Water Treatment Technology (Laboratory)

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Abstract:
This book presents the hands-on activities on experimental works related to water treatment process of a drinkable pilot plant that can be performed by students from Bachelor of Civil Engineering Technology (Environment), UTHM. Each chapter present different experimental works that is conducted in sequence (for chapter one until six) as in real water treatment plant using a drinkable pilot plant. First chapter is on coagulation and flocculation process. Followed by second chapter which is sedimentation process. The third chapter is about sand and carbon filtration process while the fourth chapter is on chlorination and fluoridation process. In chapter five is about ultrafiltration membrane and ultraviolet sterilization process. After the treatment processes, chapter six present on slurry dewatering process. Chapter seven is about reverse osmosis process which is conducted using an RO unit for the experiment of membrane resistance and salt rejection.

Keywords : Activated carbon, Disinfection, Lamella settler, Slurry dewatering & UV sterilization

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(LABORATORY)

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2023

Published 2023

ISBN: 978-629-7566-70-2
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Published & Printing by:
Penerbit UTHM
Universiti Tun Hussein Onn Malaysia
86400 Parit Raja,
Batu Pahat, Johor
Tel: 07-453 8698/8529
Fax: 07-453 6145

Website: http://penerbit.uthm.edu.my
E-mail: pemasaran.uthm@gmail.com
http://e-bookstore.uthm.edu.my

Penerbit UTHM is a member of
Majlis Penerbitan Ilmiah Malaysia
(MAPIM)

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

ISBN 978-629-7566-70-2

CONTENT

Let’s Start!

https://me-qr.com/fIEoUgjm

PREFACE

Water treatment technology laboratory book presents the hands-on activities that can be performed by students from Bachelor of Civil Engineering Technology (Environment), UTHM which relates to fundamentals of water treatment process. This book is a student's guideline for performing experimental works on the water treatment process of a drinkable pilot plant and RO unit. In Chapter 1 coagulation and flocculation process, students learn about the process of coagulation and flocculation that destabilize particle charge in water allowing particle collision and growth into bigger particle size known as 'floc'. Next, in Chapter 2 sedimentation process is the subsequent process that allow for particles suspension in water to settle out of the suspension under the effect of gravity. In Chapter 3, sand and carbon filtration process using sand media and carbon filter to remove remaining of suspended solids and contaminants. In Chapter 4 chlorination and fluoridation process is to reduce the pathogens in water to an acceptable level using chlorine and the addition of fluoride into the water to prevent tooth decay. In Chapter 5 ultrafiltration membrane and ultraviolet sterilization is the removal of particulates and macromolecules using ultrafiltration membrane while the ultraviolet sterilization process effectively disinfects pathogens from the water using ultraviolet light. Chapter 6 is the slurry dewatering process that remove liquids from a sludge slurry using filter press for its effective disposal. Finally, Chapter 7 is a reverse osmosis process that removes salts, microorganisms, and many high molecular weight organics from water by using pressure to force water molecules through a semipermeable membrane. Please visit the following YouTube channel by scanning the QR code for more explanation regarding the procedure for the water treatment technology laboratory experiment.

CHAPTER 1

COAGULATION AND FLOCCULATION PROCESS

1.1 Introduction

Coagulation is a process for the removal of raw water organic and solids contents in suspended or colloidal form. Colloidal particles including humic and tannic acid carry a cloud of charges, which prevent each other from getting nearer. Colloids are presented by particles over a size range of 1nm to 0.1 nm. These particles do not settle out on standing and cannot be removed by conventional physical treatment processes. Colloidal species encountered in raw water and wastewater include clay, silica, iron and other heavy metals, color, and organic solids such as the debris of dead organisms. Colloids may also be produced in precipitation processes such as lime softening. Oil in wastewater is frequently colloidal. Among the wide variety of colloidal materials in water, there is a broad distribution of particle sizes. Colloids always require coagulation to achieve an effective size and settling rate; but even larger particles, which are not truly colloidal and would settle if given enough time; may require coagulation to form larger, faster settling floc. When insufficient settling time is available in a treatment plant to remove suspended solids, coagulation and flocculation may cause them to grow in size and settle rapidly enough to overcome the physical limitation of the plant design.

Since most colloids in raw water and industrial wastes process are a negative charge, the zeta potential is lowered, and coagulation is induced by the addition of high-valence cation. Optimum coagulation will occur when zeta potential is zero. However, when a coagulant is added at a pH between 8 to 9, the excess positive charges of Al^{3+}, Fe^{3+} and Ca^{2+} destabilize the negatively charged cloud, hence reducing its effective radius until the clouds collapse an d the colloids agglomerate. The vigorous stirring serves to homogenize the coagulant and provide energy for the colloids to collide with each other more frequently and with greater ease.

CHAPTER 2

SEDIMENTATION PROCESS

2.1 Introduction

Sedimentation also known as settling is defined as the removal of solid particles from a suspension by settling under gravity as shown in Figure 2.1. In a similar term, Clarification usually refers specifically to the function of a sedimentation tank in removing suspended matter from the water to give a clarified effluent. In a broader sense, clarification could include flotation and filtration.

A settler is a primary treatment technology designed to remove suspended solids by sedimentation. The low flow velocity in a settler allows settleable particles to sink to the bottom, while constituents lighter than water float to the surface. Settlers can achieve a significant initial reduction in suspended solids and organic material after chemical coagulation/precipitation is added. It also ensures that these constituents do not impair subsequent treatment processes. Generally, settlers may take a variety of forms, sometimes fulfilling additional functions. They can be independent tanks or integrated into combined treatment units.

Thickening in sedimentation tanks is the process whereby the settled impurities are concentrated and compacted on the floor of the tank and in the sludge-collecting hoppers. Concentrated impurities withdrawn from the bottom of sedimentation tanks are called sludge, while material that floats to the top of the tank is called scum.

CHAPTER 3

SAND AND CARBON FILTRATION PROCESS

3.1 Introduction

Generally, there are two types of water filters: (a) Sand (mechanical) filter which filters depending on particle size. (b) Adsorptive or reactive filter which contains a medium that absorbs and reacts with a water contaminant. Sand filter offers an efficient means of removing suspended particulate matter. This is achieved by loading larger media granules of lower density at the top of the bed, with at least one layer of smaller media granules of higher density below it as shown in Figure 3.1. The layers of media are selected for their particular size, specific gravity and ability to trap particles of specific size ranges. As water flows through the bed, it encounters layers of media with decreasing porosity, so successively smaller particles are trapped in each layer, providing true depth filtration.

The effectiveness of media filtration is dependent on achieving low water velocities through the media bed. At a higher velocity, the shear force of the water flow against the suspended particles will tend to reduce the effectiveness of media filtration. It will also result in high-pressure drops. The media will tend to trap particles in the top few inches of media. As the holes between the media granules plug, the pressure drops across the media and foulants will increase. The pressure drop will dictate when to backwash the filter.

Smaller granules of a given media density will be lifted higher in the filter vessel during backwash than will larger granules of that same media density. After the backwashing, the media will settle back down, with the larger granules settling first. Since it is desirable to keep the larger granules at the top of the filter media, different media densities must be used in a multimedia filter.

Anthracite, which is processed from hard coal, serves this purpose because of its lower density than sand, and larger granule size. In this manner, it will lift higher than sand during backwashing and will settle on the top of the media bed. Anthracite has irregular

CHAPTER 4

CHLORINATION AND FLUORIDATION PROCESS

4.1 Introduction

Chlorination is the process of adding chlorine to drinking water to disinfect it and kill germs (Figure 4.1). Different processes can be used to achieve safe levels of chlorine in drinking water. Chlorine is available as compressed elemental gas, sodium hypochlorite solution (NaOCl) or solid calcium hypochlorite ($Ca(OCl)_2$). While the chemicals could be harmful in high doses, when they are added to water, they all mix in and spread out, resulting in low levels that kill germs but are still safe to drink.

Chlorine kills pathogens such as bacteria and viruses by breaking the chemical bonds in their molecules. Disinfectants that are used for this purpose consist of chlorine compounds which can exchange atoms with other compounds, such as enzymes in bacteria and other cells. When enzymes come in contact with chlorine, one or more of the hydrogen atoms in the molecule are replaced by chlorine. This causes the entire molecule to change shape or fall apart. When enzymes do not function properly, a cell or bacterium will die.

Pre-chlorination is when chlorine is applied to the water almost immediately after it enters the treatment facility. In the pre-chlorination step, the chlorine is usually added directly to the raw water or added to the flash mixer. Chlorine is added to raw water to eliminate algae and other forms of aquatic life from the water, so they won't cause problems in the later stages of water treatment. Pre-chlorination in the flash mixer is found to remove tastes and odours, and control biological growth throughout the water treatment system, thus preventing growth in the sedimentation tanks and the filtration media. The addition of chlorine will also oxidize any iron, manganese and/or hydrogen sulphide that is present so that they too can be removed in the sedimentation and filtration steps.

CHAPTER 5

ULTRAFILTRATION MEMBRANE AND ULTRAVIOLET STERILIZATION PROCESS

5.1 Introduction

Ultrafiltration (UF) is a type of membrane filtration method. It is a filtration process which utilizes trans-membrane pressure differential to separate particles according to molecular weights. By using hollow fibers UF membrane as filtration media, raw water particles which are smaller than the "pore" of the UF membrane will permeate through and be collected as permeate; whilst, particles which are larger than the UF membrane pore size will be separated as concentrate under certain pressure applied (Figure 5.1).

UF membrane is an asymmetric semi-permeable membrane made of high molecular material by special technology. Its' hollow fiber tube cover densely by micro-pores which allow the solution to flow in or out of the membrane under the influence of pressure. UF membrane pore size ranges from 0.1 to 0.005 μm or molecular weight (200,000 to 10,000 Daltons) for different applications. Generally, it is used to remove high molecular-weight substances, colloidal materials, bacteria, organic and inorganic polymeric molecules.

CHAPTER 6

SLURRY DEWATERING PROCESS

6.1 Introduction

In water treatment process, dewatering is the part of the process whereby sludges are reduced in volume and converted from a liquid to a solid product. Biosolid dewatering typically occurs when transportation and storage costs for large volumes can be reduced or when the material is destined for a landfill. The biosolids dewatering process not only affects the volume but also the nutrient and odour levels of the material.

Filter press as shown in Figure 6.1 is an equipment that is used to filtrate suspension under pressure to separate the liquid and the solid phases. The sludge results from the dewatering process, while the filtrate is the liquid which is extracted from the sludge. Filter presses comprise a set of chamber plates covered by filter cloth and a hydraulic cylinder between a stationary frame and a mobile supporting beam.

The plates determine a watertight volume in which is pumped the pressurized sludge. A hydraulic unit allows the water tightness between the plates at the surface of the joints. Utilizing a cylinder, the hydraulic unit keeps the balance between the plates squeezing and the filling pressure induced by the feeding pump throughout the filtration process. Under this pressure, the liquids pass through the filter cloth that holds the solid particles.

The filtrates are drained out either by taps set on each plate or by launders at the end of the filter. The feeding pump must regulate its flow rate according to the pressure increase produced by the formation of sludges in the chambers. At the end of the plate compressing process, the sludges formed between the filter clothes are discharged by the backward movement of the supporting beam and the successive separation of the plates.

CHAPTER 7

REVERSE OSMOSIS PROCESS

7.1 Introduction

Osmosis is the natural movement of solvent from an area of low solute concentration, through a membrane, to an area of high solute concentration if no external pressure is applied. When two solutions with different concentrations of a solute are mixed, the total amount of solutes in the two solutions will be equally distributed in the total amount of solvent from the two solutions. This is achieved by diffusion, in which solutes will move from areas of higher concentration to areas of lower concentrations until the concentration in all the different areas of the resulting mixture is the same, a state called equilibrium.

Instead of mixing the two solutions, they can be put in two compartments where they are separated from each other by a semipermeable membrane. The semipermeable membrane does not allow the solutes to move from one compartment to the other but allows the solvent to move. Since equilibrium cannot be achieved by the movement of solutes from the compartment with high solute concentration to the one with low solute concentration, it is instead, achieved by the movement of the solvent from areas of low solute concentration to areas of high solute concentration. When the solvent moves away from low-concentration areas, it causes these areas to become more concentrated. On the other side, when the solvent moves into areas of high concentration, solute concentration will decrease. This process is termed osmosis. The tendency for the solvent to flow through the membrane can be expressed as "osmotic pressure", since it is analogous to flow caused by a pressure differential.

In reverse osmosis (RO), in a similar setup as that in osmosis, pressure is applied to the compartment with high concentration. In this case, there are two forces to consider influencing the movement of water: the pressure caused by the difference in solute concentration between the two compartments (the osmotic pressure) and the externally applied pressure. In the same way as in conventional osmosis, the solute cannot move from areas of high pressure to areas of low pressure because the membrane is not

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ISBN 978-629-7566-70-2

02900

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