper manufacturing, and electrolysis. Heavy metal-contaminated wastewater enters the environment, endangering human health and the ecosystem. Heavy metals are non-biodegradable and may be carcinogenic, therefore their presence in water in large amounts could cause health issues for living things. Lead (Pb), zinc (Zn), mercury (Hg), nickel (Ni), cadmium (Cd), copper (Cu), chromium (Cr), and arsenic (As) are the most common heavy metals. Despite the fact that certain heavy metals can be identified in small amounts, they are still dangerous. Metals such as silver (Ag), iron (Fe), manganese (Mn), molybdenum (Mo), boron (B), calcium (Ca), antimony (Sb), cobalt (Co), and others are regularly found in wastewater and must be removed (Qasem et al., 2021).

Table 2.1 Typical heavy metal existing in wastewater and their sources

Common Heavy Metal	Main Source	Main organ and system affected	Permitted amounts (μg)
Lead (Pb)	Lead-based batteries, solder, alloys, cable sheathing pigments, rust inhibitors, ammunition, glazes, and plastic stabilizers.	Bones, liver, kidneys, brain, lungs, spleen, immunological system, hematological system, cardiovascular system, and reproductive system.	10
Arsenic (As)	Electronics and glass production	Skin, lungs, brain, kidneys, metabolic system, cardiovascular system, immunological system, and endocrine.	10
Copper (Cu)	Corroded plumbing systems, electronic and cables industry.	Liver, brain, kidneys, cornea, gastrointestinal system, lungs, immunological system.	2000
Zinc (Zn)	Brass coating, rubber products, some cosmetics, and aerosol deodorants.	Stomach cramps, skin irritations, vomiting, nausea, and anemia, and convulsions.	3000
Chromium (Cr)	Steel and pulp mills and tanneries.	Skin, lungs, kidneys, liver, brain, pancreas,	50

Common Heavy Metal	Main Source	Main organ and system affected	Permitted amounts (μg)
		tastes, gastrointestinal system, and reproductive system	
Cadmium (Cd)	Batteries, paints, steel industry, plastic industries, metal refineries,	Bones, liver, kidneys, lungs, testes, brain, immunological system, and cardiovascular system.	3
Mercury (Hg)	Electrolytic production of chlorine and caustic soda, runoff from landfills and agriculture, electrical appliances, Industrial and control instruments, laboratory apparatus, and refineries.	Brain, lungs, kidneys, liver, immunological system, cardiovascular system, endocrine, and reproductive system.	6
Nickel (Ni)	Stainless steel and nickel alloy production.	Lung, kidney, gastrointestinal distress, pulmonary fibrosis, and skin.	70

Source: (Demiral et al., 2021)

2.2 Shrimp Farm Water

Shrimp farms are mostly found along the coast, with many of them being right on the water's edge. Farmers often use water from the ocean or wells to fill their ponds as they begin a production cycle.

The water effluent from shrimp farms contains nutrients such as nitrogen and phosphorus, as well as suspended particles and organic materials. From uneaten feed, shrimp faeces, and dead skin to decomposing bacteria and phytoplankton, these are all by-products of aquaculture activities. Water waste with a high organic content will combine with the surrounding water bodies once discharged. (2021)

Shrimp is a common crustacean eaten all over the world and can be a healthy addition to our diet. Shrimp is low in fat and calories, high in omega-3 fatty acids, and high in important nutrients like iodine, phosphorus, choline, copper, zinc, B-complex vitamins, vitamin A and E, and antioxidants such astaxanthin. Shrimps are capable of retaining contaminants from their surroundings. Organochlorine pesticides (OCPs), organophosphorus pesticides (OPPs), brominated flame retardants (BFRs), polychlorinated biphenyls (PCBs), and synthetic musk are all examples of these pollutants. These substances are lipophilic endocrine disruptors that remain in the environment and can be passed down the food chain. These contaminants are a global health and environmental concern (Maia et al., 2021). The purpose of use, the type of organisms under culture, the life cycle stage for which they are employed, the culture system and intensity of culture, and the individuals who utilize them can all be classified as aquaculture chemicals. Aquaculture development requires the use of more pesticides and antibiotics in this industry. Chemicals and antibiotics are important components in aquatic animal health management, pond construction, soil, and water management, improving natural aquatic productivity, live fish transportation, feed formulation, reproduction manipulation, growth promotion, processing, and final product value addition. (Mostafa Shamsuzzaman & Kumar Biswas, 2012)

Shrimp farmers provide massive volumes of feed to suit the nutritional needs of intensively farmed shrimp and optimize growth. The feed is frequently collected and dried. The three principal components of a normal shrimp feed are wheat flour, soybean meal, and fishmeal, which supply energy, amino acids, and protein. Because shrimp chew rather than swallow the entire pellet, up to 40% of the additional feed drops to the bottom of the ponds and goes unused because feeds are heavy in nitrogen and phosphorus, the accumulation of uneaten feed in shrimp ponds severely influences a severe influence on the ecosystem. In shrimp ponds, the breakdown of uneaten feed considerably raises nutritional levels. The rate of feed pellet breakdown is affected by a combination of parameters, including pH, temperature, and osmotic pressure, among others.

The breakdown of feed pellets not only increases the concentration of suspended solids in the pond, but also releases nitrogen (N) and phosphorus (P) from the pellet. So, because shrimp do not absorb 77% of the nitrogen and 85% of the phosphorus in the feed pellets, the system gains a considerable amount of these two nutrients. (Royan, 2020)

2.2.1 Environmental Impact on Shrimp Farm

Coastal locations are frequently discovered to have ideal farming conditions. The farming environment is deteriorating in many regions for a variety of reasons. Shrimp mortality in vast areas due to poor water quality is not uncommon. Organic contamination generated by shrimp farming is another key factor.

Many farms employ low-quality artificial feed in ineffective methods, resulting in water that lacks the essential stability. Untreated industrial waste and home sewage are released into coastal seas in large quantities. According to estimates, major cities and industrial zones along the coast dispose of billions of tons of solid waste and sewage, causing the offshore seas to deteriorate and jeopardizing marine farming. Antibiotics, disinfectants, and water conditioners are frequently used in ponds, and they have a negative impact on the aquatic ecology. Another element contributing to poor water quality is pond design. For example, shrimp ponds in some bays are too maintained, resulting in agricultural sewage that exceeds their self-cleaning capacity, assuming any exists. (“Sustainable Shrimp Farming: Biosecure Systems to Prevent or Control Emerging Diseases,” 2020)

The usage and release of water in shrimp ponds contribute significantly to water contamination. Effluent is discharged into the surrounding surface waterways each time water is exchanged. The contaminants carried by wastewater are represented in the selected indicators. Chemicals, fertilizers, and feed supplied to the ponds are the source of these contaminants. Raising market-sized shrimp takes three to six months in tropical regions, with many farmers cultivating two to three crops each year. Shrimp farms can damage groundwater and coastal estuaries with a continual influx of organic waste, pesticides, and antibiotics. The salt from the ponds might seep into the groundwater and onto farmland. This has had long-term consequences, affecting the hydrology that supports wetland habitats. (Ribeiro et al., 2016)

A large amount of feed remains in the water during the middle and late stages of production; part forms suspended solid pellets, and some dissolves and releases a large amount of nitrogen and phosphorus. The amount of soluble organic nitrogen in the water can be greatly increased by feed and fish meal remaining in the water, and nitrogen and phosphorus are released into the water by shrimp waste. A lot of fertilizers comprising nitrogen, phosphate, potassium, and some trace elements are poured into the water during the early stages of shrimp production to improve the growth of the algae that provides the shrimp with enough food. (Crockett & Lawrence, 2017)

2.3 Parameters on Shrimp Farm

Bottom soil sediment offers food and shelter to shrimp in culture pond environments, as well as acting as a reservoir of nutrients for the growth of microalgae, which are natural food for aquatic creatures. The qualities of bottom soil sediment have a big impact on the physical and chemical parameters of shrimp farm water. Temperature, pH, total suspended solids (TSS), dissolved gases, and nutrients all have an impact on water quality, which affects the healthy survival of species in the aquatic ecosystem. Salt concentration also plays an essential role in the physiological functioning of culture organisms. The concentration of hydrogen ions in water (pH) and pond bottom soils can have a massive effect on aquatic species' health, survival, and growth. The balance of salt and water in tissue is critical for ensuring the coordination of metabolic (Physiological) functions. (SHRIMP CULTURE: POND DESIGN, OPERATION AND MANAGEMENT, 2019)

Water quality issues in shrimp aquaculture are caused by overstocking, increasing feeding rates, and the intake of contaminated water. The release of pond water effluent is another activity associated to environmental degradation in receiving waters. Water quality has an impact on shrimp growth, survival, and total output. Sickness, death, poor growth, and reduced shrimp production are all effects of poor water quality. (Bommireddy et al., 2021)

Table 2.2 Parameters of Shrimp Farm Water

Parameters	Standard Level
COD	50 mg/L
BOD	6 mg/L
Ph	6 – 9
Turbidity	<38 to 47 NTU
Copper	0.05 – 2.00 mg/L
DO	3- 5 ppm (the best is closer to 5 ppm)

Source: Department of Fishery Malaysia

2.3.1 pH

For shrimp farm water, the pH is one of the most important chemical characteristics. The concentration of hydrogen ions is measured by the pH scale. In the shrimp pond, the ideal pH range is 6 to 9. The greatest daily pH fluctuation should not exceed 0.5 for best water quality. Stabilizing the pH in this range is critical because it impacts the metabolism and other physiological functions of culture organisms, maintaining a steady pH in a safe range is critical. The water's pH value is usually lowest in the morning and highest in the afternoon. (A, 2018)

Depending on the aquatic life in the pond, the pH levels of the water will fluctuate. When aquatic organisms respire, carbon dioxide is released into the water, causing an acidic reaction because of respiration and CO2 synthesis by all species, and the pH drops at night. During the day, phytoplankton and other aquatic plants extract CO2 from the water through photosynthesis, raising the pH in ponds. Waters with moderate alkalinity are better buffered and have less pH volatility. The pH levels within the pond change.

2.3.2 Turbidity

In the shrimp pond, these turbidity levels were nevertheless within the tolerance limit for shrimp farm culture. Turbidity in wastewater results from tiny particles mixing with the water stream and remaining suspended due to the water's velocity (colloids). Soil, biological solids, and decomposing organic debris are examples of suspended particles in river water. Suspensions differ from emulsions in that they blend two liquids that normally do not mix, such as fat and water. (Schmitz, 2020) For shrimp farm water, the pH is one of the most important chemical characteristics. The concentration of hydrogen ions is measured by the pH scale.

2.3.3 Biological Oxygen Demand (BOD)

The amount of oxygen required by bacteria and other microorganisms while decomposing organic waste under aerobic (oxygen present) conditions at a specific temperature is known as biological oxygen demand (BOD). Maintaining aquatic life and the aesthetic value of streams and lakes requires a suitable quantity of dissolved oxygen. Water-quality management requires determining how organic matter influences the concentration of dissolved oxygen (DO) in a stream or lake. Biochemical or chemical oxygen demand is a measurement of the decomposition of organic materials in water. The amounts of oxidizable compounds in a water sample that can lower DO levels is determined by oxygen demand. (Biological Oxygen Demand (BOD) and Water | U.S. Geological Survey, 2019)

Wastewater effluents contribute to another phase of deoxygenation, in addition to eutrophication of water bodies. The biological (bacterial) decomposition of the organic materials in effluent diminishes dissolved oxygen, resulting in a biological oxygen demand (BOD). Furthermore, through chemical processes, the breakdown of compounds in the effluent consumes oxygen from the water - the chemical oxygen required.

Dissolved contamination in water can have severe immediate, short-term, and long-term effects on aquatic life. Low oxygen levels have a significant impact on fish survival. Low dissolved oxygen concentrations cause decreased disease resistance, reduced development, changed swimming behavior, feeding, migration, and reproduction, increased predation risk, and even rapid mortality. (Flushing Our Environment Down the Drain, 2019) These turbidity levels were nevertheless within the tolerance limit for shrimp farm culture.

2.3.4 Chemical Oxygen Demand (COD)

The COD is a measure of the quantity of oxygen necessary to oxidize the part of organic matter in wastewater, as well as the amount of oxygen used by organic matter in a boiling acid potassium dichromate solution. COD is a water quality indicator that is used to evaluate not only the number of biologically active things like bacteria but also the amount of biologically inactive organic matter in water.

2.3.5 Dissolved Oxygen (DO)

In aquaculture, dissolved oxygen (DO) is important. In general, levels below 5.0 mg/L are linked to stunted growth and a significant risk of death. In shrimp and fish, low dissolved oxygen in the water can cause anoxia, sluggish growth, and mortality. A low oxygen concentration can be caused by a variety of factors, including: (i) Dissolved oxygen reduces as temperature and salinity rise; (ii) Aquatic plants die as a result of excessive herbicide use, resulting in dissolved oxygen shortages; (iii) Dissolved oxygen falls at night

Algae and plankton photosynthesize (using sunlight) and produce oxygen dissolved in water during the day. The absence of sunlight at night prevents photosynthesis. Despite the lack of photosynthesis, algae and aquatic plants continue to breathe at night. As a result, the oxygen level drops. On days when there is no sunlight or when the weather is dark and rainy, a similar situation can arise. If the cause is dissolved oxygen is generally increased by utilising a paddlewheel aerator or an aeration blower. Water exchange is another popular procedure. (Rahman et al., 2020)

2.4 Adsorption

Adsorption is a surface process in which a molecule is transferred from a liquid bulk to a solid surface. Physical forces or chemical bonds can cause this to happen. It is usually reversible (the reverse process is called desorption), and it is then responsible for both substance removal and release. In the majority of cases, this process is characterized at equilibrium using equations that quantify the amount of substance attached to the surface based on the fluid concentration.

Because their values are dependent on temperature, one of the most important environmental elements affecting adsorption, these equations are called isotherms (de Gisi et al., 2016). Adsorption is a well-known and effective method for removing organic and inorganic contaminants from waste fluids. In gas and liquid phase separation, activated carbon is commonly employed as an adsorbent. Adsorption differs from absorption in that it is a surface-based process in which atoms, ions, or molecules from a substance adhere to the adsorbent's surface. Absorption is a process of a substance's entire volume being absorbed into a solid material body.

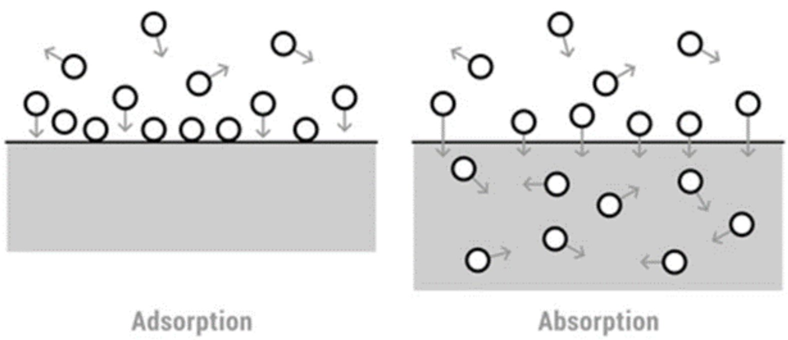


Figure 2.1 Adsorption and Absorption

The adsorption process can be divided into two types: chemical adsorption (chemisorption) and physical adsorption (physisorption). There will be periods when both forms of bonds occur at the same time. Since chemisorption is highly selective and can only be done by the potential of chemical bonding formation, adsorption happens only in the area where chemical bonding between adsorbent and adsorbate such as ionic and covalent bonds are operating. The chemisorption enthalpy ranges from 200 to 400 kJ/mol due to chemical bonding between the adsorbent and the adsorbate. The adsorption efficacy of chemisorption is greatly influenced by surface area and temperature. (Gao et al., 2020)

Selectivity and affinity are two factors that influence the efficacy of any adsorption process. Adsorption is categorized into three types based on the type of adsorbent and adsorbate bonds formed:

Physical Adsorption

Physical adsorption is usually quick and reversible because it involves the development of weak bonds between the adsorbate and the adsorbent. As a result, adsorption bonds are quickly established and destroyed. It happens when the adsorbate adheres to the adsorbent's surface entirely through Van der Waals (weak intermolecular) interactions. (Thommes & Cychosz, 2014)

The characteristic of physical adsorption is:

a. Physical forces cause this form of adsorption.

b. Physical adsorption is a rare occurrence.

c. This is a multi-layered adsorption method.

d. Physical adsorption is indiscriminate and occurs all over the adsorbent.

e. Surface area, temperature, pressure, and adsorbate type all have an impact on physisorption.

f. The activation energy is minimal (20–40 kg/mol).

Chemical Adsorption

The adsorbate molecules interact chemically with the adsorbent surface, resulting in adsorption. Chemisorption is usually slower and irreversible because it includes the implementation of effective interactions between the adsorbate and the adsorbent, which can affect both the surface and chemical character of the adsorbate. (Miljojkovic et al., 2019)

The characteristic of chemical adsorption is:

a. Chemical forces are to blame for this form of adsorption.

b. It's a powerful method.

c. This form of adsorption occurs in a single layer.

d. Chemisorption occurs at reaction centers on the adsorbent and is extremely selective.

e. Chemisorption is influenced by surface area, temperature, and adsorbate type.

f. The activation energy is extremely high, ranging between 40 and 400 kJ/mol.

2.4.1 Type of Adsorbents

Heavy metal ions have been removed using several traditional procedures such as ion exchange, chemical precipitation, coagulation, membrane separation, reverse osmosis, and adsorption methods in the pursuit of remedial action. Adsorbents have been created to remove a wide range of heavy metal ions from wastewater, particularly those that are harmful to live organisms. Adsorption techniques have been hailed for their excellent removal effectiveness of heavy metal ions even at trace levels, as well as the inexpensive cost as compared to traditional approaches. Adsorbents for the adsorption of heavy metal ions from wastewater must consequently be developed at a reasonable cost and widely available (Chakraborty et al., 2020). Adsorption utilizing solid materials, known as adsorbents, is a simple, practical, and successful procedure among the many ways available for pollutant removal. Mineral, organic, or biological adsorbent materials can be used. At the industrial scale, activated carbon is the favoured and traditional material.

Activated carbon is widely used to adsorb contaminants from drinking water sources such as groundwater, rivers, lakes, and reservoirs, in addition to eliminating pollutants from wastewater streams. However, because of its expensive cost, activated carbon is not widely used. Several approaches employing non-conventional adsorbents have been researched for the creation of cheaper and more effective adsorbents to eliminate contaminants at trace levels throughout the last three decades.

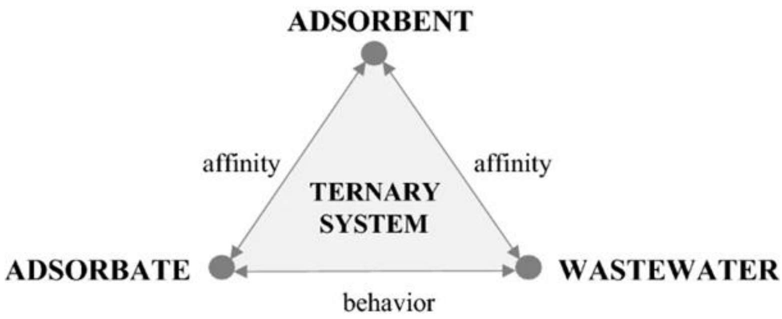


Figure 2.2 Types of Adsorbents

According to the source, adsorbents can be divided into:

Natural Adsorbents: Natural adsorbents include zeolites, clay minerals, charcoal, red mud, silt and soil, ore minerals, and so on. They are inexpensive to acquire and plentiful in quantity. They can simply be changed to improve their adsorption abilities (Nageeb, 2013).

Synthetic Adsorbents: Adsorbents that have been chemically processed have a larger surface area and adsorption capacity than normal adsorbents. Household trash, industrial waste, agricultural waste, sewage sludge, and polymeric adsorbents, for example, are used to make these adsorbents. They are more expensive than natural adsorbents (Nageeb, 2013).

2.4.2 Low-Cost Alternative Adsorbents

Low-cost adsorbents are readily available in large numbers locally. These materials' adsorption rate could be greatly increased by modifying them. The cost factor plays a crucial part in selecting an adsorbent because they are often low cost and generally available in large quantities. As a result, efforts have been focused on finding low-cost alternative adsorbents, with a wide range of materials being studied. They can be categorized in two ways: (i) by availability, such as (a) natural material, (b) agricultural waste or by-products, or (c) industrial waste or by-products; or (ii) by nature, such as (a) inorganic or (b) organic material. (Muhammad Bozlur et al., 2010)

Water treatment by adsorption with a low-cost adsorbent is a major topic since it provides two benefits: water purification and waste management. Various waste products have been transformed into low-cost adsorbents and used for water treatment, as detailed in this article. The statistics presented is fascinating, and there is an increasing interest in water purification. As a result, low-cost adsorbents for water purification are more likely to be used in the near future. Furthermore, the general and low-cost nature of adsorption technology are assets for the bright future of low-cost adsorbents. Besides that, low-cost adsorbents are thought to have a bright potential in developing and underdeveloped countries.

Low-cost adsorbents are usually effective in removing pollutants at a concentration of mg/mL. Attempts should be made to modular them such that they can work at g/mL concentrations as well. Additionally, to avoid any environmental hazards, these adsorbents should be manufactured in an environmentally benign manner and used in a controlled way. Adsorption in batch mode is described in various studies reviewed in this. However, there are few studies on water treatment at the experimental and industrial stages. As a result, the future is focused on the design and development of effective columns for large-scale water treatment. Water treatment requires the development of more efficient, selective, low-cost, and environmentally friendly adsorbents. (Ali et al., 2012)

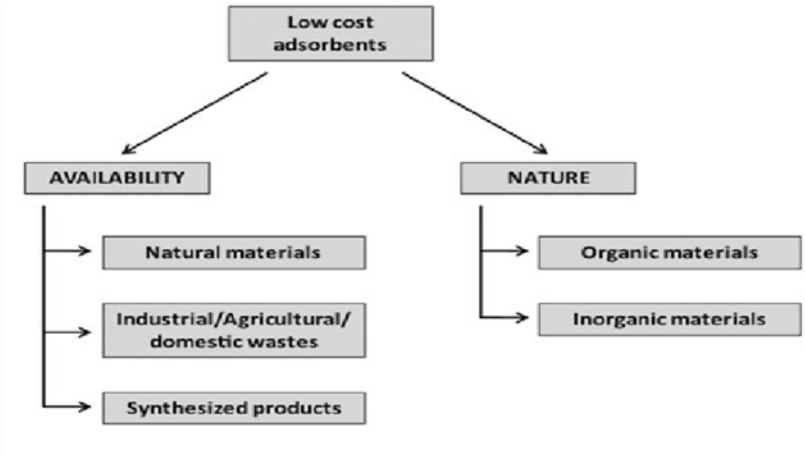


Figure 2.3 Low-Cost Adsorbent

2.4.3 Mechanism of Adsorption

A mass separating agent, a solid substance, or an adsorbent is responsible for numerous separation processes. As a result, the quality of any adsorptive separation or purification procedure influences its performance. Separation is viewed as a system that converts a combination of substances into two or more products with different compositions in an adsorption-oriented process. Because it is the exact opposite of mixing, which the second law of thermodynamics favours, the process is hard to achieve. The research for a solid material with high capacity, selectivity, and rate of adsorption is thus a critical initial step toward an efficient adsorption process. (Crini et al., 2018)

Other parameters to consider when selecting a material are low cost and availability, appropriate mechanical properties, high physical strength (not dissolving) in solution, extended life, ability to be regenerated if necessary, and so on. In general, the degree of liquid packing that can occur in the pores determines adsorption capacity. The adsorbate molecule and the adsorbent surface must have similar pore sizes for an effective adsorption process. As an example, because of dye molecules are considerably larger than the pore size of the coconut shell, a carbon with small pores has weak decolorizing effects. However, it holds a great potential for adsorption of smaller compounds. It has also been discovered that as the concentration rises, so does the adsorption capacity.

Furthermore, some adsorbents, such as activated carbon, exhibit competitive or preferred adsorption for any complicated system with many components. It has been proven that low molecular weight pollutants that are initially adsorbed are eventually replaced by high - molecular - weight species. As a result, activated carbon absorbed propane more efficiently than methane. At a given temperature, the efficiency of adsorption improves as the surface area of the adsorbent increases. Because molecular species are less accessible at low temperatures, adsorption efficiency increases. However, the adsorption process can sometimes include groups on the surface of adsorbent materials as well as the pollutants–chemisorption process. (Ali et al., 2012) Low-cost adsorbents are readily available in large numbers locally. These materials' adsorption rate could be greatly increased by modifying them.

2.5 Green Tea

Camellia sinensis (L.) is one of the world's oldest and most popular beverages. Green tea is characterized primarily by the tradition of green tea leaves processing, the country of origin, and the type of soil on which the bushes have grown. Japan, China, and Taiwan are the leading producers of green tea. The main distinction between green and black tea production is the technological process. In comparison to other forms of infusions, Matcha green tea leaves infusion contains the most caffeine and L-theanine. According to available scientific evidence, L-theanine radically changes the effects of caffeine, reducing its stimulatory effects while also boosting cognitive functions, mood, and focus, as well as lowering blood pressure.

There are two types of matcha tea: Matcha–Usucha and Macha–Koicha. Mecha, Genmaicha, Kukicha, Kamairicha, Kariganech, Kokeicha, Fukamushicha, and Tamaryokucha are among the Japanese green tea infusions. Gunpowder, Chun Mee, Lung Ching, Mao Feng, and China Sencha, a Chinese version of Japanese Sencha infusion, are all Chinese green teas. (Musial et al., 2020) Polyphenols, which include flavanols, flavandiols, flavonoids, and phenolic acids, are found in green tea and can make up to 30% of the dry weight. Green tea polyphenols (GTPs) are mostly flavonols, often known as catechins. Green tea products are mostly extracts of green tea in liquid or powder form, with varying amounts of polyphenols (45-90 percent) and caffeine content

(0.4-10 percent). Green tea's main flavonoids are catechins, which are found in higher concentrations in green tea than in black or Oolong tea.

Epicatechin, epigallocatechin, epicatechin-3-gallate, and Epigallocatechin are the four types of catechins found in green tea. The amount of catechins in the original tea leaves varies due to differences in variety, origin, and growing conditions; the amount of catechins in the original tea leaves also changes due to differences in variety, origin, and growing conditions. Because catechins cannot be completely extracted from the leaves during the production of fresh green tea, the concentration found differs from the absolute values determined during complete leaves extraction. Furthermore, catechins are relatively unstable, and their quantity and quality can be modified during the duration of an experiment. (Chacko et al., 2010)

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a way to find out the result of a given problem on a specific research. This chapter will describe the method to identify and justify the sampling method and demonstrate the techniques and instrument used for qualitative and quantitative of the expected result for given research problem. Various elements and materials were evaluated for this study in order to determine the function of green tea as an adsorbent in removing the pollutant from shrimp ponds. The batch approach was used to evaluate the applicability of green tea leaves as an adsorbent for the parameters that characterized shrimp wastewater using the circulation-flowing method. The materials and procedures used in this research are explained under the methodology for this study.

3.2 Research Approach

The research emphasized on both field study analysis and laboratory methods. In-situ analysis involved in this research include the usage of green tea leaves as adsorbent and the effectiveness to remove pollutants from shrimp pond. A general diagram detailing about the flow of research work is shown in the following flowchart (Figure 3.1)

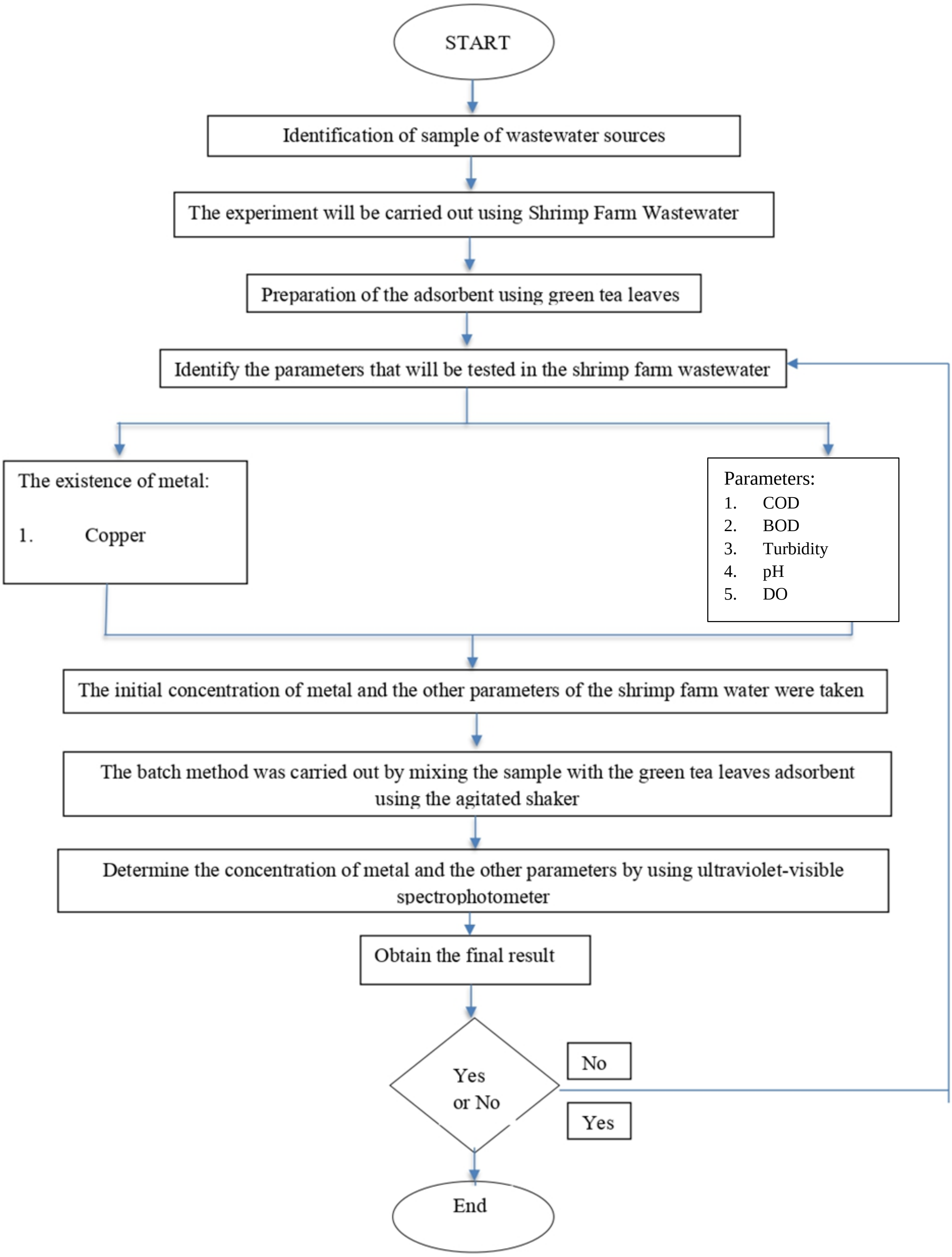


Figure 3.1 Methodology flowchart

3.3 Identification of sample from Shrimp Pond Wastewater

Determination on a suitable location of collecting the sample that could be represented, as well as possible, the effectiveness of the of the green tea leaves as natural adsorbent as it obtained. Wastewater was kept in 2L sample bottle was collected from the shrimp farm in Pekan, Pahang.

Figure 3.2 Shrimp Farm

3.4 Preparation of Adsorbent

The green tea leaves were obtained by repeatedly washing them in distilled water. After that, rinse with hot water until it was colorless. The tea leaves were decolorized and cleaned before being dried in a 105°C oven. A total of five washing cycles were required. The tea leaves were crushed after drying and utilized in further adsorption studies without further modification. The green tea leaves were grounded to make the sieving procedure easier and to produce enough adsorbent for the batch experiments. There was no noticeable interfering colour because the adsorption experiments were carried out at room temperature (25 ± 1°C). Polythene bags were used to keep the dried and crushed tea leaves.

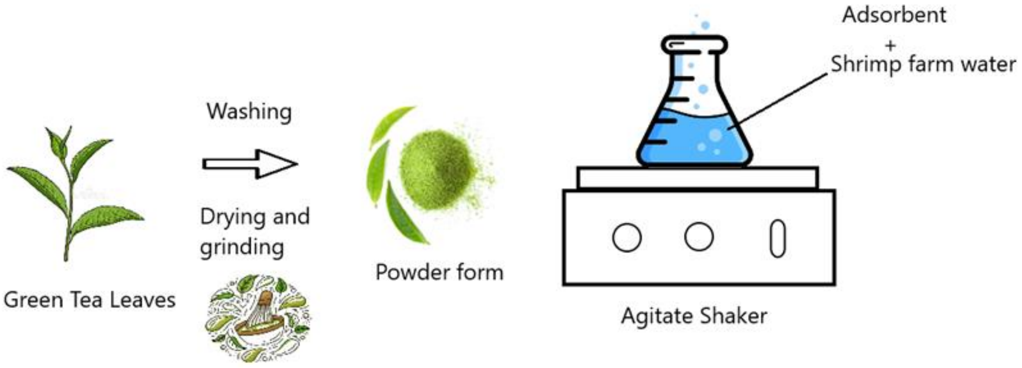


Figure 3.3 Preparation of Adsorbent

Figure 3.4 Green Tea Leaves

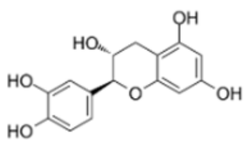
The dried green tea leaves are crushed and sieved via a 1.18 mm – 2.00 mm sieve size to obtain the necessary particle size after being crushed and ground. The green tea leaves are sieved for 2 minutes in a horizontal motion to acquire the required amount of green tea leaves for the adsorption process. Using insufficient force during the sieving would result in obtaining low quantity of the desired green tea leaves size.

Crushing and sieving are continued until the necessary batch experiment quantity is obtained. The whole mass of green tea leaves that needs to be prepared is estimated to be around 100 g based on the adsorbent dose required for each series of batch experiment.

Figure 3.5 Dried Green Tea Leaves

3.5 Characterization of the Catechin in the Green Tea Leaves

Density, boiling point, melting point and flash point were determined using a during the preparation of adsorbent.



Common Name	(-)-catechin		
CAS Number	18829-70-4	**Molecular Weight**	290.26800
Density	1.593 g/cm3	**Boiling Point**	630.4°C at 760 mmHg
Molecular Formula	$C_{15}H_{14}O_6$	**Melting Point**	175-176°C
MSDS	Chinese USA	**Flash Point**	335°C

Figure 3.6 Properties of Catechin

3.6 pH Test

Users can determine how acidic or basic the water is at any given time by checking its pH. Normal pH of pure, unpolluted water is 7, which is neutral (neither acidic nor basic). The pH of water can provide information about potential pollution and serve as a crucial safety measure for preserving the wellbeing of people, animals, and plant life.

Comply with the manufacturer's recommendations when calibrating the probe and metre. The metre may need to be calibrated by being tested in a substance with a known pH value. The metre can then be adjusted accordingly and carry out this calibration a few hours before taking the metre. Prior to use, thoroughly rinse the probe with double-deionized water. With a fresh tissue, dry it off. Take a sample of the water and place it in a sterile container. To cover the electrode tip, the water sample must be deep enough. After allowing the sample to rest for a while to allow the temperature to stabilise, take a thermometer reading of the sample's temperature.

To match the sample temperature, adjust the metre. The water temperature has an impact on the probe's sensitivity, therefore if do not input the temperature information, the reading of the metre won't be correct. The temperature of the water will also have an impact on its pH. Clean water has a higher pH at lower temperatures and a lower pH at higher temperatures. Enter the sample with the probe. Hold off until the metre reaches equilibrium. When the reading turns steady, the metre has attained equilibrium. Find the sample's pH value and read it. The pH metre should give you a result between 0 and 14. It should be about 7 if the water is pure. When the pH value is less than 7, the water is considered acidic, and when it is greater than 7, the water is considered basic.

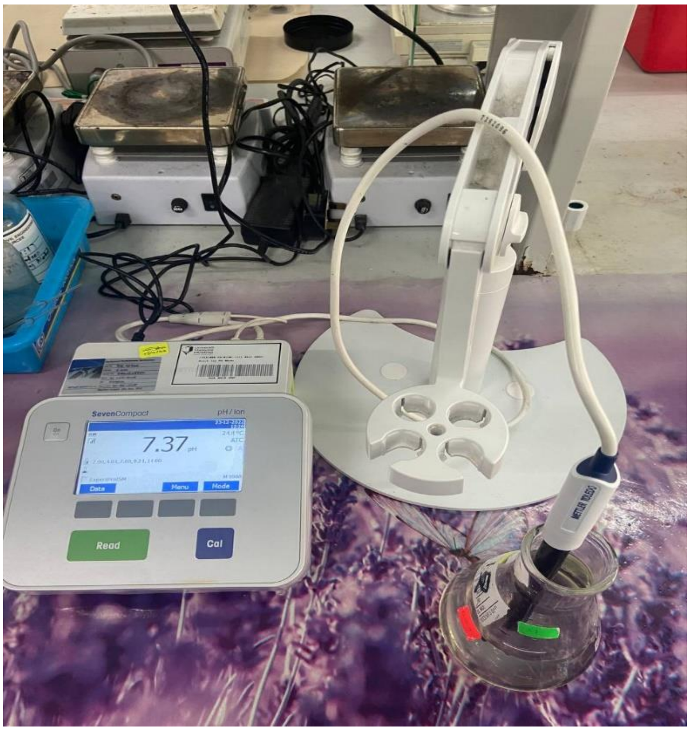


Figure 3.7 pH Test

3.7 Turbidity Test

Water clarity is gauged by turbidity like transparency. Water can seem foggy or murky when suspended particles, such as silt, algae, plankton, and sewage, are present. Instead of allowing light to pass through the water directly, these particles scatter and absorb light waves. A greater turbidity rating denotes cloudier, "thicker," and more particle-filled water. Clear water has little turbidity when it is present.

Steps to test the turbidity

Make sure the test vials are clean before using them. Then, transfer approximately 10 ml of water sample into a test vial using a pipette. When collecting a sample from a jar of settled water, obtain the sample about 1 inch below the surface of water. Calibrate the turbidity meter for the range in which the test water falls where the instrument itself will be pre-calibrated. After that, wipe the sides and bottom of the test vial with tissues and place the sample in turbidity meter. Then, cover the vial and read, record the result.

Figure 3.8 Turbidity Meter

3.8 Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO)

A 5 mL sample of water is pipetted and poured into a BOD bottle. The BOD bottle was filled with BOD dilution water until it reaches its maximum capacity of 300 ml. The stopped is used to close the bottle, which is then shaken many times to remove any visible bubbles. The vibrated probe is cleaned with dilution water when the DO meter is turned on. The stopper was removed and the vibrated probe was inserted into the BOD bottle, then turn it on. The value of the stable DO concentration was recorded. The value was 34 taken as DO0 (mg/L). The DO meter emits a beep sound, indicating that the reading is stable and can be recorded. After that, the BOD bottle is sealed with a stopper and placed in the BOD incubator for 5 days. The previous steps were followed to determine and record DO5 after 5 days of incubation.

BOD concentration is calculated based on the formula below:

$$BOD5 = \left(\frac{DO_0 - DO_5}{P}\right)$$

Figure 3.9 BOD Test

3.9 Chemical Oxygen Demand (COD)

This experiment evaluated the shrimp farm wastewater. The shrimp farm wastewater and 2 mL of each sample were then added to digestion vials. When adding the sample, the digestion bottle was held at a 45-degree angle. The bottle was inverted many times after the sample was introduced and the cover was tightly closed to mix the contents. The samples were labelled and placed on a 150°C heating block for two hours after being manufactured.

3.10 Copper Test

The spectrophotometer is turned on and the 356, Cu program is selected. This program is a standard procedure provided by HACH specifically for the analysis study. The procedures provided include the preparation of the sample as well as the proper steps of handling the machine. After turning on the spectrophotometer, a glass sample cell is filled with 10 mL of blank sample and a glass of sample cell is filled with the sample. After that, sample is then added Cu Ver@1 copper reagent. The sample cell is then closed and is shaken for 20 to 30 seconds to obtain the proper reaction of the reagent. Put the blank sample and press zero. After that, put the sample with copper reagent and record the reading.

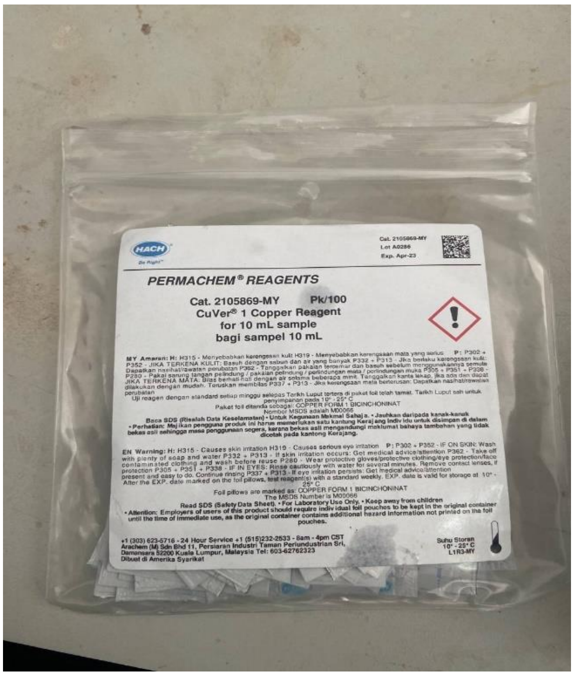


Figure 3.10 Copper Reagent

Figure 3.11 DR 5000

3.11 Batch Method

A 150 mL of shrimp farm wastewater was prepared. The experiment was carried out in 250 mL flasks with the appropriate amount of adsorbent. These flasks were then stirred on a shaker at a fixed rpm agitation speed for a period of time to achieve equilibrium. An ultraviolet-visible spectrophotometer set to 540 nm was used to determine the metal content and other parameters. Variations in experimental circumstances such as contact time, adsorbent dosage, beginning metal and other parameters content, and pH were used in batch adsorption investigations.

The metal reduction percentage was computed as follows:

$$\text{Metal Removal (\%)} = \frac{C_i - C_f}{C_i} \text{ x } 100\%$$

where Ci and Cf are the concentrations of metal and other parameters before and after the treatment.

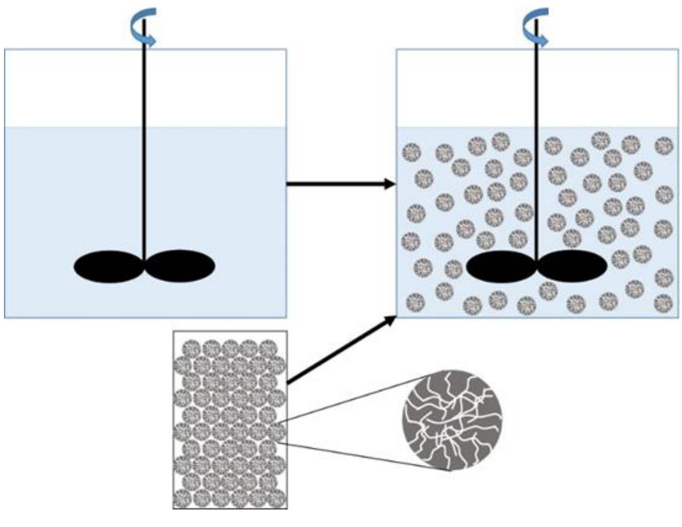


Figure 3.12 Schematic representation of a liquid phase batch adsorption experiment

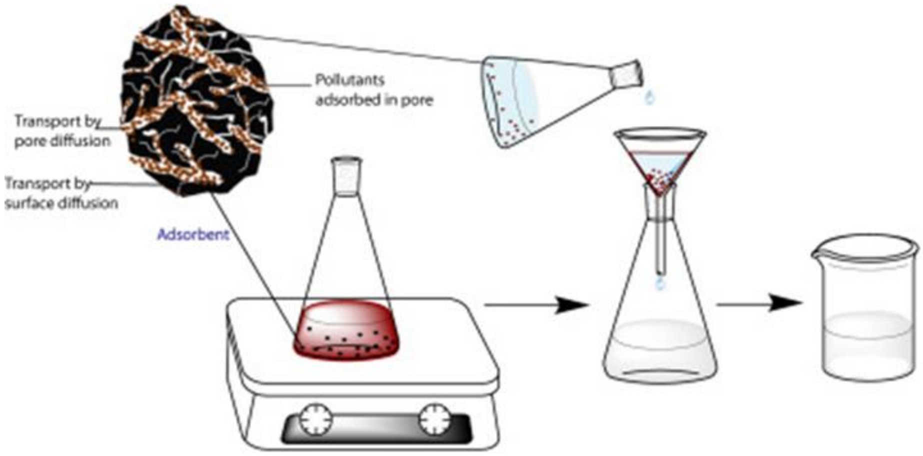


Figure 3.13 Batch Adsorption Process

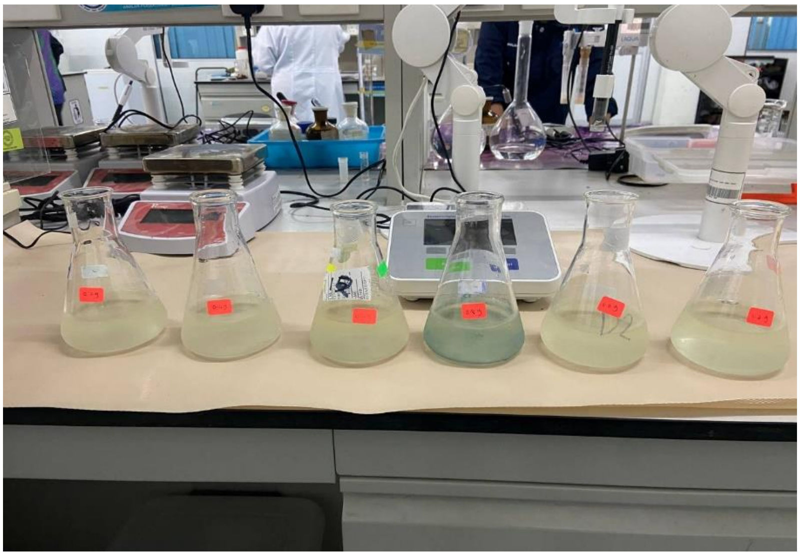


Figure 3.14 Preparation of Batch Method

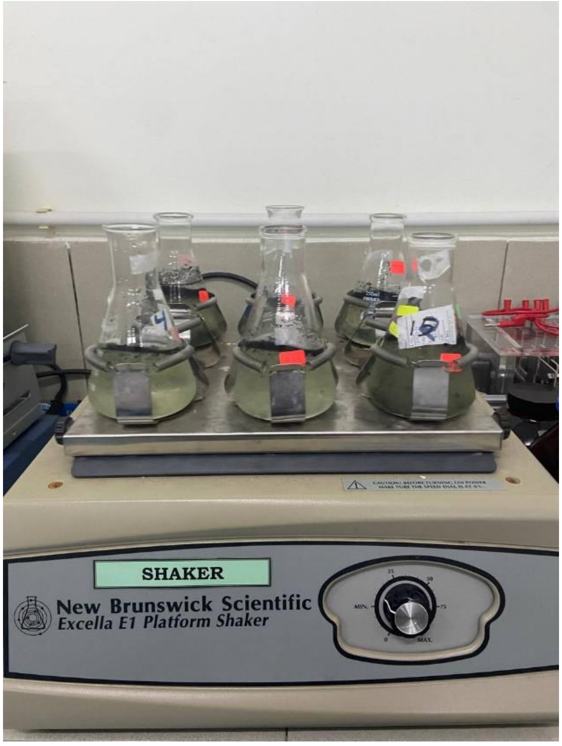


Figure 3.15 Batch Method on Shaker

The adsorption studies of green tea leaves are conducted through a series of testing of the contact time and adsorbent dose. The experiments are done at room temperature to simulate common environmental condition and at a certain time interval until constant result can be seen. Testing of all the parameters is conducted according to Standard Methods for the Examination of Water Wastewater. (APHA, 2005)

3.11.1 Determination of Optimum Amount of Adsorbent

The 150 ml shrimp farm wastewater was placed in a series of flasks with varying amounts of green tea adsorbent: 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 g to determine the optimum amount of adsorbent at which maximal adsorption occurs. Hence, six flasks of shrimp farm wastewater are prepared in advance. The adsorbents are carefully inserted into clear plastic bags and are only mixed in with the shrimp farm wastewater in 100 mL conical flasks immediately before the experiment begins. The samples are then shaken on an orbital shaker at 120 rpm to allow equilibrium adsorption to occur. The samples are all taken out together after 60 mins, which is the selected end time for this study. The samples are all analysed immediately after being taken out of the orbital shaker to ensure that the exact data of pollutants removal is obtained. The procedures of the analysis stage are discussed in the analytical study method. Following that time period, the content was filtered and the absorbance was measured with a UV visible spectrophotometer. The optimum amount of adsorbent was poured in the various flasks with 30 ml of shrimp farm wastewater for various intervals of time of 10, 20, 30, 40, 50 and 60 minutes

The optimum amount of adsorbent was poured in the various flasks with 30 ml of shrimp farm wastewater for various intervals of time of 10, 20, 30, 40, 50 and 60 minutes to determine the effect of contact time on the adsorption of green tea adsorbent. During that time period, the content was filtered and the absorbance was measured with a UV visible spectrophotometer.

Figure 3.16 Analytical Balance

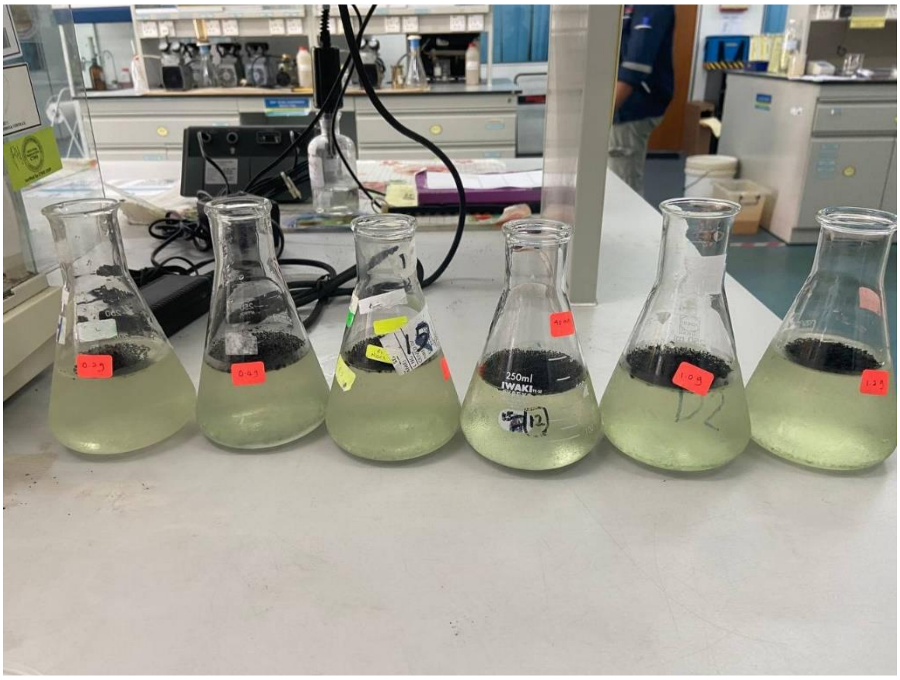


Figure 3.17 Different weight of adsorbent

3.11.2 Determination of Contact Time

In a 200 mL conical flask, 150 mL of shrimp farm wastewater is combined with 1.0 g of adsorbent for tests on the effects of contact time. An electronic weight balance was used to weigh the adsorbent mass to a precision of 0.001 g. The adsorbent is placed in a clear plastic bag once it has been weighed and will only be injected into the solution just before the experiment begins. About seven samples were created to accommodate the set of contact times chosen to acquire findings for this study. The samples are then shaken on an orbital shaker at 120 rpm to allow an equilibrium adsorption process within the samples. The samples are taken out from the orbital shaker at different intervals of time which are at 10 min, 20 min, 30 min, 40 min, 50 min, and 60 min.

The samples are instantly analyzed to determine the correct parameters level in the solution before desorption takes place. In the analytical studies technique, the procedures for data analysis are explored in greater detail.

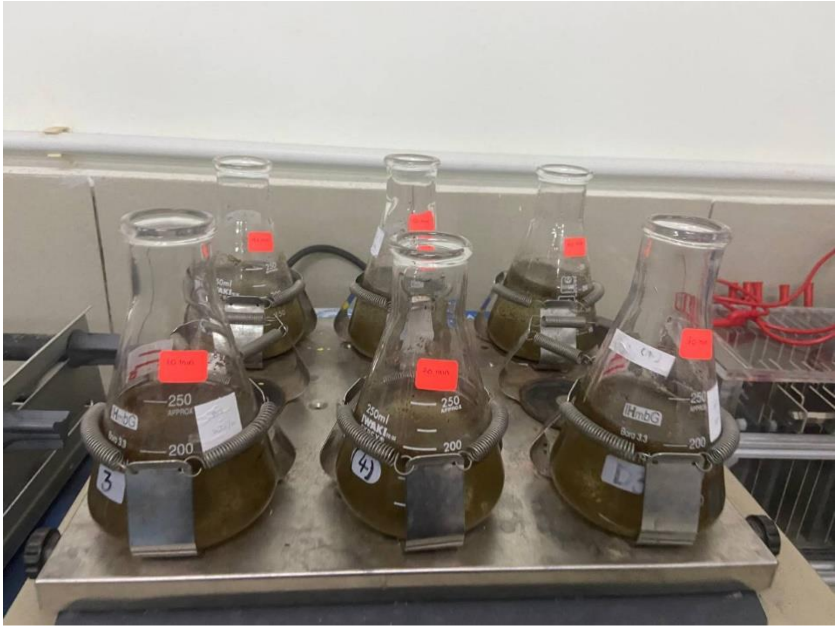


Figure 3.18 Batch Method Process

3.12 Expected Findings

The experiments are expected to show that green tea leaves are a good adsorbent for pollutants removal. The adsorbent's contact time with the shrimp farm wastewater could be a significant factor to consider throughout the adsorption process. The better the efficiency of pollutants removal from the sample, the longer the powder green tea leaves are in contact with the shrimp farm wastewater.

The study should show that organic material, such as green tea leaves, is an effective adsorbent and that pollutants removal via adsorption is a viable option. Adsorption is also predicted to lower the cost of treating wastewater, particularly in terms of eliminating pollutants, increase the shrimp production and encourage a more environmentally responsible method of obtaining a cleaner source of water in the future.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effect of Adsorbent Dosage

The effects adsorbent dosage in this study is tested for the adsorption process. In this case, the results will be taken for 30 minutes of the experiment. The adsorbent dosages used in this study are 0.2g, 0.4g, 0.6g, 0.8g, 1.0g and 1.2g. The purpose of maintaining an arithmetic mass variable is to observe whether there is a distinctive pattern between the results. Other variables which are kept constant for this batch experiment is the particle size of the adsorbent which is 1.18 mm – 2.00 mm and the experiment is conducted in room temperature.

4.1.1 Effect of Adsorbent Dosage on COD Value

Table 4.1 Effect of Adsorbent Dosage on COD Value

Weight (g)	Initial value of COD (mg/L)	Final value of COD (mg/L)	Removal Efficiency (%)
0.2	130	129	0.8
0.4	130	129	0.8
0.6	130	127	2.3
0.8	130	116	10.8
1.0	130	64	50.8
1.2	130	83	36.15

From **Table 4.1**, the final value of COD in the shrimp farm water after adsorption for different adsorbent dosage can be determined. For adsorbent dosage 0.2 g and 0.4 g, the final level of COD is 129 mg/L. The COD level at equilibrium for adsorbent dosage 0.6 g and 0.8 g are 127 mg/L and 116 mg/L respectively. The use of adsorbent dosage 1.0 g has a retained COD level of 64 mg/L whereas the COD level in the sample for adsorbent dose 1.2 g has increased to 83 mg/L.

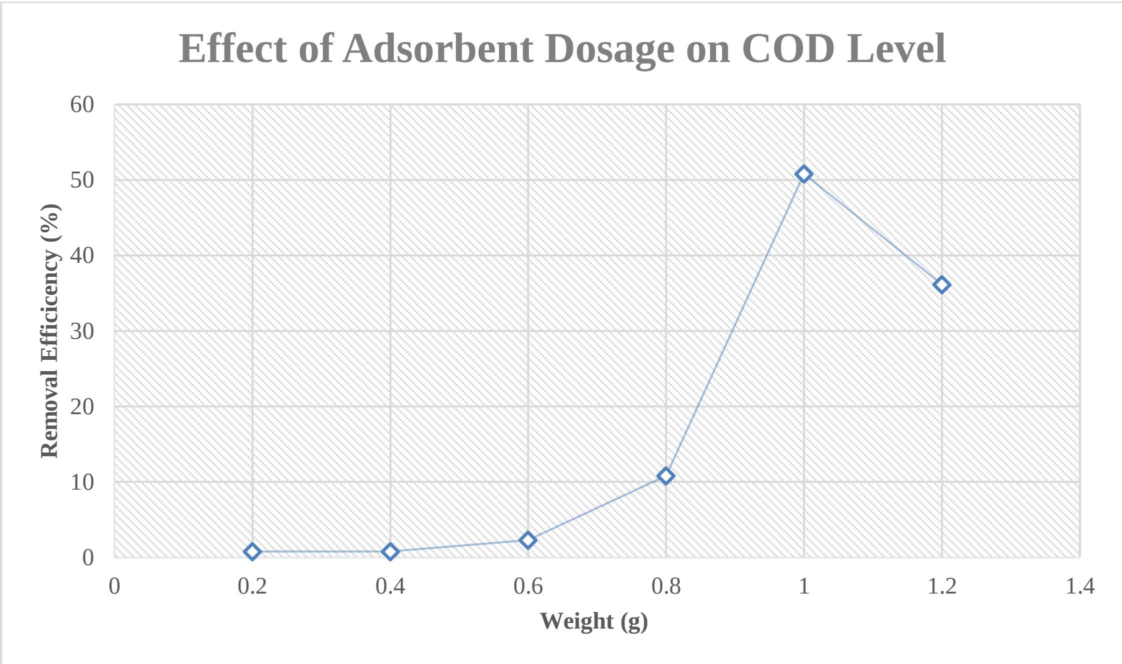


Figure 4.1 Removal Efficiency of COD Value

From Figure 4.1 above, the reduction efficiency of COD was constant at 0.8% for 0.2 g and 0.4 g adsorbent dosage. For adsorbent dose of 0.6 g, the percentage of COD reduction efficiency is 2.3%. The COD reduction efficiency is at 10.8% at 0.8 g and highly increased to 50.8% for the adsorbent dose 1.0 g respectively. Finally, the use of adsorbent dose 1.2 g results in reduction efficiency of 36.15%, which is rapidly decreasing compared to the previous result.

Due to that, the results taken have proven that the green tea adsorbent are suitable enough to treat and reduce the COD value of shrimp farm water. The standard COD level for shrimp farm water is below 50 mg/L.

4.1.2 Effect of Adsorbent Dosage on BOD Value

Table 4.2 Effect of Adsorbent Dosage on BOD Value

Weight (g)	Initial value of BOD (mg/L)	Final value of BOD (mg/L)	Removal Efficiency (%)
0.2	10.1	9.8	2.97
0.4	10.1	8.9	11.88
0.6	10.1	8.8	12.87
0.8	10.1	7.0	30.70
1.0	10.1	3.5	65.34
1.2	10.1	2.4	76.24

Table 4.2 shows the BOD level for the shrimp farm water after interacting with the green tea waste adsorbent. The final BOD level is for the adsorbent dosage of 0.2 g is 9.8 mg/L. But, for adsorbent doses of 0.4 g and 0.6 g, BOD level is slightly decreasing to 8.9 mg/L and 8.8 mg/L. For the BOD level in the sample for adsorbent dose 0.8 g has significantly decreased to 7.0 mg/L, and the BOD level for adsorbent dosage 1.0 g is 3.5 mg/L. The BOD level for 1.2 g adsorbent dosage is 2.4 mg/L. The standard BOD level for the shrimp farm is below 6 mg/L which make it the best condition for the shrimp water.

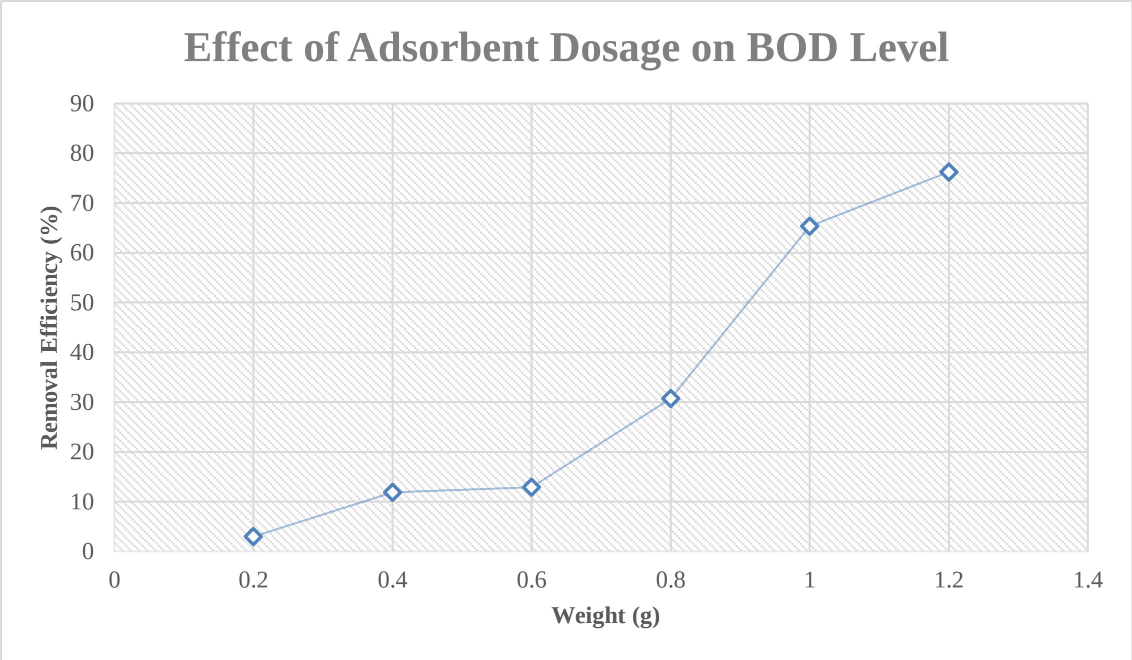


Figure 4.2 Removal Efficiency of BOD Value

From Figure 4.2 above, the reduction efficiency of BOD level was steadily increased from 2.97% at 0.2g adsorbent dosage to 11.88% at 0.4g adsorbent dosage. For adsorbent dose of 0.6 g, the percentage of BOD reduction efficiency is 12.87%. The BOD reduction efficiency is at 30.70% and 65.34% for the adsorbent dose of 0.8 g and 1.0 g respectively. Finally, the use of adsorbent dose 1.2 g results in reduction efficiency of 76.24%. From this figure, the BOD reduction efficiency is slightly increasing as the level is reduced to the best levels which is below 6 mg/L. Higher BOD indicates more oxygen is required, which is less for oxygen-demanding species to feed on, and signifies lower water quality. Inversely, low BOD means less oxygen is being removed from water, so water is generally purer.

4.1.3 Effect of Adsorbent Dosage on Copper Value

Table 4.3 Effect of Adsorbent Dosage on Copper Value

Weight (g)	Initial value of copper (mg/L)	Final value of copper (mg/L)	Removal Efficiency (%)
0.2	3.64	2.63	27.74
0.4	3.64	0.19	94.78
0.6	3.64	0.12	96.70
0.8	3.64	0.06	98.35
1.0	3.64	0.03	99.17
1.2	3.64	2.57	29.40

From **Table 4.3**, the final concentration of copper retained in the sample after adsorption for different adsorbent doses can be determined. For adsorbent dose 0.2 g, the final concentration of copper is 2.63 mg/L. The concentration of copper at equilibrium for adsorbent dose 0.4 g and 0.6 g are 0.19 mg/L and 0.12 mg/L respectively. The use of adsorbent dose 0.8 g has a retained copper concentration of 0.06 mg/L whereas the copper concentration in the sample for adsorbent dose 1.0 g has greatly decreased from 3.64 mg/L to 0.03 mg/L. However, for adsorbent dose 1.2 g the copper was increased to 2.57 mg/L.

Based on the results presented in Table 4.3, it can be seen that there is a relation between the amount of adsorbent and the percentage of copper removed from the sample. It is observed that the adsorbent mass of 0.2 g achieves 27.74% copper removal efficiency. For adsorbent dose of 0.4 g, the percentage of copper removal efficiency is 94.78% which is higher than the adsorbent dose of 0.2 g. The copper removal efficiency is at 96.70% and 98.35% for the adsorbent dose of 0.6 g and 0.8 g respectively. Finally, the use of adsorbent dose 1.0 g results in removal efficiency of 99.17%, making it the highest removal efficiency of all the adsorbent dose. While for adsorbent 1.2 g, the removal efficiency was dropped 29.40%. This result shows that the greater the adsorbent dose, the higher the removal efficiency of copper.

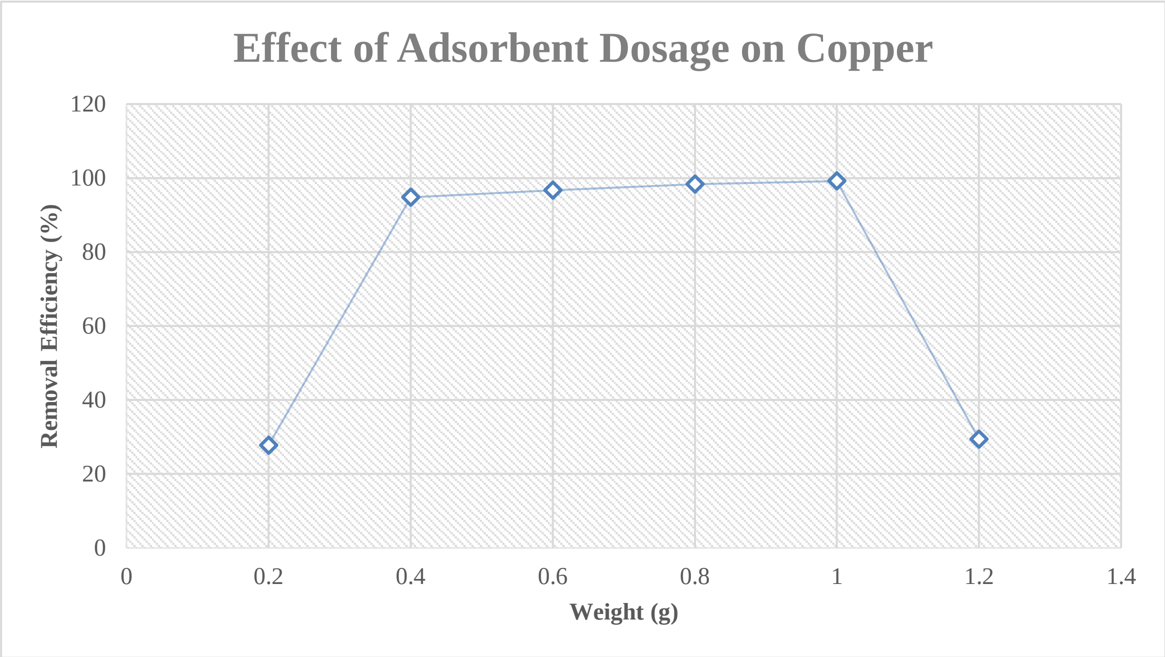


Figure 4.3 Removal Efficiency of Copper Value

It became mostly steady after reaching the optimal percentage elimination of 95%. This is explained by the fact that as the amount of adsorbent is increased, more binding sites will become available for the complexation of copper and the rate of adsorption will increase. However, the percentage of removal will only slowly decrease at an optimal dose of 1.0 g, which may be because the adsorbate and adsorbent are in an equilibrium state. Low metal removal per unit adsorbent is caused by the screening action of an exterior layer of a cell at high adsorbent doses that obstruct the binding sites for metal ions.

Comparing these results, it is obvious that the adsorbent dose used in a sample has a great impact on the effectiveness of copper removal. The main cause of the effect must be due to the fact that adsorption process relies heavily on the total surface area provided by the adsorbent. When combining this aspect with higher dosage of adsorbent used in the experiments, it resulted in the high percentage of copper removal efficiency for 1.0 g adsorbent dose as compared to 0.2 g adsorbent dose due its larger total surface area.

4.1.4 Effect of Adsorbent Dosage on Turbidity Value

Table 4.4 Effect on adsorbent dosage on turbidity value

Weight (g)	Initial turbidity level (NTU)	Final turbidity level (NTU)	Removal Efficiency (%)
0.2	49.4	48.0	2.83
0.4	49.4	21.9	55.66
0.6	49.4	20.3	58.90
0.8	49.4	20.0	59.50
1.0	49.4	17.6	64.37
1.2	49.4	20.7	59.10

The maximum turbidity level retained in the shrimp water following adsorption for various adsorbent dosages can be calculated from **Table 4.4**. The final turbidity level is 48 NTU for the adsorbent dosage of 0.2 g. For adsorbent doses of 0.4 g and 0.6 g, the turbidity level 21.9 NTU and 20.3 NTU, respectively. The turbidity in the sample for adsorbent dose 1.0 g has significantly dropped 17.6 mg/L, whereas the turbidity level in the sample for adsorbent dose 0.8 g is retained at 20 NTU. However, the turbidity level was raised to 20.7 NTU for 1.2 g of adsorbent dosage.

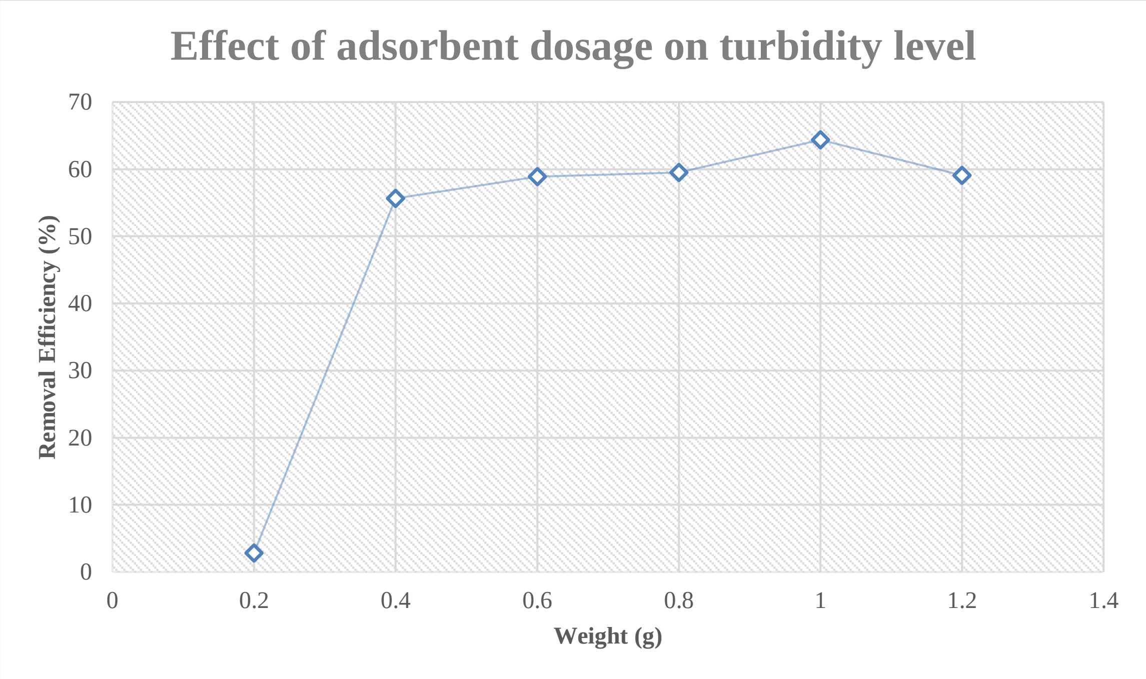


Figure 4.4 Removal Efficiency of turbidity level

From **Figure 4.4** above, the removal efficiency of turbidity was highly increased from 2.83% at 0.2g adsorbent dosage to 55.66% at 0.4g adsorbent dosage. For adsorbent dose of 0.6 g, the percentage of turbidity removal efficiency is 58.90%. The turbidity removal efficiency is at 95.50% and 64.37% for the adsorbent dose of 0.8 g and 1.0 g respectively. Finally, the use of adsorbent dose 1.2 g results in removal efficiency of 59.10%, which is rapidly decreasing compared to the previous results.

Due to that, the results taken have proven that the green tea adsorbent are suitable enough to treat and reduce the turbidity of shrimp farm water. The standard turbidity level for shrimp farm water is below 38 to 47 NTU. (Bommireddy et al., 2021). From this study shows that the turbidity level of the shrimp farm water was better with 0.4 g to 1.2 g green tea adsorbent. But, in this case the lowest level of turbidity was chosen which is 20.7 NTU. The shrimp ponds often contain turbid water because of erosion in drainage basins, tidal action in the estuary, and also the direct drained water from surrounding culture ponds. This results in a large number of filth particles and also organic wastewater entry into the source water. This high turbid water demands high oxygen levels and subsequently increases the stress levels on shrimp in the pond (Sreekakula Anusha Kathyayani et al., 2019). Thus, reduced turbidity levels from clean water systems may encourage the improvement of productivity in shrimp culture ponds.

4.1.5 Effect of Adsorbent Dosage on pH Value

Table 4.5 Effect of adsorbent dosage on pH value

Weight (g)	Initial pH level	Final pH level
0.2	7.92	6.0
0.4	7.92	6.5
0.6	7.92	6.6
0.8	7.92	6.7
1.0	7.92	6.7
1.2	7.92	6.7

Table 4.5 shows the pH readings for the shrimp farm water after interacting with the green tea waste adsorbent. The result shows a slightly lower removal effectiveness. The final pH level is for the adsorbent dosage of 0.2 g is pH 6 which is too acidic to the shrimp farm water. But, for adsorbent doses of 0.4 g and 0.6 g, pH levels are increasing to pH 6.5 and 6.6. For the pH level in the sample for adsorbent dose 0.8 g has significantly increased to 6.7, and the pH level are constant for adsorbent dosage 1.0 g and 1.2 g. The standard pH level for the shrimp farm is 6 to 9 which make it the best condition for the

shrimp farm water. The level of pH is important because if pH changes significantly whether too high or too low, it can make shrimp shocked, weakened and stop eating.

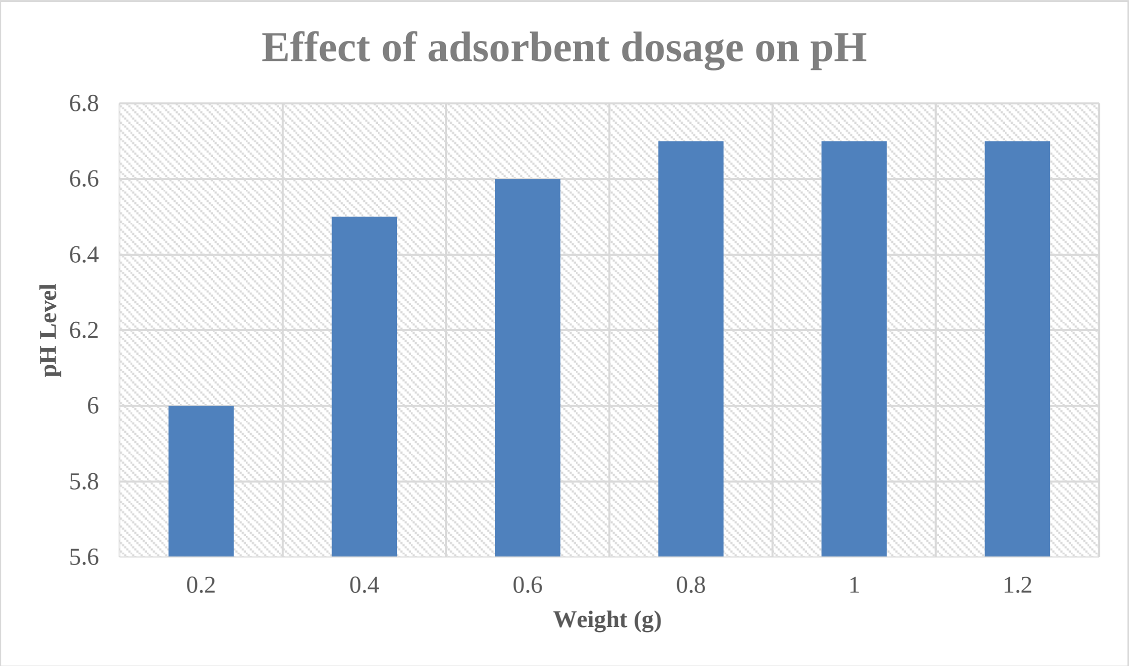


Figure 4.5 Reduction Efficiency of pH Value

Based on the results presented in **Figure 4.5**, it is observed that the adsorbent dosage does not affect the pH value of the shrimp farm water. This is because the initial pH value of the shrimp farm water is already in the suitable range according to the standard level of Department of Fishery (DOF) Malaysia. The green tea adsorbent dosage just control the pH to make it the best condition for shrimp farm water.

4.1.6 Effect of Adsorbent Dosage on Dissolved Oxygen (DO) Level

Table 4.6 Effect of adsorbent dosage on DO level

Weight (g)	**Initial DO level (ppm)**	**Final DO level (ppm)**
0.2	7.67	6.57
0.4	7.67	6.26
0.6	7.67	6.11
0.8	7.67	6.01
1.0	7.67	6.00
1.2	7.67	5.98

Table 4.6 shows the final DO level is for the adsorbent dosage of 0.2 g is 6.57 which is good for the shrimp farm water. For adsorbent doses of 0.4 g and 0.6 g, the DO levels are decreasing to 6.26 and 6.11 ppm. For the DO level in the sample for adsorbent dose 0.8 g has significantly increased to 6.01, and the DO level for adsorbent dosage 1.0 g is 6.0 ppm and 1.2 g is 5.98 ppm. Based on *Shrimp Farm Technical Guidlines*, the standard DO level for the shrimp farm is 3 to 5 ppm.

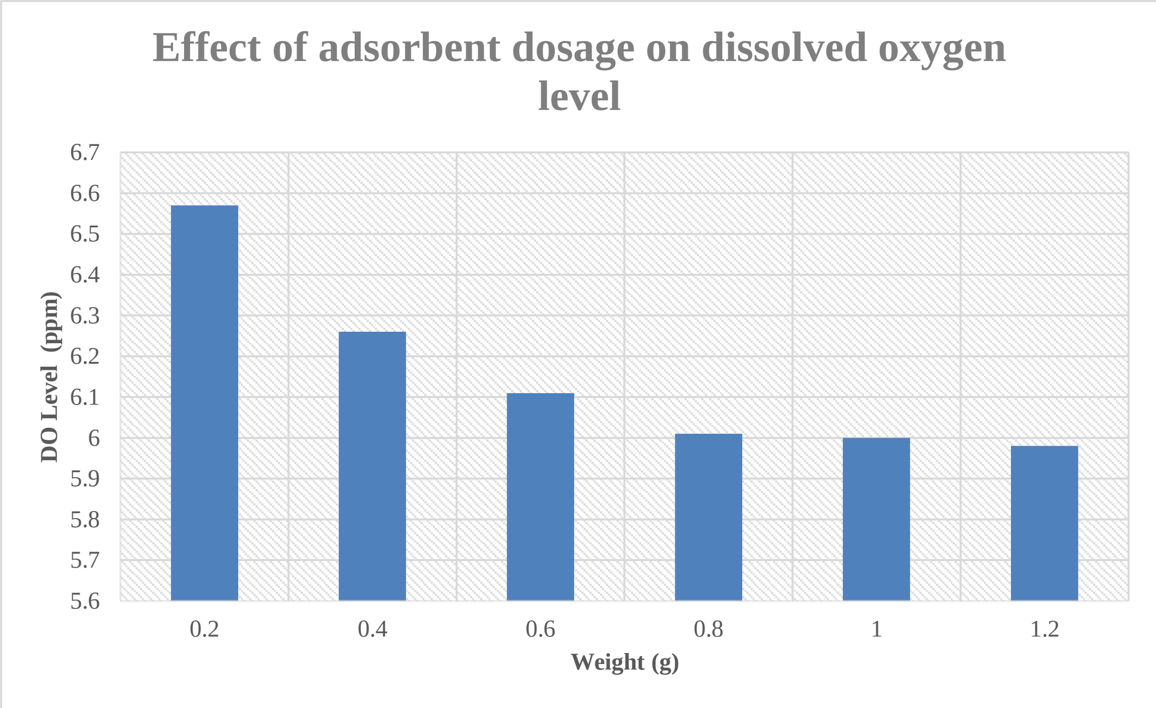


Figure 4.6 Reduction Efficiency of DO level

From **Figure 4.6** above, the value of dissolved oxygen level was steadily decreased to the lowest at 1.2 g of adsorbent dosage with 5.98 ppm. This shown that the green tea adsorbent does not do any significant change to the level of DO in the shrimp farm water.

4.1.7 Optimum Adsorbent Dosage

Table 4.7 Optimum Adsorbent Dosage

Weight (g)	COD	BOD	Copper	Turbidity	pH	DO
0	130	10.1	3.64	49.4	7.92	7.67
1.0	64	3.75	0.03	20.7	6.7	6.00

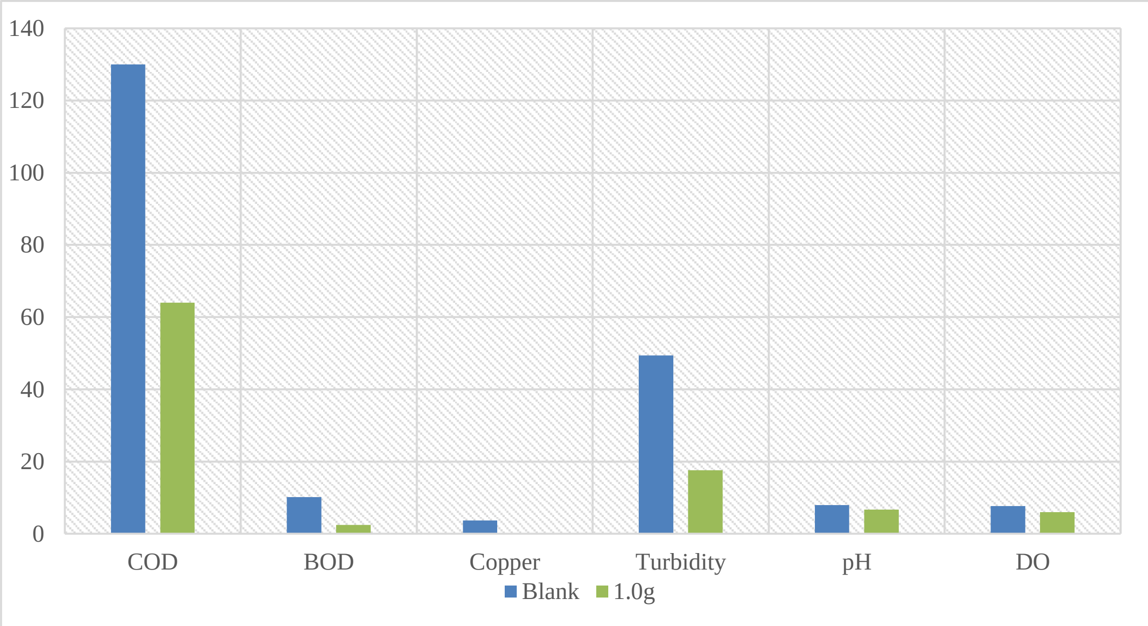


Figure 4.7 Optimum Adsorbent Dosage

Figure 4.7 shows the difference between the level of the parameters for the blank sample and after it is mixed with 1.0 g green tea adsorbent dosage. As seen in the chart above, the COD, BOD, copper, turbidity were decreasing. This result proves that green tea leaves are a very effective adsorbent for the removal of pollutants from the shrimp water.

4.2 Effect of Contact Time

The effect of the contact time of the adsorbent with the shrimp farm water is one of the most common factors observed in studies regarding pollutant removal. This is due to the fact that identifying the optimum time of parameters removal is essential in determining whether the time needed would indicate whether it is suitable to be used in an actual treatment system. In this study, the experiments on the effect of contact time are observed for up to 60 minutes as it is considered to be the maximum appropriate time to allow proper adsorption to occur. The contact time experiment is conducted using adsorbent mass of 1.0 g. The contact that has been used in this experiment is 10 min, 20 min, 30 min, 40 min, 50 min and 60 min.

The partitioning of the adsorbate between the fluid phase and the adsorbent can be viewed as the adsorption process. Long-term contact between the solid and the fluid leads to the development of an equilibrium distribution, which is mathematically explicable.

4.2.1 Effect of Contact Time on COD Value

Table 4.8 Effect of Contact Time on COD Value

Time (Min)	Initial value of COD (mg/L)	Final value of COD (mg/L)	Removal Efficiency (%)
10	130	81	36.70
20	130	74	43.08
30	130	68	47.70
40	130	65	50.0
50	130	53	59.20
60	130	47	63.85

From **Table 4.8**, the final value of COD in the shrimp farm water after adsorption for different contact time can be determined. For contact time 10 min and 20 min, the final level of COD is 81 mg/L and 74 mg/L. The COD level at equilibrium for contact time 30 min and 40 min are 68 mg/L and 65 mg/L respectively. The use of contact time 50 min has a retained COD level of 53 mg/L whereas the COD level in the sample for adsorbent dose 1.2 g has greatly decreased from 47 mg/L.

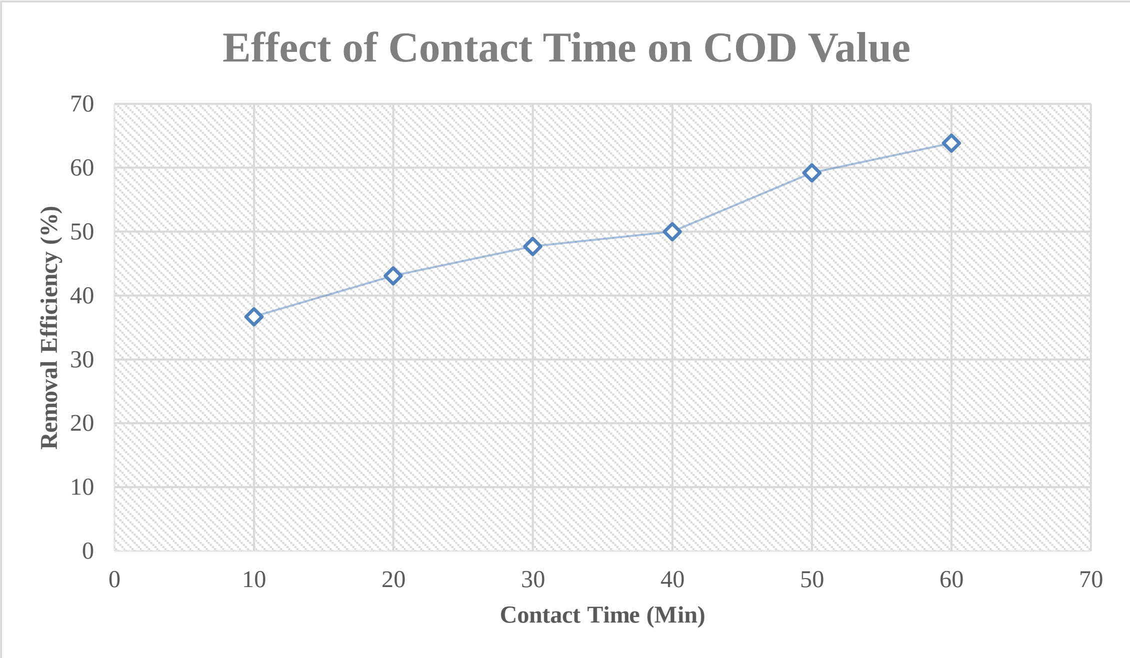


Figure 4.9 Removal Efficiency of COD value

From Figure 4.9 above, the reduction efficiency of COD was at 36.70% for 10 min and 43.08% for 20 min contact time. For contact time 30 min, the percentage of COD reduction efficiency is 47.70%. The COD reduction efficiency is increased to 50.0% at 40 min and slightly increased to 59.20% for the contact time 50 min respectively. Finally, the use of contact 60 min results in reduction efficiency of 63.85%, which is the highest percentage compared to the previous result. Due to that, the results taken have proven that the green tea adsorbent are suitable enough to treat and reduce the COD value of shrimp farm water.

4.2.2 Effect of Contact Time on BOD Value

Table 4.9 Effect of Contact Time on BOD Value

Time (Min)	Initial value of BOD (mg/L)	Final value of BOD (mg/L)	Removal Efficiency (%)
10	10.1	8.50	15.84
20	10.1	8.65	14.35
30	10.1	3.85	60.89
40	10.1	3.40	66.34
50	10.1	3.30	67.33
60	10.1	3.00	70.30

Table 4.9 shows the BOD level for the shrimp farm water after interacting with the green tea waste adsorbent with several contact times. The final BOD level is for the contact time of 10 min is 8.50 mg/L. For contact time of 20 min and 30 min, BOD level is slightly increased to 8.65 mg/L and then decreased to 3.85 mg/L. For the BOD level in the sample for contact time 40 min has significantly decreased to 3.4 mg/L, and the BOD level for adsorbent dosage 1.0 g is 3.30 mg/L. The BOD level for 1.2 g adsorbent dosage is 3.0 mg/L. The standard BOD level for the shrimp farm is below 6 mg/L which make it the best condition for the shrimp mg/L.

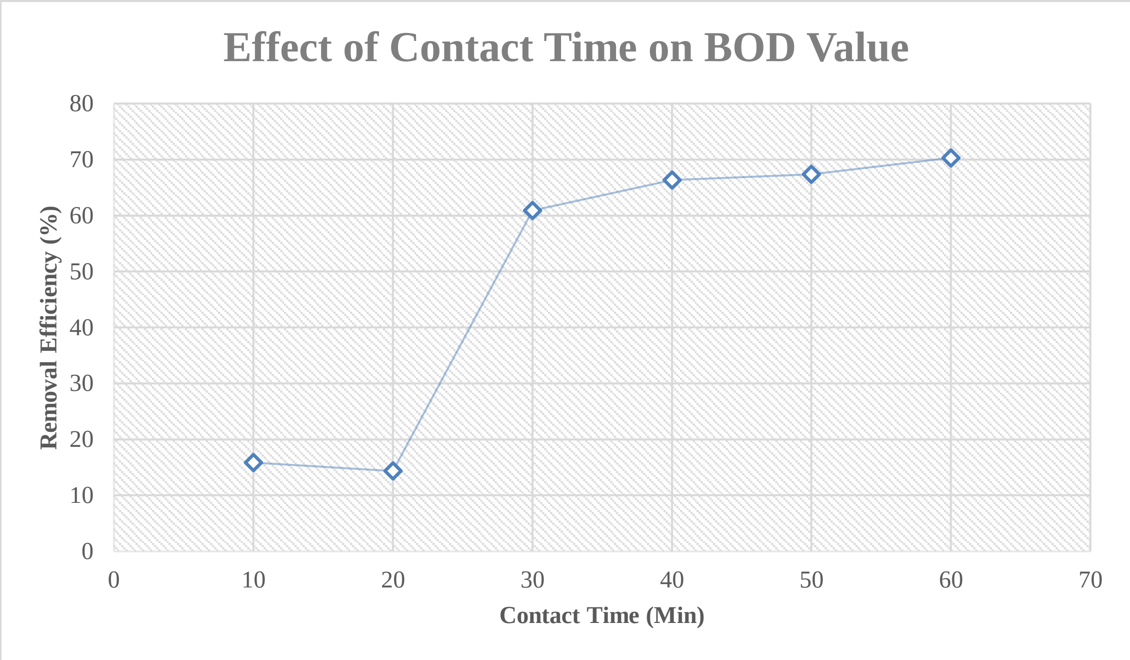


Figure 4.9 Removal Efficiency of BOD value

From **Figure 4.9** above, the reduction efficiency of BOD level was steadily decreased from 15.40% at 10 min contact time to 14.35% at 20 min contact time. For contact time 30 min, the percentage of BOD reduction efficiency is 60.89%. The BOD reduction efficiency is at 66.34% and 67.33% for the contact time 40 min and 50 min respectively. Finally, the use of contact time 60 min results in reduction efficiency of 70.30%. From this figure, the BOD reduction efficiency is slightly increasing as the level is reduced to the best levels which is below 6 mg/L.

4.2.3 Effect of Contact Time on Copper Value

Table 4.10 Effect of contact time on copper value

Time (min)	Initial value of copper (mg/L)	Final value of copper (mg/L)	Removal Efficiency (%)
10	3.64	2.24	38.46
20	3.64	1.96	46.15
30	3.64	1.10	69.70
40	3.64	0.58	84.06
50	3.64	0.51	86.00
60	3.64	0.18	95.05

The final concentration of copper retained in the sample following adsorption for various contact times can be calculated from **Table 4.10**. Copper has a final concentration of 2.24 mg/L after 10 min of contact time. For contact times of 20 min and 30 min, the equilibrium copper concentrations are 1.96 mg/L and 1.10 mg/L, respectively. While the copper content in the sample for contact time 40 min has significantly decreased to 0.58 mg/L, the copper concentration for contact time 50 g has been kept at 0.51 mg/L. Finally, the copper level was 0.18 mg/L during contact time 60 min. Depending on the pH, alkalinity, and hardness of the water, copper concentration for fish and shrimp ranges from 0.05 to 2.00 mg/L. Copper toxicity increases at low pH and particularly low alkalinity. (Global Seafood Alliance, 2018) This result shows that the greater the contact time, the higher the removal efficiency of copper.

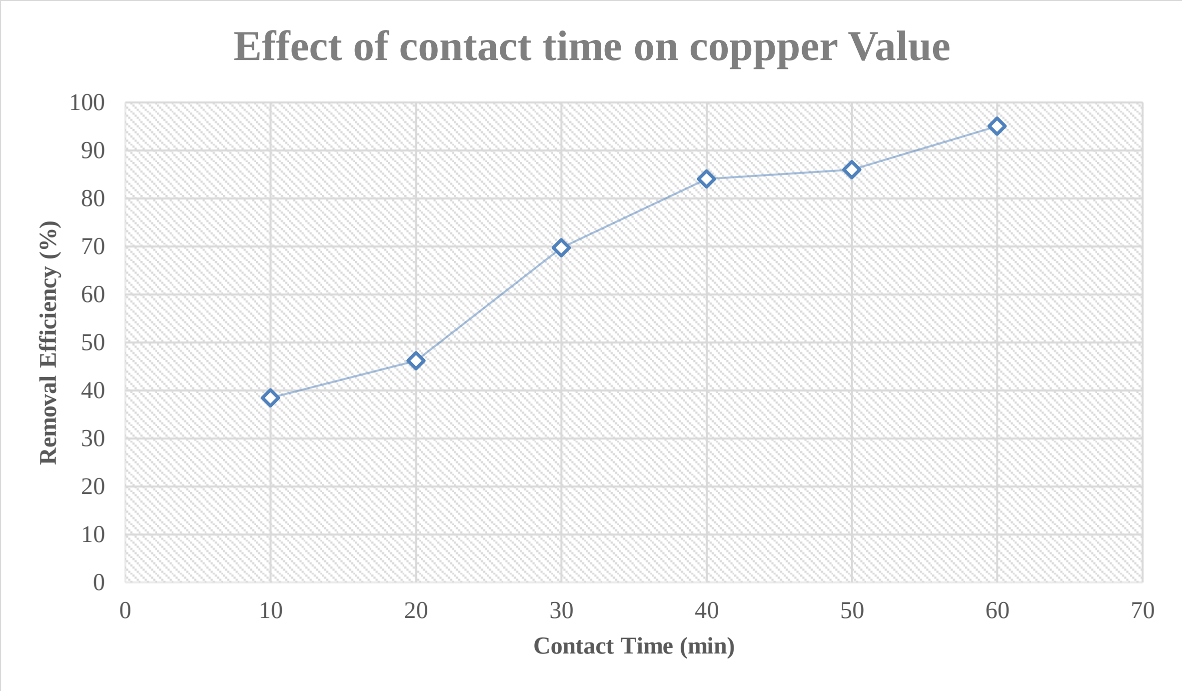


Figure 4.10 Removal Efficiency of copper value

Based on the results presented in **Figure 4.10**, it can be seen that there is a relation between the contact time and the percentage of copper removed from the sample. It is observed that the contact time of 10 min achieves 38.46% copper removal efficiency. For contact time 20 min, the percentage of copper removal efficiency is 46.15% which is higher than the contact time 10 min. The copper removal efficiency is at 69.70% and 84.06% for the contact time of 30 min and 40 min respectively. Finally, the contact time 50 min results in removal efficiency of 86.00%. While for contact time 60 min the removal efficiency was 95.05% making it the highest removal efficiency of all the adsorbent dose.

After achieving the ideal percentage removal of 95%, it typically remained stable. This is accounted for by the fact that as the adsorbent quantity is raised, more binding sites will open up for the complexation of copper and the rate of adsorption will rise.

4.2.4 Effect of Contact Time on Turbidity Value

Table 4.11 Effect of contact time on turbidity value

Time (min)	Initial value of turbidity (NTU)	Final value of turbidity (NTU)	Reduction Efficiency (%)
10	49.4	30.1	39.06
20	49.4	23.5	52.43
30	49.4	17.5	64.57
40	49.4	17.1	65.39
50	49.4	16.8	66.00
60	49.4	16.2	67.21

Table 4.11 shows the turbidity level retained in the shrimp water following adsorption for various contact time can be calculated. The final turbidity level is 30.1 NTU for the contact time 10 min. For contact time of 20 min and 30 min, the turbidity level 23.5 NTU and 17.5 NTU, respectively. The turbidity in the sample for the contact time of 40 min has slightly dropped to 17.1 mg/L, whereas the turbidity level in the sample for contact time 50 min is retained at 16.8 NTU. Lastly, the turbidity level was decreasing to 16.2 NTU for 60 min of contact time.

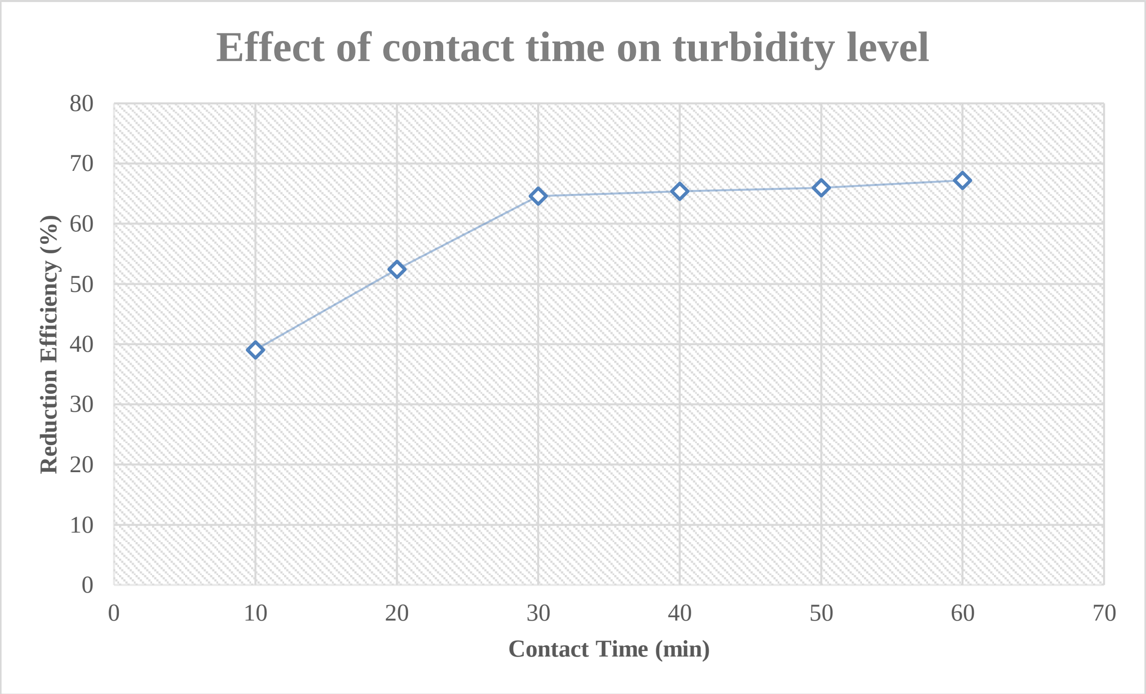


Figure 4.11 Reduction Efficiency on turbidity level

From **Figure 4.11** above, the removal efficiency of turbidity was steadily increased from 39.06% at 10 min to 52.43% at 20 min of contact time. For contact time 30 min, the percentage of turbidity removal efficiency is 64.57%. The turbidity removal efficiency is at 65.39% and 66.00% for the contact time of 40 min and 50 min respectively. Finally, for the contact time 60 min results in removal efficiency of 67.21%, which is slightly increasing compared to the previous results. This study found that adding 0.4 to 1.2 grammes of green tea adsorbent improved the water's turbidity level in the shrimp farm. However, in this instance the lowest turbidity level, 20.7 NTU, was chosen.

This study found that all of the contact times improved the water's turbidity level in the shrimp farm. This makes the best turbidity level for the shrimp farm water as the standard turbidity level for shrimp farm water is below 38 to 47 NTU. Since it feeds tiny creatures (zooplankton) and fish that eat filters, phytoplankton is a desirable kind of turbidity when present in modest levels. It also enhances water quality by creating dissolved oxygen and eliminating potentially hazardous substances like ammonia. However, clay-induced turbidity is typically undesirable because it prevents light from entering the water, which is necessary for algae development. Clay particles can suffocate eggs and clog the shrimps in very high concentrations. So, the final turbidity level in this experiment which is 16.20 NTU is suitable for the shrimp farm water.

4.2.5 Effect of Contact Time on pH Value

Table 4.12 Effect of contact time on pH value

Time (min)	Initial value of pH	Final value of pH
10	7.92	6.56
20	7.92	6.65
30	7.92	6.79
40	7.92	6.83
50	7.92	6.85
60	7.92	6.89

Table 4.10 displays the pH values for the water from the shrimp farm following contact with the green tea waste adsorbent. The outcome indicates a little decreased removal efficiency. The final pH level for the 10 min of adsorbent dose is pH 6.56, which is still lower than the standard pH value for the shrimp farm water. Then, pH levels rise to pH 6.65 and 6.79 for contact time of 20 min and 30 min. The pH level in the sample increased to 6.83 at minute 40, and keep slightly increase to 6.85 and 6.89 at 50 min and 60 min. The ideal pH range for shrimp farm water is between 6 to 9, which is the industry standard.

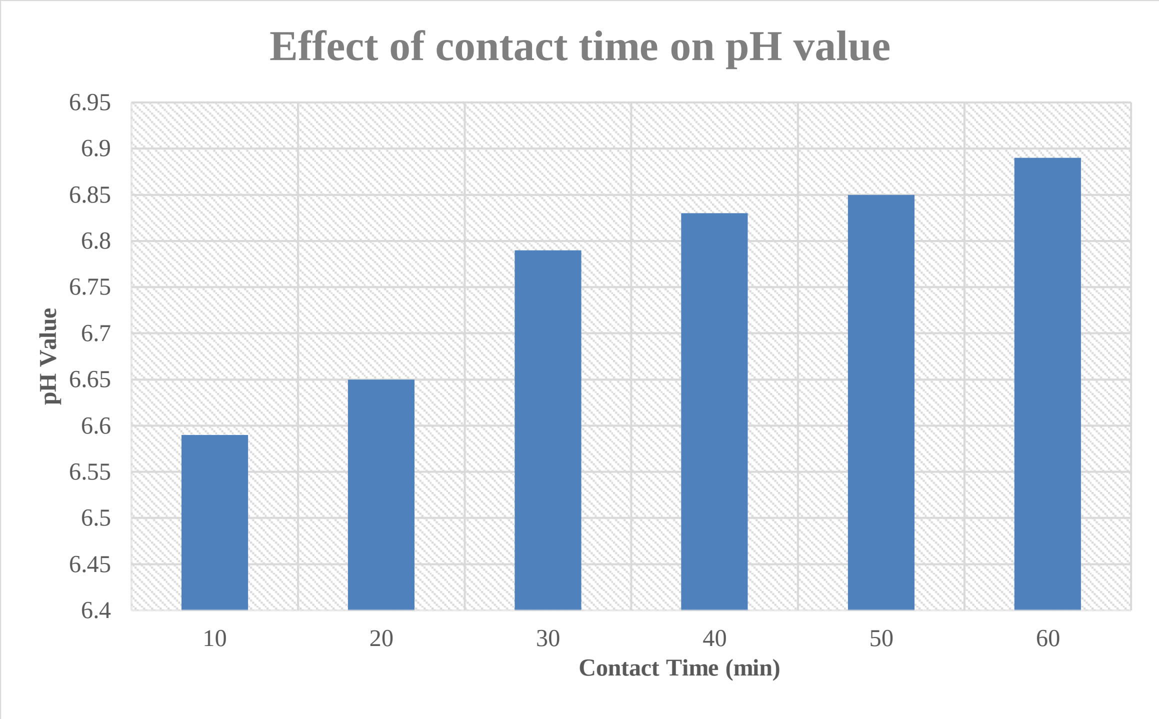


Figure 4.12 Reduction Efficiency of Ph value

According to the findings shown in **Figure 4.12**, the contact time does not change the water's pH level in the shrimp farm. This is due to the original pH value of the shrimp farm water being in the acceptable range by Department of Fishery (DOF) Malaysia standards. To get the optimal conditions for shrimp farm water, the green tea adsorbent dosage simply controls the pH.

Since one of the most important chemical parameters for shrimp cultivation is water pH. The concentration of hydrogen ions is measured by pH. The shrimp pond's ideal pH range is 6 to 9. Stabilizing the pH within this range is crucial. Early in the morning is often when the water's pH value is lowest and late in the afternoon when it is highest. Since pH has an impact on the shrimp metabolism and other physiological functions, it is crucial to keep it steady and within acceptable limits.

4.2.6 Effect of Contact Time on DO Value

Table 4.13 Effect of contact time on DO value

Time (min)	Initial value of DO (ppm)	Final value of DO (ppm)
10	7.67	7.37
20	7.67	7.29
30	7.67	7.27
40	7.67	7.24
50	7.67	7.23
60	7.67	7.20

The ultimate DO level for the contact time 10 min is 7.37 ppm, which is high for the water in the shrimp farm, according to **Table 4.13**. The DO levels drop to 7.29 ppm and 7.27 ppm for contact time 20 min and 30 min, respectively. The sample's DO level for contact time 40 min has slightly decreased to 7.24 ppm, whereas for contact time 50 min and 60 min, the DO level is 7.23 and 7.20 respectively.

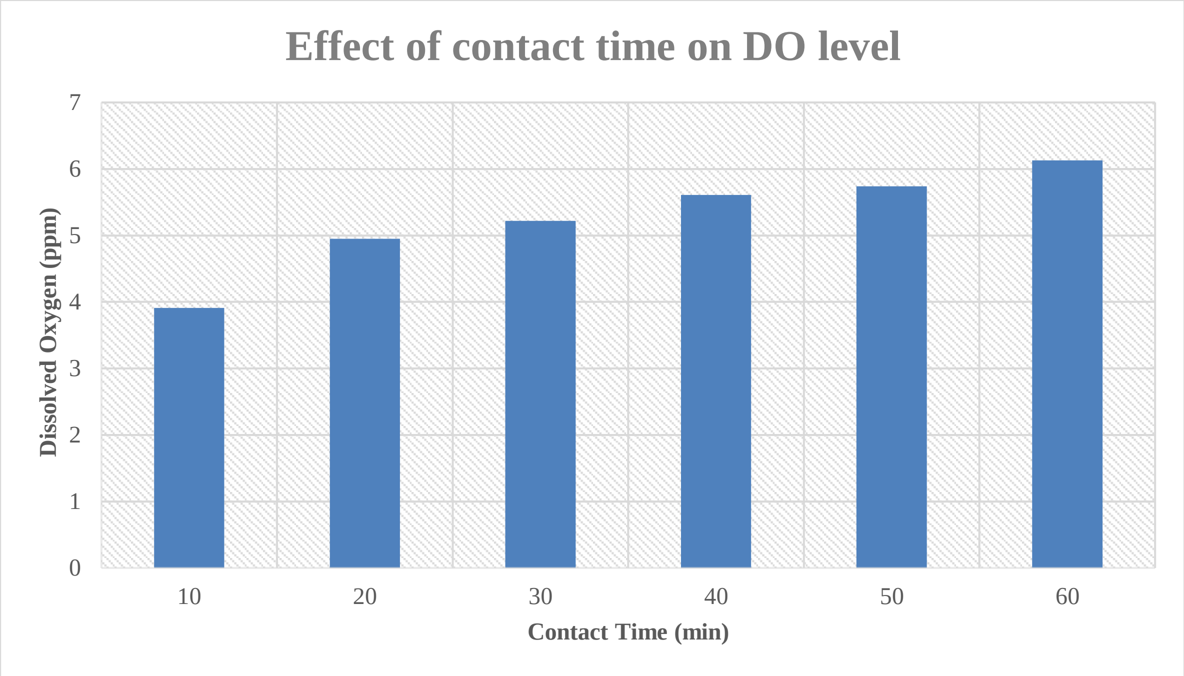


Figure 4.13 Reduction Efficiency of DO level

From **Figure 4.13** above, the contact time between green tea adsorbent and the shrimp farm water does not change the level of the DO according to the standard level of DOF. The final value of the DO is 7.20 ppm which is above the standard level. This result shown that the green tea adsorbent does not efficient in reducing the DO level in shrimp water.

Hyperoxygenation, which stresses fish and other creatures and is harmful to invertebrates like crabs and shrimp, can result from high dissolved oxygen levels. When too little CO2 is present in with lots of plants, the effects are more evident. If there isn't enough CO2 available to counteract these interactions, the resulting bonds quickly disintegrate into radical pairs. (Ramzan, 2022)

4.2.7 Optimum Contact Time

Table 4.14 Optimum Contact Time

Time	COD	BOD	Copper	Turbidity	pH	DO
0	130	10.1	3.64	49.4	7.92	7.67
60	47	3.3	0.18	16.2	6.89	7.20

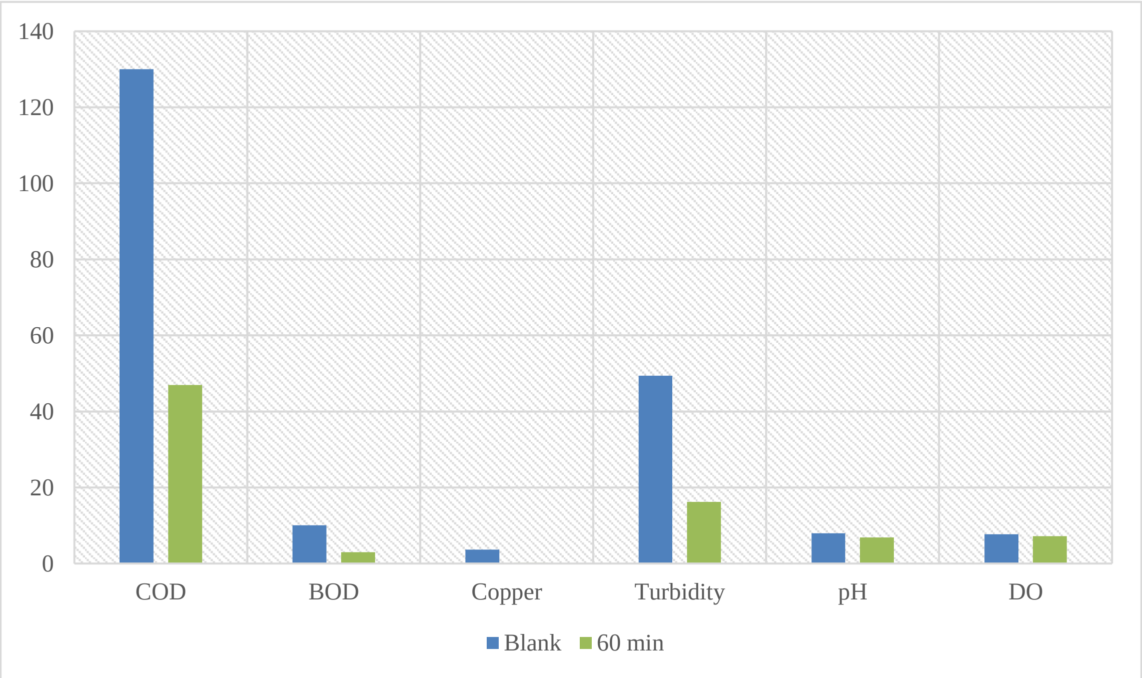


Figure 4.14 Optimum Contact Time

Figure 4.14 shows the difference between the final level of the parameters for the blank sample and after it is mixed with 1.0 g green tea adsorbent dosage with contact time 60 min. As seen in the chart above, the green tea adsorbent has removed 63.85% of COD, 70.30% of BOD, 95.05% of copper, and 67.21% of turbidity. This result proves that green tea leaves are a very effective adsorbent with 60 min of contact time for the removal of pollutants from the shrimp water.

CHAPTER 5

CONCLUSION

5.1 Conclusion

For this study, the use of green tea leaves as an adsorbent for pollutant removal from shrimp farm water was proposed. The main objective of this project which was to make the green tea leaves as adsorbent to remove pollutant from shrimp farm water was achieved.

The use of green tea leaves for pollution adsorption could be applied in shrimp farm water treatment system to reduce the parameters level according to the standard content in the shrimp farm water. The use of green tea leaves as adsorbent for the pollutant removal is effective as seen from the results of the batch experiments with optimum removal of COD 63.85%, BOD 70.30%, copper 95.05%, and turbidity 67.21%. The green tea adsorbent does not give any significant change of the pH value as the initial value of the pH is already according to the standard level. So, the green tea adsorbent just controlled the value of pH based on the allowed range. From the result, the green tea adsorbent is not efficient to reduce the level of DO in the shrimp farm water. Based on the analysis from each parameter of the study, the effects of adsorbent dosage achieved optimum removal is 1.0 g at the contact time of 60 minutes and at room temperature.

As a conclusion to this study, green tea leaves are promising adsorbent to remove pollutant from wastewater which makes it suitable for shrimp farm water treatment. As seen in the analysis, waste green tea leaves show adsorption properties which makes it an ideal adsorbent with high adsorption capability. Another supporting factor of using waste green tea leaves is the fact that waste green tea leaves can be obtained easily and is available in large quantities. The use of green tea leaves as an adsorbent is practical and it is an environmentally friendly solution to reduce pollutant in shrimp farm water as it is a waste product from industries and act as natural adsorbents. These adsorbents are easily available, economic, and show high adsorption efficiency, and thus are more effective in the removal of pollutants.

Based on the rough assessment of capital cost for green tea leaves adsorbent production, the cost involved is lower compared to activated carbon, as it is more economical.

5.2 Recommendations

Some recommendations for future research are summarized below:

1. It is suggested to further evaluate the adsorption performance of the adsorbents prepared in this study for removing the pollutants from wastewater emanating from different industrial process. This will provide insight concerning the adsorption mechanism and performance of the adsorbent which may be interfered by other components present in the effluents.

2. It is recommended to modify the adsorbent prepared in this study with appropriate surfactants or oxidizing agents to enhance their adsorption performance since the adsorption ability of the adsorbents are found to be influenced by their surface charges and their functional groups.

3. It is suggested to do the test of green tea leaves adsorption on the different parameters such as different types of metal in the shrimp farm water to observe the efficiency of the green tea leaves adsorbent.

REFERENCES

Mohammed, S. S. (2015). Effect of pH on the Turbidity Removal of Wastewater. OALib, 02(12), 1–9. https://doi.org/10.4236/oalib.1102283

Kusari, L. (2011). The use of Turbidity and Total Suspended Solids Correlation for the Surface Water Quality Monitoring. International Journal of Current Engineering and Technology. https://doi.org/10.14741/ijcet/v.3.4.29

H, K. (2017). Effect of pH and Initial pb(II) Concentration on The Lead Removal Efficiency from Industrial Wastewater Using Ca(OH)2. International Journal of Water and Wastewater Treatment, 3(2). https://doi.org/10.16966/2381-5299.139

A., & A. (2021, October 20). Preparing shrimp farms for wet weather. Alune. https://thefishsite.com/articles/how-to-manage-water-effluent-from-shrimp-farms

Prasanth, M., Sivamaruthi, B., Chaiyasut, C., & Tencomnao, T. (2019). A Review of the Role of Green Tea (Camellia sinensis) in Antiphotoaging, Stress Resistance, Neuroprotection, and Autophagy. Nutrients, 11(2), 474. https://doi.org/10.3390/nu11020474

Demirbas, A. (2008). Heavy metal adsorption onto agro-based waste materials: A review. Journal of Hazardous Materials, 157(2–3), 220–229. https://doi.org/10.1016/j.jhazmat.2008.01.024

Brandani, S. (2020). Kinetics of liquid phase batch adsorption experiments. Adsorption, 27(3), 353–368. https://doi.org/10.1007/s10450-020-00258-9

Biswas, C., Soma, S. S., Rohani, M. F., Rahman, M. H., Bashar, A., & Hossain, M. S. (2021). Assessment of heavy metals in farmed shrimp, Penaeus monodon sampled from Khulna, Bangladesh: An inimical to food safety aspects. Heliyon, 7(3), e06587. https://doi.org/10.1016/j.heliyon.2021.e06587

MP, S. (2018). Wastewater Treatment – Recent Scenario. International Journal of Water and Wastewater Treatment, 4(1). https://doi.org/10.16966/2381-5299.e104

Bommireddy, S., K, S. K., P, A. P., & A., C. R. (2021). INFLUENCE OF TURBIDITY ON SURVIVAL OF WHITE LEG SHRIMP (LITOPENAEUS VANNAMEI) GROW OUT PHASE IN SPSR NELLORE DISTRICT, ANDHRA PRADESH, INDIA. Journal of Bio Innovation, 10(1), 1–9. https://doi.org/10.46344/jbino.2021.v010i01.01

Towers, L., & Towers, L. (2022, May 11). Aquaculture experts to discuss role of synthetic biology in aquafeed. Lucy Towers. https://thefishsite.com/articles/suspended-solids-effects-in-shrimp-biofloc-systems

A, A. (2018, December 7). Effects of pH, Alkalinity, and hardness on growth and Survivals of Vannamei shrimp in Aquaculture. My CMS. https://www.aquacultureinafrica.com/?p=1315

Nathanson, J. A. (2022, March 3). water pollution. Encyclopedia Britannica. https://www.britannica.com/science/water-pollution

Biological Oxygen Demand (BOD) and Water | U.S. Geological Survey. (2019, October 22). U.S Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/biological-oxygen-demand-bod-and-water

Schmitz, K. (2020, December 23). Turbidity I wastewater treatment - How to reduce turbidity. Smart Water Magazine. https://smartwatermagazine.com/blogs/karl-uwe-schmitz/turbidity-i-wastewater-treatment-how-reduce-turbidity#:%7E:text=Turbidity%20in%20wastewater%20is%20caused,solids%2C%20or%20decaying%20organic%20matter.

A., & A. (2021, October 20). Preparing shrimp farms for wet weather. The Fish Site. https://thefishsite.com/articles/how-to-manage-water-effluent-from-shrimp-farms

Thommes, M., & Cychosz, K. A. (2014). Physical adsorption characterization of nanoporous materials: progress and challenges. Adsorption, 20(2–3), 233–250. https://doi.org/10.1007/s10450-014-9606-z

Miljojkovic, D., Trepsic, I., & Milovancevic, M. (2019). Assessment of physical and chemical indicators on water turbidity. Physica A: Statistical Mechanics and Its Applications, 527, 121171. https://doi.org/10.1016/j.physa.2019.121171

Nageeb, R.M. (2013) Adsorption Technique for the Removal of Organic Pollutants from Water and Wastewater, Chapter 7

Muhammad Bozlur, R., Shibata, S., Farah Diba, C., & Uono, M. (2010). Low Cost Biodegradable Adsorbent Material for the Removal of Dissolved Dyes from Aqueous Solutions: An Economical Process. International Journal of Engineering and Technology, 2(5), 468–473. https://doi.org/10.7763/ijet.2010.v2.166

SHRIMP CULTURE: POND DESIGN, OPERATION AND MANAGEMENT. (2019). Food and Agriculture Organization of the United Nations. https://www.fao.org/3/ac210e/AC210E09.htm

de Gisi, S., Lofrano, G., Grassi, M., & Notarnicola, M. (2016). Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review. Sustainable Materials and Technologies, 9, 10–40. https://doi.org/10.1016/j.susmat.2016.06.002

Ribeiro, L. F., Eça, G. F., Barros, F., & Hatje, V. (2016). Impacts of shrimp farming cultivation cycles on macrobenthic assemblages and chemistry of sediments. Environmental Pollution, 211, 307–315. https://doi.org/10.1016/j.envpol.2015.12.031

Flushing Our Environment Down the Drain. (2019, May 3). Fresh Outlook Foundation. https://freshoutlookfoundation.org/flushing-our-environment-down-the-drain/

Sustainable Shrimp Farming: Biosecure Systems to Prevent or Control Emerging Diseases. (2020). Journal of Marine Science Research and Oceanography, 3(3). https://doi.org/10.33140/jmsro.03.03.01

Crockett, J., & Lawrence, A. (2017). Two organic carbon application rates to control inorganic nitrogen in minimal water exchange, biofloc, shallow water, shrimp nursery systems. International Journal of Recirculating Aquaculture, 14, 1–7. https://doi.org/10.21061/ijra.v14i0.1579

Rahman, A., Dabrowski, J., & McCulloch, J. (2020). Dissolved oxygen prediction in prawn ponds from a group of one step predictors. Information Processing in Agriculture, 7(2), 307–317. https://doi.org/10.1016/j.inpa.2019.08.002

Crini, G., Lichtfouse, E., Wilson, L. D., & Morin-Crini, N. (2018). Conventional and non-conventional adsorbents for wastewater treatment. Environmental Chemistry Letters, 17(1), 195–213. https://doi.org/10.1007/s10311-018-0786-8

Chakraborty, R., Asthana, A., Singh, A. K., Jain, B., & Susan, A. B. H. (2020). Adsorption of heavy metal ions by various low-cost adsorbents: a review. International Journal of Environmental Analytical Chemistry, 102(2), 342–379. https://doi.org/10.1080/03067319.2020.1722811

Ali, I., Asim, M., & Khan, T. A. (2012). Low cost adsorbents for the removal of organic pollutants from wastewater. Journal of Environmental Management, 113, 170–183. https://doi.org/10.1016/j.jenvman.2012.08.028

Gao, X., Guo, C., Hao, J., Zhao, Z., Long, H., & Li, M. (2020). Adsorption of heavy metal ions by sodium alginate based adsorbent-a review and new perspectives. International Journal of Biological Macromolecules, 164, 4423–4434. https://doi.org/10.1016/j.ijbiomac.2020.09.046

Zaimee, M. Z. A., Sarjadi, M. S., & Rahman, M. L. (2021). Heavy Metals Removal from Water by Efficient Adsorbents. Water, 13(19), 2659. https://doi.org/10.3390/w13192659

Musial, C., Kuban-Jankowska, A., & Gorska-Ponikowska, M. (2020). Beneficial Properties of Green Tea Catechins. International Journal of Molecular Sciences, 21(5), 1744. https://doi.org/10.3390/ijms21051744

Chacko, S. M., Thambi, P. T., Kuttan, R., & Nishigaki, I. (2010). Beneficial effects of green tea: A literature review. Chinese Medicine, 5(1), 13. https://doi.org/10.1186/1749-8546-5-13

Auta, M., & Hameed, B. (2011). Preparation of waste tea activated carbon using potassium acetate as an activating agent for adsorption of Acid Blue 25 dye. Chemical Engineering Journal, 171(2), 502–509. https://doi.org/10.1016/j.cej.2011.04.017

Maia, M. L., Delerue-Matos, C., Calhau, C., & Domingues, V. F. (2021). Validation and Evaluation of Selected Organic Pollutants in Shrimp and Seawater Samples from the NW Portuguese Coast. Molecules, 26(19), 5774. https://doi.org/10.3390/molecules26195774

Mostafa Shamsuzzaman, M., & Kumar Biswas, T. (2012). Aqua chemicals in shrimp farm: A study from south-west coast of Bangladesh. The Egyptian Journal of Aquatic Research, 38(4), 275–285. https://doi.org/10.1016/j.ejar.2012.12.008

Denchak, M. (2022). Water Pollution: Everything You Need to Know. NRDC. https://www.nrdc.org/stories/water-pollution-everything-you-need-know

Royan, M. R. (2020). Integrated Multi-Trophic Aquaculture (IMTA) as a Solution for Shrimp Aquaculture Side Effects on Northern Coast of Java, Indonesia. Grouper, 11(1), 31. https://doi.org/10.30736/grouper.v11i1.66

Demiral, L., Samdan, C., & Demiral, H. (2021). Enrichment of the surface functional groups of activated carbon by modification method. Surfaces and Interfaces, 22, 100873. https://doi.org/10.1016/j.surfin.2020.100873

G, C. (2016). Challenges in Water Resources and Wastewater Treatment. International Journal of Water and Wastewater Treatment (ISSN 2381–5299), 2(2). https://doi.org/10.16966/2381-5299.e102

Zhao, X., Xu, Z., & Wang, S. (2012). Effect Factors of Soy Sauce Wastewater Treatment by Allure-type Wastewater Treatment Equipment. Energy Procedia, 16, 65–69. https://doi.org/10.1016/j.egypro.2012.01.012

A, L. (2017). Holistic Wastewater Reuse Solutions – Evaluation of Treatment Efficiency, Environmental Impacts and Costs. International Journal of Water and Wastewater Treatment, 3(1). https://doi.org/10.16966/2381-5299.135

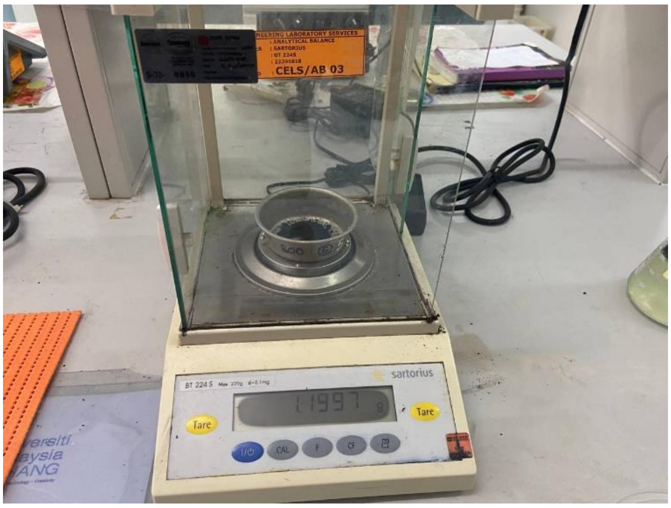
Wuana, R. A., & Okieimen, F. E. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. ISRN Ecology, 2011, 1–20. https://doi.org/10.5402/2011/402647

Prasanth, M., Sivamaruthi, B., Chaiyasut, C., & Tencomnao, T. (2019). A Review of the Role of Green Tea (Camellia sinensis) in Antiphotoaging, Stress Resistance, Neuroprotection, and Autophagy. Nutrients, 11(2), 474. https://doi.org/10.3390/nu11020474

Sreekakula Anusha Kathyayani, Moturi Muralidhar, Thangaraj Sathish Kumar, Shankar Vinayakarao Alavandi, 2019. Stress quantification in Penaeus vannamei exposed to varying levels of turbidity. Journal of Coastal Research, 1, 86 (SI): 177–183.

APPENDIX A

PREPARATION OF ADSORBENT



APPENDIX B

BATCH METHOD EXPERIMENT