# REMOVAL *Escherichia coli* FROM SEWAGE USING COMBINATION OF ELECTROCOAGULATION AND ULTRASONIC METHOD

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METHOD

by

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**PENGHAPUSAN *Escherichia coli* DARI SEWAGE MENGGUNAKAN KAEDAH GABUNGAN ELEKTROGUMPALAN DAN ULTRASONIK**

## ABSTRAK

Air kumbahan adalah gabungan efluen organik dan bukan organik dari pelbagai sumber domestik, awam, dan perindustrian. Kumbahan juga mengandungi mikroorganisma yang boleh menyebabkan penyakit, seperti protozoa dan bakteria. Kumbahan menghasilkan air sisa yang tercemar dan kotor. Jadi, kumbahan perlu dirawat terlebih dahulu sebelum dibuang ke sungai mana pun untuk mengelakkannya tercemar oleh air sisa ini. Objektif utama kajian ini adalah untuk mencari kaedah kecekapan paling banyak yang dapat merawat *Escherichia Coli* di kumbahan dengan kaedah rawatan yang berbeza iaitu kaedah elektrogumpalan, bunyi-elektrogumpalan dan ultrasonik. Dalam kajian ini, elektrod aluminium dan besi digunakan semasa rawatan pada elektrod anod dan katod. Elektrod aluminium dan besi dipilih sebagai elektrod untuk penyiasatan ini kerana ia murah dan mudah diperoleh. Ujian yang digunakan dalam kajian ini mempunyai pelbagai masa rawatan 5 minit, 10 minit, 15 minit, 20 minit dan 25 minit, serta voltan bervariasi 5V, 10V, 15V, 20V dan 25V. Tambahan pula, jarak elektrod berubah-ubah iaitu 1cm, 2cm dan 3cm. Peratusan tertinggi penyingkiran *E. coli* adalah pada voltan 25V, rawatan masa pada 25 minit dan jarak elektrod 1cm iaitu 99.58% untuk electrocoagulation. Untuk sono-electrocoagulation, peratusan tertinggi penyingkiran *E. coli* adalah pada voltan 5V, rawatan masa pada 25 minit dan jarak elektrod 3cm iaitu 99.31%. Untuk kaedah ultrasonicultrasonic adalah 90.63% apabila masa rawatan adalah 10 minit. Oleh itu, kaedah yang paling berkesan untuk merawat *E. coli* dalam air kumbahan adalah kaedah electrocoagulation. Kemudian, diikuti dengan sono-electrocoagulation dan ultrasonik.

**REMOVAL *Escherichia coli* FROM SEWAGE USING COMBINATION OF ELECTROCOAGULATION AND ULTRASONIC METHOD**

## ABSTRACT

Sewage is a combination of organic and inorganic effluent from diverse domestic, public, and industrial sources. Sewage also contains microorganisms that can cause sicknesses, such as protozoa and bacteria. Furthermore, sewage generates high contaminated and dirty wastewater. So, the sewage needs to be treated first before discharge to any river to avoid it polluted by this wastewater. The main objective of this study is to find the most efficient method that can treat the *Escherichia coli* in the sewage with different methods of treatment: electrocoagulation, sono-electrocoagulation and ultrasonic method. In this study, aluminium and iron electrodes were employed during the treatment procedure on anode and cathode electrodes, respectively. The aluminium and iron electrode were chosen as the electrode for this investigation because it was inexpensive and easy to obtain. The tests used in this study had various treatment times of 5 minutes, 10 minutes, 15 minutes, 20 minutes and 25 minutes, and varied voltages of 5V, 10V, 15V, 20V and 25V. Also, variable electrode distance which are1m, 2cm and 3cm. The highest percentage of *E. coli* removal is at the voltage of 25V, time treatment at 25min and electrode distance 1cm, which is 99.58% for electrocoagulation. For sono-electrocoagulation, the highest percentage of *E. coli* removal is at the voltage of 5V, time treatment at 25min and electrode distance 3cm, 99.31%. For ultrasonic method is 90.63% when the treatment time is 10min. Therefore, the most effective method to treat *E. coli* in sewage water is the electrocoagulation method. Then, followed by sono-electrocoagulation and ultrasonic.

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## LIST OF SYMBOLS

| | |
|---|---|
| $C_i$ | Initial Concentrations of Parameter |
| $C_f$ | Final Concentrations of Parameter |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| APHA | American Public Health Association |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| DO | Dissolved Oxygen |
| EC | Electrocoagulation |
| *E. coli* | *Escherichia coli* |
| pH | Potential of Hydrogen |
| STP | Sewage Treatment Plant |
| TDS | Total Dissolved Solids |
| US | Ultrasonic |
| USM | Universiti Sains Malaysia |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Sewage is the mixture of wastewater from various residential, public, and industrial areas containing organic matter and inorganic matter. Sewage also contains harmful microorganisms such as protozoa and bacteria that can cause illness. The addition of chloride in sewage is to remove pathogen bacteria. It is a standard method that has been used, and it is employed in approximately 90% of water treatment plants(Aguilar-Ascon, 2019). A pond system is also a commonly used method of treating sewage wastewater. This treatment system has been widely used in all countries, especially in tropical countries like Malaysia, which has more suitable hot weather. There is ample land for the operating processes of this type of pond.

Several methods are used to treat sewage, such as biological treatment, including anaerobic and aerobic processes, electrochemical oxidation, membrane process, and dissolved air floatation method. Each method has its advantages and disadvantages, but the combination of ultrasonic and electrocoagulation methods is chosen for this project.

The electrocoagulation method is creating the cationic species that can neutralize the non stabilizes suspended and the pollutant changes in the sample. This can lead toward the attraction of the particles of the different charges and the flocculants be formed. The ultrasonic technique lets the waves strike the sediments established at the electrode surface. It also produces excessive numbers of extreme species to eliminate pollutants by generating high-level pressure points interior (Moradi et al., 2021). Combining these two techniques makes the mineralization degree increases by reducing the electrode passivation and fouling problem (Ritesh and Srivastava, 2020). To determine the presence and population of Escherichia coli, agar plate counts were used, which required some serial dilution of samples to ensure the growth of isolated colonies in the cells plate and some incubation time to make the bacteria invisible so that it could be counted. (Guo et al., 2017).

This method has been proven effective in treating several types of wastewater such as landfill leachate, textile wastewater, tannery wastewater, paint wastewater and poultry wastewater. These methods are comparable with other wastewater treatment methods in terms of overall cost, optimum treatment time, and effectiveness in treating the wastewater. This method varies in the use of different electrode types such as aluminium, iron, platinum and other types of alloy.

## 1.2 Problem Statement

The population of human increase year by year which means that the sewage wastewater will be generated more every year. Thus, domestic sewage becomes a significant issue for the country, and the financial burden of the treatment become increases. The sewage discharged without treat first may cause numerous environmental problems and health risks for the people. To make sure the environment and people's health are protected, the best method or solution needs to find out to overcome this problem.

Sewage is polluted wastewater that contains organic and inorganic matter. The pathogen bacteria such as *Escherichia coli* in the sewage are high due to the high level of organic matter in that wastewater. *Escherichia coli* is pathogenic, which means it may cause sickness, either diarrhoea or illness outside of the gastrointestinal system. If the sewage is not treated properly, it cannot be discharged to the river and may affect the contaminant in the river. The sewage wastewater is collected from the sewage pond at USM Engineering Campus.

Therefore, the purpose of this study is to determine the effectiveness of the combination of ultrasonic and electrocoagulation treatment methods. Three controlled parameters to be considered when doing the treatment are treatment time, voltage, and distance between electrodes.

## 1.3 Objectives

1. To determine the removal efficiency of electrocoagulation alone on the removal of *Escherichia coli* from sewage.
2. To compare the efficiency of the combination of ultrasonic and electrocoagulation with electrocoagulation alone.
3. To determine the floc formation of electrocoagulation of *Escherichia coli* from sewage.

## 1.4 Scope of Works

1. The sewage water used in this study is collected from the sewage pond of the USM Engineering Campus. The samples were collected and stored in a high-density polyethene bottle.
2. The sample is then brought back to the School of Civil Engineering Environmental Lab and stored in a 4°C cold room to minimize the changes in its constituents. To get the wastewater characteristic before the treatment, some tests were done, which includes the testing and measurement of:
    - pH value
    - Biochemical Oxygen Demand (BOD)
    - Chemical Oxygen Demand (COD)
    - Turbidity
    - Salinity
3. The sewage water are treated using electrocoagulation and ultrasonic method by using aluminium as an electrode at the cathode and iron as an electrode at the anode.
4. The treatment conditions are determined by considering the conditions that will influence the treatment: voltage, treatment time, and distance between electrodes.
5. Therefore, *Escherichia coli* is analyzed to determine the efficiency of the combination method to treat the sewage water. Electrocoagulation and Ultrasonic methods have been compared to each other to know the most efficient treatment.

## 1.5 Thesis Outline

There are five chapters of this thesis: Introduction, Literature review, Methodology, Results and Discussion followed by Conclusion and Recommendation. The outline and description of each chapter mentioned above are listed below:

Chapter 1: Introduction. Discuss briefly the introductory information about the background of this study, the problem statement of this study, the objectives of this study and the scope of work of this study.

Chapter 2: Literature Review. This section briefly discusses the previous related study by other researchers to this thesis title about the electrocoagulation and ultrasonic application to treat the sewage.

Chapter 3: Methodology. This section describes in detail the outline of the experimental works and methods used to test this study hypothesis and achieve this study's objective.

Chapter 4: Result and Discussion. This section shows the outcome obtained from all the experimental work that has been done throughout the study. The result is then discussed with the supporting evidence and reports.

Chapter 5: Conclusion and Recommendation. The study will be concluded in this final section, and some recommendations will be given regarding further research.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Sewage

All the water that we know on earth is not pure and may contain harmful material. As we know, rainwater is the safest water to drink without doing the treatment. Still, it also includes some minor dust and dissolved oxygen such as oxygen and carbon dioxide (Han *et al*., 2006). So, wastewater treatment is needed before discharge to any river; even the rainwater is necessary to treat before drink. The secondary and tertiary of the wastewater treatment also not so suitable and cannot be used for reused purposes it did not perform the further treatment towards that wastewater (Shon *et al.*, 2007).

Sewage wastewater is a complex model with several distinct chemical characteristics (Roehrdanz *et al.*, 2017). These characteristics include very high concentrations of COD, BOD, Nitrogen, Phosphorus, Nitrite, and Nitrate, as well as extremely high conductivity (due to extremely high dissolved particles) and a pH that varies between 7 and 8 (Sabeen *et al.*, 2018).

## 2.2 Effect of Sewage Wastewater

Sewage wastewater effluent is a good source for farmers to use it to grow their plants because it contains plant nutrients and organic matter. Still, it also contains heavy metals such as zinc, manganese, iron, and copper that can harm plants. Despite the fact that sewage water contains modest amounts of heavy metals (Fe, Mn, Pb, Cd, and Cr), soil and plant samples revealed greater levels owing to accumulation. The following shows the trend of metal accumulation in wastewater-irrigated soil: Fe >Mn > Pb >Cr > Cd (Alghobar and Suresha, 2017). From the previous study, using sewage effluent continuously for the long term can be dangerously toxic to the plants and cause the soil's corrosion (Butt *et al.*, 2005).

There are many sicknesses towards humans and plants that can cause by the low or high level of heavy metal contains in sewage wastewater. The large level of heavy metals absorbed by the plant from the soil will affect their photosynthesis process (Khan *et al.*, 2019). The danger of sewage-irrigated soils affecting trace element transfer to rice and wheat grain. The toxic limit of extractable Cd and As in soil for rice was defined in connection to soil characteristics and the human health hazard connected with human eating of rice grain (Meena *et al.*, 2016). The pathogenic bacteria such as *Escherichia coli* in the sewage are not suitable for human health that can cause death.

## 2.3 Generation of Sewage

According to Organisation for Economic Co-Operation and Development (OECD), Turkey had generated wastewater about 766.686 $m^3$/year in 2016 and increase to 994.547 $m^3$/year in 2018. However, according to the European Business and Technology Centre research, only below 20 % of household wastewater and below 60 % of industrial wastewater are treated in India.

Another research found that large cities in India create 38,354 million litres of sewage per day, while the available capacity for treatment is only 11,786 million litres per day (Karthikraj *et al.*, 2017). First, sewage or domestic wastewater is generated from the community of people who are from their toilet, sink and kitchen. Then, that wastewater flows into a sewer pipe that has been installed. Finally, all the wastewaters are collected and stored at the nearest sewage treatment plant (STP).

## 2.4 Characteristic and Composition of Sewage

99.9% of the sewage wastewater is water, and 0.1% is organic and inorganic matter, dissolved and suspended solids. Furthermore, the minor percentage is the wastewater that needs to be treated (Marcos et al., 2007). Table 2-1 shows the characteristic of the sewage.

Table 2-1:Description Characteristic of sewage.

(Marcos et al., 2007)

| Parameter | Description |
|---|---|
| Temperature | Slightly higher than drinking water |
| Colour | Fresh sewage: Slight grey<br>Septic sewage: Dark grey |
| Turbidity | Cause by variety suspended solid |
| $BOD_5$ | Biodegradable fraction of carbonaceous organic compound |
| COD | The amount of oxygen required to chemically stabilize carbonaceous organic matter. |
| Bacteria | Pathogenic bacteria, present in various sizes. |

## 2.5 Treatment Method of Sewage

The sewage treatment methods are comparable with municipal wastewater treatment, including the primary, secondary, and tertiary treatment. However, it does not eliminate the need for primary care. There are numerous treatment methods available after preliminary treatment; currently, the four main categories of treatment methods available after preliminary treatment are physicochemical treatment, biological treatment, advanced oxidation processes, and combined processes. Typically, conventional wastewater treatment operations use a combination of physical, chemical, and biological processes in their treatment plant to degrade organic matter, extract solids, and reduce wastewater nutrients (Sanamdikar and Harne, 2012). The more effective the capacity of wastewater treatment, the lower the energy cost per unit wastewater treatment was (Li and Qiu, 2017). Figure 2-1 shows the process of sewage treatment at the Sewage Treatment Plant.

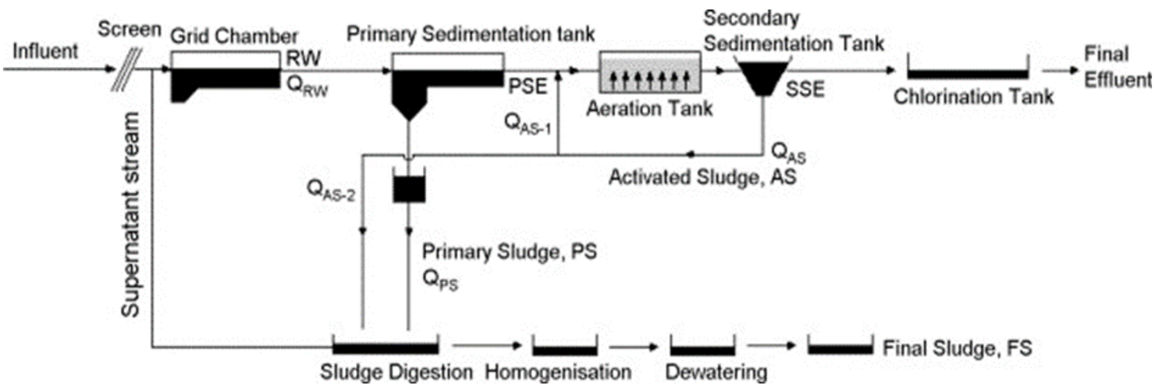



Figure 2-1:Flow chart of treatment plant
(Katsoyiannis and Samara, 2007)

### 2.5.1 Preliminary Stage

In this stage, the objective is to remove a large solid or particle such as tissues, plastic, which can cause a problem when the treatment occurs. The removal of this solid will aid in the enhancement and reduction of maintenance and service work on subsequent treatment units such as grit removal and screening. The value of BOD also can be reduced in this stage by about 15% until 30% (Prabu et al., 2011).

#### 2.5.1(a) Screening

Screening systems will be installed upstream of core processes in all wastewater treatment and effluent treatment plants to reduce the larger particles carried over to the primary treatment before biological treatment (Newhart *et al.*, 2019). If gross solids are not removed, they become entrained in the treatment plant's pipes and moving parts, causing significant damage and inefficiency. Therefore, in some modern wastewater treatment plants, coarse and fine screens are used. This first process will remove fat, internal organs, and other large, heavy, and coarse solids. This waste component can be removed using bar screens, drum screens, or band screens (Li and Qiu, 2017)

#### 2.5.1(b) Grit Removal

Grit removal reduces abrasion and wears on mechanical equipment, grit deposition in pipelines and channels, and grit accumulation in anaerobic digesters and aeration basins. Grits, also known as small insoluble particles, such as sand and gravel, are removed at this stage (Talvitie *et al.*, 2017). This procedure is carried out to prevent clogging in the treatment piping system. Grit removal can also help to protect the mechanical components of a wastewater treatment plant. Grit removal methods commonly used include velocity grit channels, aerated grit channels, and gravity separators (Yacob *et al.*, 2017).

### 2.5.2 Primary Treatment Stage

In this stage, the organic matter and suspended solids are removed from the sewage. Physical operations such as sedimentation in settling basins are commonly used to accomplish this removal. Next, wastewater is routed through a series of tanks and filters, which separate the water from contaminants. The resulting "sludge" is then fed into a digester, where it is further processed. This first batch of sludge contains nearly half of the suspended solids found in wastewater. This stage also removes settleable organic and inorganic substances, as well as the floc curable suspended solid (O'Flaherty *et al.*, 2018).

### 2.5.3 Secondary Treatment Stage

In the secondary treatment stage of sewage wastewater, dissolved organic matter would be removed by a biological process, either aerobic or anaerobic, or both simultaneously. The process is similar to the primary treatment process. Still, a biological catalyst, such as sludge or other consortia, is added to activate the biodegradation process of organic matter and inorganic constituents in sewage wastewater (Talvitie *et al.*, 2017).

Biological treatment processes are very important in wastewater treatment because they can treat wastewater with varying quality characteristics from various sources. If the BOD/COD ratio of sewage is less than 0.5, it indicates that the wastewater can be treated biologically with the proper environmental conditions in place. There was an example of a secondary process, which is listed below:

1. Mesophilic and thermophilic aerobic treatments,
2. Mesophilic and thermophilic anaerobic digestion and energy recovery,
3. Composting, and
4. Activated sludge treatment.

### 2.5.4 Tertiary treatment Stage

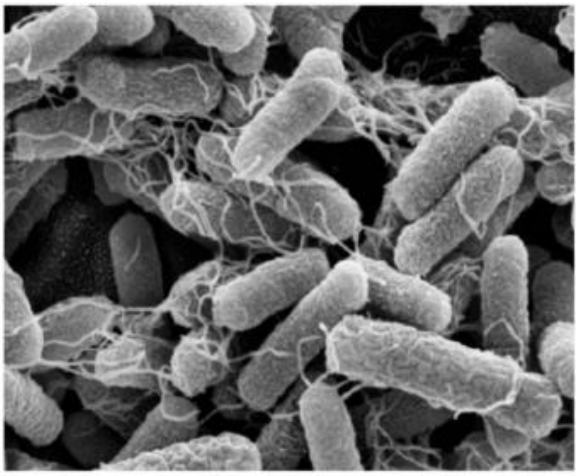
If the organic matter is still present, this stage will be used as an advanced treatment to remove nutrients, toxic and kill the pathogenic bacteria. Then it will be followed by the filtration and chlorination process. Alum and chlorine were used to treat the water. Alum aids in the separation of sludge at the bottom of the tank, allowing the water to become clean, while chlorine is utilized as a cleaning agent, killing bacteria in the water (Sanamdikar and Harne, 2012). Moreover, the process that frequently used in this advance stage is flocculation, coagulation and sedimentation. Ion exchange and reverse osmosis are less commonly used processes for specific ion removal or dissolved solids reduction. Usually, sewage disposal will not use this advanced stage, but it will be used for collecting water for reused purposes (Prabu et al., 2011).

## 2.6 Biological Treatment

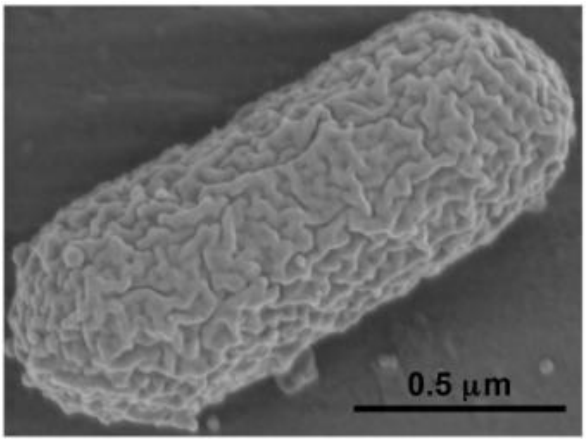
The biological treatment of the sewage is used to treat the sewage in terms of the biological properties of the sewage under some artificial conditions. The primary purpose of biological treatment is to eliminate biodegradable organic compounds (colloidal or dissolved) from wastewater. These chemicals are essentially transformed into gases that can escape into the atmosphere and biological cell tissue that may be eliminated by settling (Sanamdikar and Harne, 2012). To treat the bacteria such as *Escherichia coli* in the sewage, we need to do this treatment because the bacteria eat organic matter to create energy for their own. They convert some part of their body substance to grow in the sewage, resulting in excess of sludge (Pauli and Gmbh, 2012). Biological systems in Malaysia include prolonged aeration, sequencing batch bioreactors, oxidation ditches, oxidation ponds, and Imhoff tanks (Yacob *et al.*, 2017).

## 2.7 Escherichia Coli

*E. coli*, a member of the Enterobacteriaceae bacterial family, is the most common commensal resident of human and warm-blooded animal gastrointestinal tracts, as well as one of the most significant pathogens (Allocati et al., 2013). *E. coli* may be easily recovered from clinical specimens using the general or selective medium at 37°C in aerobic circumstances. *E. coli* in stool is most commonly recovered on MacConkey or eosin methylene-blue agar, which selectively grows members of the Enterobacteriaceae and allows morphological distinction of enteric organisms (Kai et al., 2010). The shape of *E. coli* can be seen in figure2-6.



(a)




(b)

Figure 2-2:(a) *E. coli* is an enteropathogenic strain that generates pili that resemble hairs. (b) A laboratory strain of *E. coli* with a characteristic sausage-shaped appearance. (Blount, 2015)

Ammonia is the greatest nitrogen source for *E. coli*. However, *E. coli* can also thrive on several different nitrogen sources, including several amino acids, but at a slower rate (Bren *et al.*, 2016). Even though *E. coli* infections have proven costly to the poultry industry, the specific virulence mechanisms employed by these organisms to induce illness in birds remain an intriguing area of study. Intestinal pathogenic strains, commensal strains, and extra intestinal pathogenic *E. coli* (ExPEC) strains were the three major groups of the *E. coli* strain (Abed, 2020).

There are six well-defined types of intestinal pathogens strains: enteropathogenic *E. coli* (EPEC), enterohaemorrhagic *E. coli* (EHEC), enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli* (EAEC), enteroinvasive *E. coli* (EIEC), and diffusely adherent *E. coli* (DAEC) (Allocati *et al*., 2013). These strains are classified based on their virulence and pathogenicity mechanisms, which cause gastrointestinal illnesses such as diarrhea (Jang et al., 2017).

For the extra intestinal pathogenic *E. coli*, the types of the strains are uropathogenic *E. coli* (UPEC), avian pathogenic *E. coli* (APEC), septicemia-associated *E. coli* (SEPEC) and neonatal meningitis-causing *E. coli* (NMEC). ExPEC infections in humans are a substantial source of morbidity or mortality, as well as the primary cause of economic loss in poultry owing to lower production. (Meena *et al.*, 2021). Extraintestinal E. coli strains have bigger genomes and encode more virulence factors than commensal bacteria. (Micenková *et al.*, 2016)

Other phenotypic characteristics of *E. coli* strains differ, such as the ability to produce biofilms and the use of carbon sources (Jang *et al.*, 2017). The development of biofilms by commensal strains and pathovars of *E. coli* is mostly unknown, due to the significant number of largely uncharacterized fimbriae as well as the confirmed and potential of extracellular polymeric substance operons (Vila *et al.*, 2016).

Human disease caused by *E. coli* O157:H7 can have a range of clinical symptoms. Some infected people may be asymptomatic, while others may exhibit in-testinal and extraintestinal symptoms of variable severity (Stein and Katz, 2017). Uropathogenic *E. coli* (UPEC), which causes urinary tract infection in humans and animals, neonatal meningitis-associated *E. coli* (NMEC), septicaemic *E. coli* (SePEC), which causes systemic infection in humans and animals, avian pathogenic *E. coli* (APEC), which causes avian colibacillosis, and a potentially emerging ExPEC lineage named endometrial pathogenic *E. coli* (EnPEC) (Lindstedt *et al.*, 2018).

## 2.8 Treatment of Escherichia Coli

### 2.8.1 Ultrasonic (US) Treatment

Ultrasonic (US) treatment is the treatment that uses a sound wave with some frequency that exceeds the frequency that a human can receive. By the wave of frequency that is used, the sound wave can be utilized in such industrial applications in this world (Awad *et al.*, 2012). Moreover, this treatment is the cell lysis-cryptic development method with a high functioning cost. Also, this method is effective in decreasing the biological matter in sewage wastewater (Romero *et al.*, 2017). The chemical is not required when this method is running and easy to install.

A transducer is used to apply the US to a liquid medium such as distilled water. The mechanical shuddering or vibration of the transducer is conveyed to the liquid medium. Then, the formation of pressure waves will occur when the US operates. This pressure wave goes as a sinusoidal wave. In the medium, the form of compression and rarefaction are produced in a cycle form (Chen *et al*., 2011). The organic pollutant can be broken down easily into modest particles. Thus, no sludge will be produced when running this method (Adewuyi et al., 2001). Figure 2-2 shows the bubble formation, growth and collapse when the wave is used for the treatment and Figure 2-3 shows the graphical representation of bubble formation, growth, and implosion at 20 kHz for ultra-sonic application in water. The formation of the bubble brake after it reaches the maximum or critical size.

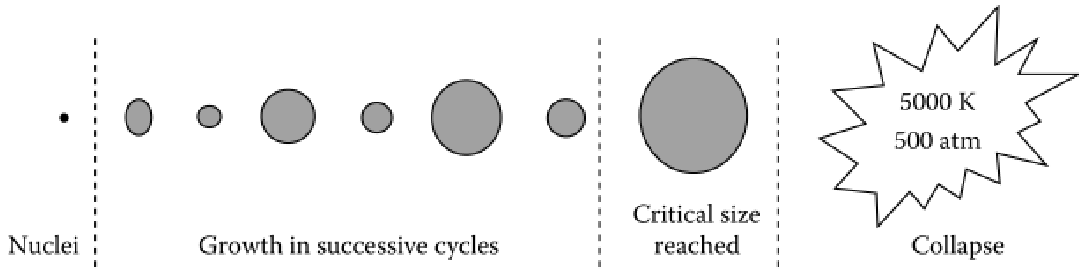



Figure 2-3:Bubble formation, growth and collapse

(Chen et al., 2011)

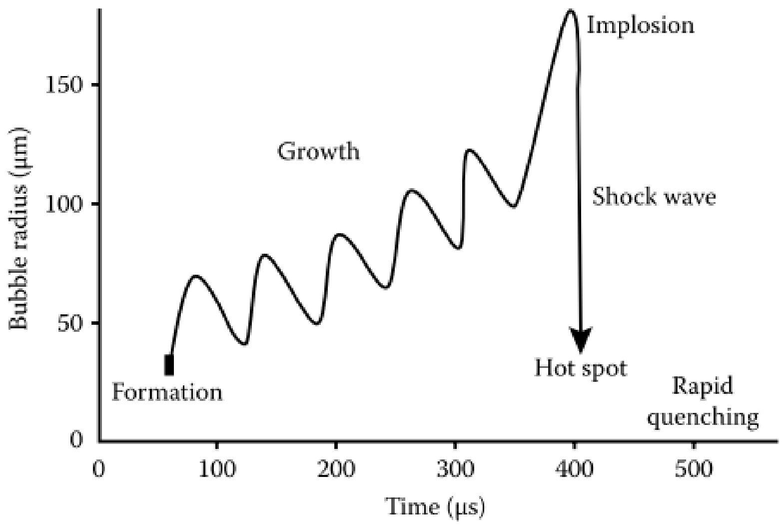



Figure 2-4:Graphical representation of bubble formation, growth, and implosion at 20 kHz ultra-sonic application in water

(Chen et al., 2011)

When the pressure is low, the bubble will grow, but it will shrink if the high pressure is applied. At that time, the volatile organic and dissolved gases enter the bubble. When the bubble shrinks, they will moderately escape. During expansion, the volatile organic and dissolved gases will be entered the bubble and escape during reduction. This is because of the effect of the bubble surface that contact. It is called rectified diffusion (Chowdhurry and Viraraghavan, 2009). If the bubble reached the smallest after the cycle, it explodes, and the water temperature rises. The amplitude increases if the intensity of the US increases.

### 2.8.2 Electrocoagulation (EC) Treatment

Electrocoagulation is a simple technique that uses the metal electrode and dips in polluted water or wastewater (Mollah *et al.*, 2004). Then, the suspension of the metal electrode goes into the wastewater because of the electricity from the power supply. With some suitable pH, ions from the metal electrode form coagulant and metal hydroxides (Chen, 2004). The particles will be stuck between each electrode like a magnet because of the charge and create a mass in the polluted water. Then, it will have the energy to destabilized and combined the suspended particles in command to precipitate or adsorb dissolved pollutants (Fajardo *et al.*, 2015). The illustration of molecules in the electrocoagulation process can be seen in Figures 2-4.

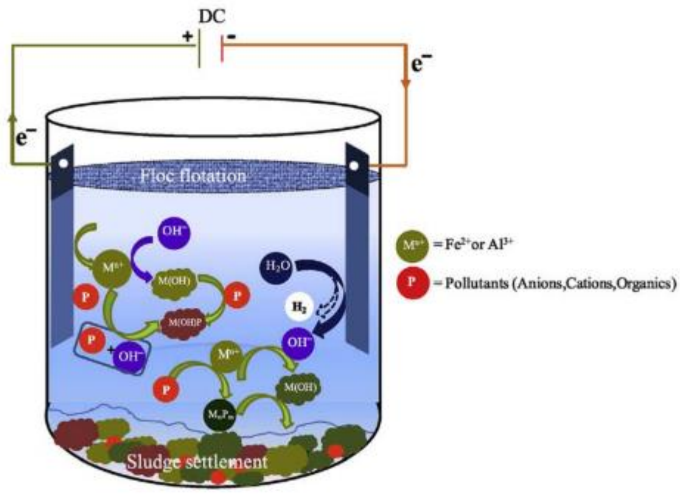



Figure 2-5:Schematic illustration of EC

(Ghernaout et al., 2019)

Uniting charge of neutralization and sweep flocculation can remove microorganisms by destabilizing the operation's trivial inactivation determinations (Ghernaout, 2012). There are three phases for the destabilization process to happen. Firstly, compression of the diffuse double film nearby the charged species upon contact of coagulant unconventional from anodic dissolution. Next, the charged neutralization through counter ion comprehended from the anode surface will be achieved because of the existent ionic species. Lastly, $O_2$ and $H_2$ will be produced respectively at anode and cathode. It will be helpful for contaminant removal (Ghernaout, Touahmia and Aichouni, 2019).

### 2.8.3 Sono-Electrocoagulation (US+EC) Treatment

When both techniques are combined, the mass transfer of pollutants rises across the electrode and decreases layer thickness diffusion (Ritesh and Srivastava, 2020). The wave from ultrasonic will compress and stretch the particle (Dizge *et al.*, 2018). When negative pressure high, the cavitation bubble formed and increased the distance between the liquid particle (Depeursinge *et al.*, 2010). The crash of these bubbles produces higher temperatures and pressure, which causes the particles inside to break down (Ritesh and Srivastava, 2020).

The rate of formation of responsive hydroxyl radical (OH) that react in bulk medium or gas phase surge because of the chemical effect of ultrasonic (Hjortsø, 2012). Moreover, some part of the US gets absorb by the liquid medium. The rate formation of (OH) radical becomes higher when the wave's frequency is high (Cornpton, Eklund and Marken, 2011). The effect of the combination between electrocoagulation and ultrasonic are: 1) the US obliterates the dense layer of consequence deposition on the electrode surface and 2) increase adsorption of pollutant by hydroxide formation (Ritesh and Srivastava, 2020). Figure 2-5 shows the sono-electrocoagulation degradation mechanism of refractory organic pollutants when the treatment begins.

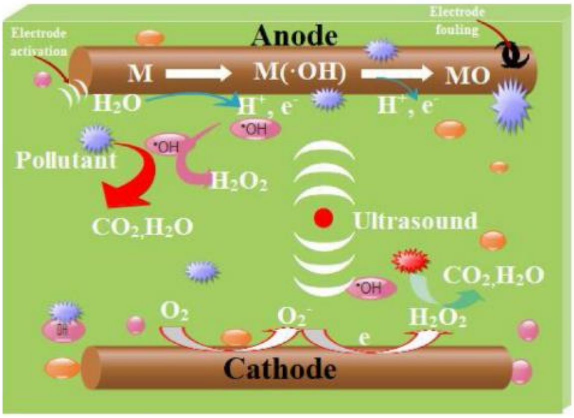



Figure 2-6:Sonoelectrocoagulation degradation mechanism of refractory organic pollutants

(Ritesh & Srivastava, 2020)

## 2.9 Factors Affecting Treatment

The results from the electrocoagulation, ultrasonic and sono-electrocoagulation used for sewage water treatment can vary depending on the influence of several factors. The factors that can affect the treatment are electrode distance, frequency, treatment time and voltage.

### 2.9.1 Electrode Distance

When the distance between electrodes increases, the amount of the metal receiving dissolved into soluble decreases (Attour et al., 2014). If the distance is decreased, the electric field with high possible gradient and little resistance to the motion of ions. As a result, the collision of the precipitate particle becomes faster, and the formation of aluminum hydroxide species also becomes faster (Hakizimana et al., 2016).

The previous study stated that the distance of 5.5cm is more effective than 7cm and 11cm (Valero et al., 2015). The result that was reported by Maleki et al. (2014) stated that electrode gap ensured positive direct effect and negative quadratic effect on retrieval effectiveness.

### 2.9.2 Frequency

At high frequency, the number of cavitation bubbles is increased (Al-Bsoul *et al.*, 2020). At low frequency, the reactions of hydroxyl radicals over more extended periods as a result of the photocatalyst surfaces' continuous cleaners' operation (Ola and Maroto-Valer, 2015). Because of the greater bubble circumference observed coupled with the pattern oscillations, a more energized crash of cavitation bubbles is estimated to happen at low frequency rather than high frequency (David, 2009).

### 2.9.3 Treatment Time

The demulsification efficiency of ultrasonic treatment increases rapidly and then stabilizes as treatment time increases, and at 10 min is found to be the optimal treatment time. After 10 minutes, the majority of the droplets had completely migrated and aggregated. Increasing the treatment duration does not improve demulsification efficiency because it inhibits the migration and aggregation of remaining stable tiny droplets in emulsions (Luo *et al.*, 2019). In addition, the concentration of metallic ions and their hydroxide flocs increases as treatment time increases (Chopra, 2014), leading to more significant pollutant coagulation and flocculation. As a result, pollutant removal effectiveness increases with retention time till it becomes constant (Khandegar, 2013).

### 2.9.4 Voltage

Voltages are the most important parameters that control the rate of pollutant removal rate by determining the rate of production of bubbles, bubble size, and floc formation, all of which can affect the efficiency of pollutant removal by the electrocoagulation process (Yusoff, 2018).

### 2.9.5 Temperature

In the electrocoagulation and sono-electrocoagulation process, the temperature is one of the parameters affecting the treatment. Therefore, in the temperature range of 288 K to 318 K, the effect of temperature on the removal efficiency of indium ions from an aqueous medium by the iron electrode was examined. After 50 minutes of electrolysis, the indium iron removal efficiency was determined to be 80.9%, 90.4%, 92.7%, and 94.1% at temperatures 288, 298, 308, and 318 K, respectively (Chou and Huang, 2009). This finding may be explained by higher temperatures resulting in more mobility and more frequent contacts of produced species, resulting in an increased reaction rate of metal hydroxides with pollution (El-Ashtoukhy, Amin and Abdelwahab, 2009).

### 2.9.6 Electrode Material

The electrode material has a considerable effect on electrical-based methods. The most typically employed metals are aluminum and iron (Llanos et al., 2004). In terms of harvesting efficiency, aluminum electrodes outperformed iron electrodes. The reduced efficiency of iron electrodes is most likely due to the decreased current efficiency produced by iron electrodes compared to aluminum electrodes (Canizares et al., 2006).

Furthermore, in comparison to aluminum hydroxides, iron hydroxides are ineffective coagulants.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This study is about the effect of treatment time, pH value and distance between electrodes for the combination of ultrasonic and electrocoagulation methods to treat sewage wastewater from the sewage pond at USM Engineering Campus. This chapter will discuss the methods, apparatus, materials used, and detailed experimental setup used throughout this study.

Plate 3-1 shows the pond's location in the USM, while Plate 3-2 shows the point of view of the sewage pond.

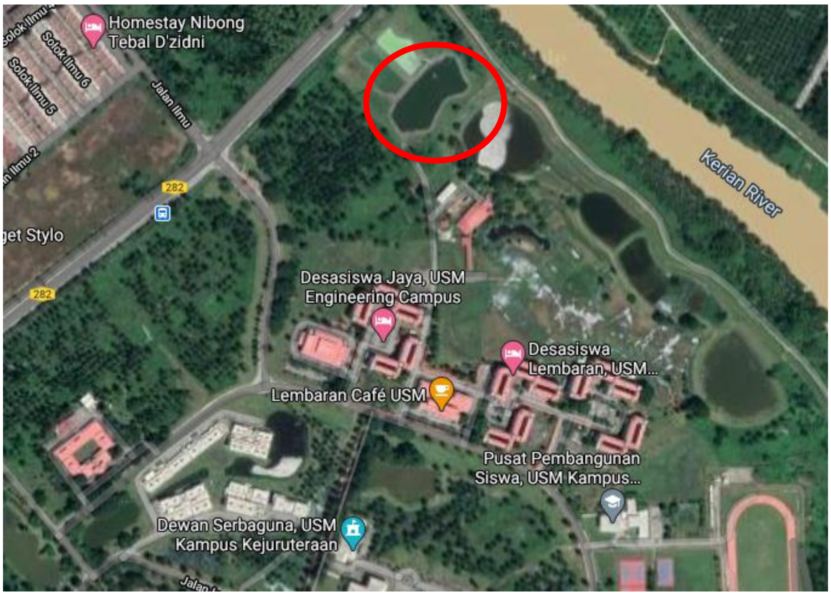



Plate 3-1:The pond’s location in USM Engineering Campus