DETERMINATION OF Na LIGNOSULFONATE EFFICIENCY AND PERFORMACE AS A NATURAL COAGULANT IN TEXTILE WASTEWATER TREATMENT

2024
Master Thesis
ENVIRONMENTAL ENGINEERING

Atheer Ali Awwad ALHAMDAN

Thesis Advisor
Prof. Dr. Sakine UGURLU KARAAĞAÇ

DETERMINATION OF Na LIGNOSULFONATE EFFICIENCY AND PERFORMACE AS A NATURAL COAGULANT IN TEXTILE WASTEWATER TREATMENT

Atheer Ali Awwad ALHAMDAN

Thesis Advisor
Prof. Dr. Sakine UGURLU KARAAĞAÇ

T.C.
Karabuk University
Institute of Graduate Programs
Department of Environmental Engineering
Prepared as
Master Thesis

KARABUK
June 2024

I certify that, in my opinion, the thesis submitted by Atheer Ali Awwad ALHAMDAN titled "DETERMINTION OF Na LIGNOSULFONATE EFFICIENCY AND PERFORMACE AS A NATURAL COAGULANT IN TEXTILE WASTEWATER TREATMENT" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Prof. Dr. Sakine UGURLU KARAAĞAÇ ....
Thesis Advisor, Department of Environmental Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Environmental Engineering as a Master of Science thesis. 07/06/ 2024.

Examining Committee Members (Institutions) Signature

Başkan : Prof.Dr. Ertuğrul ERDOĞMUŞ (BARU) ....

Üye : Prof. Dr. Sakine UGURLU KARAAĞAÇ (KBU) ....

Üye : Assoc. Prof. Dr. Rahman ÇALHAN (KBU) ....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Assoc. Prof. Dr. Zeynep ÖZCAN ....
Director of the Institute of Graduate Programs

“I hereby declare that this thesis is the result of my own work and all information included has been obtained and expounded in accordance with the academic rules and ethical policy specified by the institute. Besides, I declare that all the statements, results, materials, not original to this thesis have been cited and referenced literally. Without being bound by a particular time, I accept all moral and legal consequences of any detection contrary to the aforementioned statement.”

Atheer Ali Awwad ALHAMDAN

ABSTRACT

Master Thesis

DETERMINATION OF Na LIGNOSULFONATE EFFICIENCY AND PERFORMACE AS A NATURAL COAGULANT IN TEXTILE WASTEWATER TREATMENT

Atheer Ali Awwad ALHAMDAN

Karabük University
Institute of Graduate Programs
Department of Environmental Engineering

Thesis Advisor:
Prof. Dr. Sakine UGURLU KARAAĞAÇ
June 2024, 94 pages

Industrial enterprises produce wastewater that contains large amounts of pollutants, and this wastewater must be treated before it is released into the environment. The aim of this study is to remove pollution parameters such as chemical oxygen demand (COD), total suspended solids (TSS), color and ammonium nitrogen (NH3-N) and heavy metals from textile wastewater by using sodium lignosulfonate (SLS), which is an environmentally friendly and cost-effective substance, and to increase the removal efficiency. In this study, the optimum dose of SLS that provides the most relief by using different doses was determined. Using this optimum dose, trials were carried out at room temperature (25°C) under different pH (3,5,7,9,11) conditions, and the optimum pH that provides the most removal was determined. Similarly, by keeping the optimum dose constant, trials were carried out at different speeds and at different durations, and the optimum number of cycles and duration that provides the most removal was determined. Maximum removal from textile wastewater was achieved at a dose of 0.0625 g/L sodium lignosulfanate, at a pH of 7 and at a rotational speed of 200 rpm for 15 minutes, followed by 90 rpm for 30 minutes and at optimal concentration (0.0625 mg/L). The optimum dose removal efficiency of heavy metals is aluminum (Al) 93%, copper (Cu) 68%, zinc (Zn) 60.5%, (iron Fe) 85.9% and other pollutants boron (B) 96.6%, sodium (Na) 87.6%, phosphorus (P) 90.6%. In addition, the removal efficiency of other contaminants such as COD, TSS, color, and NH3-N was 91.5%, 94.3%, 91.8%, and 95.6%, respectively. SLS has proven to be a viable option for textile wastewater treatment due to its flocculation and dispersion capabilities. Sodium lignosulfonate is an important renewable natural resource that is expected to provide significant environmental, economic, and social benefits.

Key Word : Coagulation and Flocculation, Sodium Lignosulfonate, Industrial Wastewater, Pollutants Removal, Textile Wastewater, Natural Coagulants.

Science Code : 90319

ÖZET

Yüksek Lisan Tezi

TEKSTİL ATIK SU ARITMASINDA DOĞAL BİR Pıhtılaştırıcı Olarak Na LİGNOSÜLFONAT VERİMLİLİĞİNİN VE PERFORMANSININ BELİRLENMESİ

Atheer Ali Awwad ALHAMDAN

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Çevre Mühendisliği Anabilim Dalı

Tez Danışmanı:
Prof. Dr. Sakine UGURLU KARAAĞAÇ
Haziran 2024, 94 sayfa

Endüstriyel işletmeler, büyük miktarlarda kirletici içeren atık su üretir ve bu atıksuların çevreye salınmadan önce arıtılması gerekir. Bu çalışmanın amacı, çevresel açıdan dost ve uygun maliyetli bir madde olan sodyum lignosülfonat (SLS) kullanılarak tekstil atık sularında bulunan kirlilik parametrelerinden kimyasal oksijen ihtiyacı (KOİ), toplam askıda katı madde (TAKM), renk ve amonyum azotu (NH3-N)'nun ve ağır metallerin uzaklaştırılması ve giderim verimliliğinin arttırılmasıdır. Çalışmada SLS'nin farklı dozları kullanarak en fazla giderim sağlayan optimum doz belirlenmiştir. Bu optimum doz kullanılarak farklı pH (3,5,7,9,11) koşullarında oda sıcaklığında (25°C) denemeler yürütülmüş en fazla giderim sağlayan ve optimum pH belirlenmiştir. Benzer şekilde optimum doz sabit tutularak farklı devirlerde ve farklı sürelerde denemeler yapılarak en fazla giderimi sağlayan optimum devir sayısı ve süre belirlenmiştir. Tekstil atık suyundan en fazla giderim 0,0625 g /L sodyum lignosulfanat dozunda, 7 pH'da ve 15 dakika boyunca 200 rpm'lik bir dönüş hızında, ardından 30 dakika boyunca 90 rpm'de ve optimal konsantrasyonda (0.0625 mg / L) elde edilmiştir. Ağır metallerin optimum dozda giderim etkinliği alüminyum (Al) %93, bor (B) %96,6, sodyum (Na) %87,6, bakır (Cu) %68, çinko (Zn) %60,5, (demir Fe) %85,9 ve fosfor (P) %90,6'dır. Ek olarak, KOİ, AKM, renk ve NH3-N gibi diğer kirleticilerin giderim etkinliği sırasıyla %91,5, %94,3, %91,8 ve %95,6 idi. SLS'nin, flokülasyon ve dispersiyon yetenekleri nedeniyle tekstil atık su arıtımı için uygun bir seçenek olduğu kanıtlanmıştır. Sodyum lignosülfonat, çevresel, ekonomik ve sosyal açıdan önemli faydalar sağlaması beklenen önemli bir yenilenebilir doğal kaynaktır.

Anahtar Sözcükler : Koagülasyon ve Flokülasyon, Sodyum Lignosülfonat, Endüstriyel Atıksu, Kirleticilerin Giderilmesi, Tekstil Atıksuları, Doğal Pıhtılaştırıcılar.

Bilim Kodu : 90319

ACKNOWLEDGMENT

I thank God very much for His success and help completing my master’s thesis.
I wish to extend sincere thanks to Karabuk University Turkey, Scientific Research Projects Coordination Unit through its KBÜBAP-23-YL-063 funding.

I also extend my deepest thanks and gratitude to Prof. Dr. Sakine UGURLU KARAAĞAÇ, who kindly accepted the supervision of my master's thesis and generously shared his precious time and extensive knowledge. His guidance and advice have been invaluable, providing a beacon of light for all my research work. I ask God Almighty to reward him abundantly.

I must also thank to Assist. Prof. Mohammed Shadi Abu Jazzar, for his unwavering support and guidance throughout my research, despite the challenges in his beloved Gaza. He has my sincere gratitude, and may God reward him on our behalf. I am also very grateful to all the members of the honorable committee for accepting the discussion of my master's thesis.

To my dear mother, brothers, and sisters—your support has been invaluable to me. You have all my love and gratitude, and no matter how much I thank you, I can never fully express what you deserve.

CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

SYMBOLS AND ABBREVIATIONS

SYMBOLS

Pb : Lead
Ni : Nickel
Hg : Mercury
Cd : Cadmium
Cr. : Chromium
NH3–N :Ammonia-nitrogen

ABBREVIATIONS

WHO	World Health Organization
BOD	Biochemical oxygen demand
COD	Oxygen concentration
AL	Alkaline lignin
SLS	Sodium lignosulfonate
TSS	Total suspended solids
FTIR	Fourier transform infrared spectroscopy
SEM	Scanning electron microscopy
TDS	Total dissolved solids
POPs	Organic pollutants
SS	Suspended solids
DS	Dissolved solids
AD	Alzheimer’s disease
FI	Flocculation Index
IFA	Initial floc Aggregation
PI	Isoelectric points
UF	Ultrafiltration
NF	Nanofiltration
RO	Reverse osmosis
VOCs	Volatile organic compounds
BAFs	Biological Aerated Filters
P&P	Pulp and paper
IR	Infrared

CHAPTER 1

INTRODUCTION

Water is essential for life on Earth [1]. Water is an essential natural resource on which all social, economic and ecological activities depend [2] and the most important element of the hydrological cycle [3]. The availability of fresh water significantly influences the global economy. An adequate water supply is vital for agriculture, human consumption, industry, and recreation. Ironically, natural or man-made pollution can deprive us of this valuable resource, leading to a much more challenging world[1]. Even though the majority of the Earth's surface is covered by water, water use has always been limited in availability, quality, and quantity [2]. Approximately 70% of the Earth's surface is covered by water, but only 3% of it is fresh water. UNICEF and WHO report that over 1.1 billion people lack access to clean, fresh water, and around 2.6 billion people worldwide do not have adequate sanitation[1,4–6]. The World Health Organization (WHO) considers water “a key tool for improving health community”, because the availability of water prevents many diseases and greatly improves hygiene [5].

The increasing discharge of wastewater due to population growth has led to environmental degradation and threats to human health [2]. The need for clean water has spurred new research on water and wastewater [7]. To date, wastewater treatment remains a serious problem globally, despite many technological advances and breakthroughs [8]. Wastewater is any water whose quality and visual value have been altered by human intervention [2]. Sewage, or wastewater, comes from human and domestic wastewater, industrial waste, animal waste, rainwater, and groundwater intrusion. Types of wastewater include urban wastewater, industrial wastewater, mixed industrial and domestic wastewater, and agricultural wastewater [1,9]. Among the different sources of environmental pollution, industrial wastewater from various industries is regarded as the primary contributor to both land and water pollution.

Industrial wastewater contains numerous inorganic pollutants that can lead to environmental pollution and pose serious health risks[10]. Industrial development brings comfort to people, but it also destroys the environment. Among them, water pollution is the most serious [11]. Rapid industrial development and population growth have exacerbated the problem of water scarcity as the demand for clean water and sanitation has increased worldwide [3,4,7,12]. The The textile industry is one of the biggest consumers of chemicals and significantly pollutes drinking water[13–15]. As the demand for textile increases, the amount of industrial and textile wastewater also increases. Clothing has grown at the same speed, making It is one of the largest industries globally that cause major environmental pollution problems [15]. According to a 2003 UN report (UN WWAP 2003), two million tons of agricultural and industrial water and tons of wastewater enter the world's water resources every day [1]. The textile industry holds significant sway over the market. The textile industry consumes 800-1000 cubic meters of water per ton per day. It is estimated that producing one kilogram of clothes requires approximately 200 liters of water. Consequently, the textile industry generates substantial amounts of wastewater[16]. Treating industrial wastewater is challenging due to its elevated levels of color, biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, temperature, solids, and toxic chemicals. This kind of waste is discharged directly into water bodies like lakes and rivers. without proper prevention or treatment, causing water pollution that affects water directly and clearly [15]. As the preservation of the environment becomes a worldwide priority, the industry is looking for new solutions to develop technologies to reduce environmental damage [13]. Improper treatment of industrial waste water causes environmental pollution and affects the health of animals and plants.

It is necessary to develop an effective and environmentally friendly adsorbent to solve these problems [17]. Common methods for heavy metal pollution treatment include chemical precipitation, chemical oxidation, ion exchange, membrane separation, reverse osmosis, electrolysis, etc. These methods are costly, require substantial energy, and frequently result in the production of toxic by-products[18].

In this context, water treatment includes the elimination of suspended and colloidal particles, organic matter, microorganisms, and other substances detrimental to health, considering the costs of implementation and operation. and maintenance as well as reduce the environmental impact of the surrounding area [18–20]. Wastewater treatment using natural coagulants is extensively researched and documented in the literature, but ongoing research in this field remains of continual interest [21].

The science on sodium is old, but the topic continues to attract growing interest amid better exploitation of renewable natural resources, such as wood and its components. It, a field of research commonly referred to as "biorefinery". [22]. In the papermaking industry, lignin is extracted from cellulose fibers and transformed into water-soluble Neil through the sulfate process[23–25]. Alkaline lignin (AL) and sodium lignosulfonate (SLS) are by-products produced During the pulping process, lignin undergoes depolymerization into low molecular weight, water-soluble forms due to high temperature and various chemicals, resulting in the formation of AL and SLS [26].

Due to the global paper industry generating 50 million tons of Neil waste annually, the price of Neil is relatively low, approximately 400 USD per ton[23,24,26,27]. It includes both hydrophilic groups (such as sulfonic, hydroxyl, and phenyl groups) and hydrophobic groups (like carbon chains). It is an anionic surfactant, has a certain degree of surface activity, can promote surface adsorption and subsequent dispersion of particles, forming a thin film on the metal and thus has potential applications in corrosion and deposit inhibition. It is predicted that SLS can be used as a multifunctional water treatment agent through chemical modifications based on its structural analysis [26,28]. The hydrophilic property makes have obvious surface activity and physicochemical properties such as testability, adsorption and dispersion ability, so it can be used as an additive. Effective surface treatment in many industrial fields [23,25].

Considering the excellent flocculation and dispersion performance, should be applied in the fields of microsphere preparation and heavy metal wastewater treatment, etc.

Reusing as an important renewable natural resource will certainly bring enormous environmental, economic and social benefits [29].

The primary goal of the research was to assess the efficiency of sodium lignosulfonate (SLS) powder as a natural coagulant in the process of textile industrial wastewater, with particular emphasis on parameters like chemical oxygen demand (COD) and total suspended solids (TSS), color, ammonia, nitrogen, NH3–N and heavy metals. The study examined the influence of different coagulant doses and rotation speeds to understand how pH influences removal efficiency. Furthermore, the sodium The powder was analyzed using Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) to understand its chemical structure, thermal stability, and morphology, respectively.

CHAPTER 2

INDUSTRIAL WASTEWATER

Industrial waste can be categorized into two types: solid and liquid it is usually Generated as a result of industrial activities, including anything that is not useful during industrial production. Effluent (i.e. wastewater from various industries) is considered very dangerous to living organisms and the environment by transporting various toxic pollutants. However, the composition and characteristics of industrial wastewater vary depending on the industry type, production methods, and product quality. Industries frequently produce solid wastewater with high biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and total suspended solids (TSS), as well as many other organic and inorganic substances [10].

Wastewater from various Industries are regarded as sources of environmental pollution that affect both ecosystems and human life, various toxic substances and pollutants with the industrial wastewater enter the environment. There are two types of environmental pollution: organic and inorganic. Organic pollutants encompass phenols, nonylphenols, chlorinated phenols, azo dyes, phthalic acid esters, petroleum hydrocarbons, pesticides, and persistent organic pollutants. On the other hand, inorganic pollution consists of many types of harmful inorganic Heavy metals like nickel (Ni), lead (Pb), mercury (Hg), cadmium (Cd), mercury (Hg) and chromium (Cr). It is said that various organic and inorganic substances pollute the soil and water, causing significant effects on living organisms [30–35]. Therefore, because of their highly toxic nature, many of these substances have been classified as priority pollutants by environmental agencies like USEPA, the Agency for Toxic Substances and Disease Registry (ATSDR), and the World Health Organization (WHO) [10].

Many industries around the world cause water scarcity, s such as wastewater from pulp and paper, oil, textile and leather industries, which poses a growing risk of polluting water bodies and misusing water resources Figure 2.1. The wastewater discharged from such factories discharging into the water without adequate treatment, resulting in sources of genotoxic water pollution, including many types of natural encompassing numerous compounds [4].

2.1. OIL REFINERY WASTEWATER

Non-biodegradable organic substances include oils, various aromatic hydrocarbons such as BTEX (highly toxic to the environment), organic pollutants (POPs) like dioxins (extremely toxic), metals/metalloids, phenols, salts, and surfactants [10].

2.2. PULP AND PAPER WASTEWATER

It has a strong brown color and contains BOD, suspended solids (SS), dangerous dioxins, furans, lignin, AOX, phenolic and chlorophenol chemicals, particularly pentachlorophenol (which is toxic and harmful to the environment) [4].

Figure 2. 1. Industrial Wastewater.

2.3. TANNERY WASTEWATER

It includes various organic loads (BOD, COD, and TSS), salts (sodium, chloride, and sulfide), phenolic compounds, endocrine-disrupting chemicals like nonylphenols and phthalates, and other toxic metals, notably chromium (known to be toxic and carcinogenic) [4].

2.4. DISTILLERY WASTEWATER

High levels of organic load (BOD, COD, and TDS) with Phenolics and melanoidins contribute to a dark color (prevents sunlight from entering the body and thus reduces photosynthesis) [4].

2.5. PHARMACEUTICAL WASTEWATER

It is a natural acid with high COD and TDS values, and is used in numerous organic solvents, processing, antibiotics, and numerous commonly used medications such as antibiotics, pain relievers, etc. have [10].

2.6. TEXTILE WASTEWATER

The world's manufacturing The industry is among the most ancient, most using technology advanced, and the most important contributor to the economy [4]. Approximately 30-50 liters of water are required to produce printed clothing. The textile industry utilizes over 8,000 chemicals for various dyeing and printing processes. According to the World Bank estimates, Textile production and processing account for 17-20% of industrial water pollution. A variety of Toxic and harmful chemicals have been found in water contaminated by textile production. dyes alone, many some of which are challenging or impossible to eliminate or reduce [36]. This is a major environmental challenge for clothing and textile manufacturers. The content of industrial wastewater is of significant concern due to its high toxicity and reactivity with various antibiotics. About 40 percent of the dyes used in the world contain chlorine, a substance recognized as a carcinoge. Toxic chemicals mix with the air and cause allergic reactions that are harmful to babies if inhaled or inhaled before birth [4,37].

The textile industry is among the industries that contribute most effectively to Heavy metal contamination in natural water bodies waters. The textile sector uses a variety of chemicals such as bleach, acids, alkalis, salts, dispersants, bleaches, and occasionally heavy metals [16,38]. The amount of water used in companies varies depending on the type of company's operating system, equipment used, and water use philosophy. Wastewater often contains a complex chemical mixture. In addition, several hazards have been reported from chemicals used at different phases of textile processing [13,39–42].

The internal bed wastewater contains BOD, COD, color, dissolved solids (DS), SS (suspended solids), and heavy metals, among others. Wastewater from the textile industry is generally characterized by high pH, COD, dissolved solids, and color, which can be similar to neutral municipal wastewater [13,43–47]. Most textile wastes contain heavy metals mixed with azo compounds, which have increased significantly in recent years due to their demand in textile and other industrial industries [16,48].

Over 70% of industrial waste in developing nations ends up in untreated water, and 90% of sewage in these nations is discharged into rivers, lakes, and streams. This situation threatens access to clean drinking water, bathing, and food security [49]. Therefore, inappropriate treatment of textile industrial wastewater threatens aquatic life, receiving water bodies, human beings, and ecological stability [50,51]. Strict emission limits have been imposed on the textile industry to reduce the negative impact [52]. This need highlights the importance of developing effective technologies that can extract heavy metals from soil and wastewater [16,53,54].

Colorants (dyes and pigments) are crucial industrial chemicals. Pigments are colors that do not dissolve in water and do not interact with substrate, while dyes are used to make water dissolve and spread on the material and combine with the color of the material [55,56]. Fiber (substrate). Although "texture" in chemistry refers only to aromatic substances that can dye textiles, the word "texture" can be referred to anything that provide color, such as dyes and paints [15,57,58].

Many chemicals like alkalis, enzymes, acids, bleaching agents, starches, paints, waxes, resins, oils, and solvents are utilized flour goes through several processing steps before it becomes contaminated after consumption. Various methods of textile processing are used, which are removed from the water after use. Cleaning, or the process of extracting chemicals from textiles, is one of the most significant industrial origin of wastewater pollution [13,59,60]. The Dyeing operation produces the majority of industrial wastewater. During the painting process, the source of wastewater is used for paint washing and water washing. Wastewater often contains secondary products, dye residues and additional chemicals. Other contaminants involve cleaning agents like oxalic acid [61]. Out of the 700,000 tons of paint manufactured globally each year [39,62,63], approximately 10-15 percent of the paint is wasted as effluent waste from the dyeing process [13,64–66].

Heavy metals are often are discharged into the wastewater of various industries. Electrical and surface treatment results in the generation of waste water containing heavy metals [18]. In addition to these wastewaters from the leather, leather, textile, cloth and clothing, In industries like paint, wood processing, oil refining, and photo film production, wastewater often contains significant amounts of metals. These ions of heavy metals are kills both humans and animals. Toxic metals can lead to discomfort, life-threatening diseases, and irreversible damage to essential body systems [67]. Metals accumulate in the aquatic environment and appear to accumulate in the food chain [18]. Therefore, organisms at higher trophic levels are more sensitive to their toxins [8].

CHAPTER 3

DEFINITION AND HISTORY OF COAGULATION

Many Treatment processes, whether for water or wastewater, are closely tied to coagulation and flow rate, which is an integral part of the treatment process. The scrubbing process is a common process in water and wastewater treatment because it effectively removes suspended solids, organic matter, color and turbidity [6].

Coagulation can be defined as a process where transforms a stable, unstable, or small substance that slowly settles in a large size, by the addition a coagulation, which -make the size effective (flakes) in the sedimentation rate, or the stability process. [6,68]. On the other hand, coagulation is the most commonly used chemical pretreatment method for water and industrial waste due to its economic value and efficiency compared to others [20]. coagulation is an important process that occurs in many water and wastewater plants. This is done in a physical cleaning unit that includes transportation systems and chemical reactions to add antibiotics, neutralization and the formation of small flocs that contribute to the volume of water [69].

Agglomeration causes the collection of particles that can be made into large water, improving the gravity treatment or the flotation process to remove the sediment [69], the formation of flakes in suspension is called flocculation. This is commonly used for water purification and water treatment. Due to their low charge density, they are negatively charged at the surface and are therefore prone to instability [69]. The coagulation process is usually superficial; therefore, the coagulation efficiency can be greatly affected by the surface charge due to excessive coagulation [70].

Different chemical treatment regimens have been investigated in the form of pre-treatment, treatment or primary treatment by different researchers worldwide [13]. Historically, natural plant coagulants were used to purify drinking water before the introduction of basic chemicals such as aluminium and iron. There is evidence that nirmali

(AS potatorum) has been used for this for 4,000 years and the seeds from 400 AD (in India), the 16th century, it is used as a coagulant in Egypt and Sudan, beans those with almonds make the water better. Quality [19,71].

Synthetic polymers used in water treatment emerged after World War II, but were not widely used in the United States until the 1960s. Compounds consist of long chains of many chemical elements repeated by covalent bonds, called monomers. If they have ionizable electricity, they are called polyelectrolytes and are classified according to their weight such as cationic (positively charged), anionic (negatively charged), or non-ionic (neutral).However, natural coagulants and polymers, despite their advantages, should be used properly in waterproofing systems if they pass tests that show that they are non-toxic, non-toxic and have strength [19].

Studies related to natural coagulation went through several stages until physical therapy was used. In the last few years, there have been various reports about the properties of the natural ingredients in different varieties like Jatropha curcas, Moringa oleifera, banana peel and bagasse. These results agree that natural coagulation has a promising therapeutic effect, making it a great opportunity to replace traditional medical coagulation [6,72,73]. Conversion from chemical coagulation to Natural coagulants can be derived from another solution to reduce environmental pollution and health risks while advancing green water technologies and water treatment applications. Natural coagulants can be obtained from plants or animals. Natural coagulants from plants are not new, as they were initially discovered many years ago. Natural coagulation was first used in water treatment in, before the discovery of chemical coagulation. In recent years, the use of natural coagulation has been documented in different nations, whereas chemical coagulation has been investigated [6].

The advancement of chemical coagulation reached its peak in the 20th century, when researchers finally discovered the mechanisms responsible for effective blood clotting. With chemical attacks, the traditional water clarification method using natural coagulation is no longer used, except in rural areas and developing countries where these chemicals are limited. This marked the beginning of a shift in's reliance on chemicals and wastewater treatment. In recent years, this event has gradually slowed down the development of natural coagulation. Since then, there are endless differences between these two types of coagulation, because the traditional anticoagulation system is becoming obsolete. Despite the interest in the treatment procedure, different effects of chemical coagulation have also been discovered and demonstrated. Otherwise, interest in exploring the potential of natural coagulants The interest in substituting chemical coagulation in water and wastewater treatment has steadily grown over time [6].

Coagulation and flocculation can be achieved with a natural or a chemical coagulant. In both cases, natural coagulation is known to be used for water purification, as shown in the various documents cited. Meanwhile, the worldwide distribution of alum as a coagulant in public waters began in the 19th century. Since then, China has become the first country in the world to use alum in water purification. The whole world watched. In the United States, metal particles such as iron salts have dominated water treatment since the 1880s [12,74]. Although they are superior to chemical coagulants in wastewater treatment, they fall short in the field of green chemistry. The impacts of chemical exposure on human health were published in the 1960s. Aluminium residues in alum-treated water have been the subject of controversy due to their association with serious health problems such as Alzheimer's disease (AD) and senile dementia. Results of several epidemiological studies and clinical studies show a 70% correlation between aluminium in drinking water and AD [12,75].

Due to the reduction of chemical coagulation, other possible ways to purify water should be considered to reduce environmental damage and protect public health. Due to their biodegradability and environmental friendliness, natural antioxidants have attracted increasing interest among researchers in recent years. Various types of plant coagulants, including waste fruits and others (cactus, cereals, mushrooms, nuts, shrubs and peppers), have shown promising coagulant activity for treatment of contaminated water. In addition, many of these coagulants provide primary treatment against bacteria commonly found in surface water, while others have been shown to remove heavy metals [12].

Coagulation/ flocculation is a commonly employed method for industrial wastewater treatment worldwide due to its simple and cheap operation. According to reports, the Egyptians used aluminium sulfate (alum) to fix suspended solids in water as far back as 1500 BC. Although alum was known to the ancient Romans, its use as a water softener in pine wood was not recorded until AD 77. At this time, the coagulation-flocculation process was an important a critical step in eliminating colloidal substances, nutrients, microorganisms and inorganic ions in unsettled water [12]. The use of natural coagulation from water and wastewater has been documented since ancient times in human history and continues to this day. For over 2000 years, organic polymers have been utilized in India, Africa, and China for nutrients and coagulants for wastewater [76].

3.1. MECHANISM OF COAGULANTS IN WASTEWATER TREATMENT

Because of its simplicity and efficiency, coagulation and flow are one of the most commonly used methods for restoring growth and improving wastewater treatment. This process leads to stabilization of the colloidal particles and increases the particle size for faster settling [77]. Coagulation, coagulation is added to eliminate the ionic charge to stabilize the colloidal particles, causing the particles to aggregate into large soluble flakes. However, coagulation and flow are affected and require a stimulus that encourages the flow to collect large amounts of solution. This means fast and slow mixing, where the flakes are distributed quickly, while fast mixing promotes the association of different particles in the liquid suspension [20].

All the treatment of coagulation - flocculation can be divided into two different ways, which must can be utilized individually. The initial called coagulation, which is the process of instability of the suspension or solution. The role of blood clotting is to counteract factors that enhance stability within the system. The second process, known as flocculation, involves encouraging stable particles to coalesce, make contact, and form larger agglomerates that can be separated more easily using gravity, similar to the first process [78].

Usually occurs when the appropriate flocculant is added. Two main types of flocculation can distinguished: micro flocculation (or peri kinetic flocculation), which is caused by the thermal movement of water molecules (Brownian Motion), and micro flocculation (orthokinetic flocculation), which is partially him. it is produced by releasing the increased speed in the suspension combination [78].

Initially, the colloidal particles in water are in a stable arrangement. When mixed with well-charged compounds, the colloidal material is stable, so a complex system is created. Another addition of the coagulant causes the recovery of the colloidal particles, thus stopping the aggregation of the particles. Various coagulants interact in distinct ways with colloidal particles, intention destabilization of the colloidal particles [6].

To expedite the settling process, destabilization is necessary to speed up the processing time, indicating the importance of coagulation. The suspension is obtained by one or a combination of two or more of the following methods, when a coagulant is added: Compression of the adsorption, double layer, and charge neutralization, as well as interparticle bridging, Precipitation (use of large amounts of antibiotics, "sweep flocculation") [3,78].

3.1.1. Compression of The Double Layer

Compression of the double layer refers to a process in which ions with counterions and colloids penetrate into the surrounding bilayer. Inhibition changes the properties of the bilayer in a thin and small volume. The constant pressure of the electrolyte reduces the electric current and increases the van der Waals forces, which help bind two stable colloids together. The formed objects are larger due to the high level of aggregation, but their level of structure is low due to the lack of strength between the common flakes. In addition, floc strength depends on the ionic strength of the coagulant. Weakly charged monovalent ions create larger particles and take longer to settle. In the case of weak ions, the double layer is still negatively charged, which reduces the chance of irritation [6].

3.1.2. Adsorption and Charge Neutralization

Adsorption and charge neutralization occurs in the balance between the anticoagulant and the colloid surface. Chemical coagulants undergo hydrolysis to form various positively charged species before reacting with the colloid. The charge is removed from the surface of the part using a clever technique referred to as "Technical patch technology". Different positively charged species bind to the colloidal surface, leading to a positive charge and surface charge. The colloidal composition surface reduces the drag force and increases the van der Waals forces between the bodies. What happened with the charge neutralization system is strong compared to the flow sweepers, but weak compared to the capture of the small body, although they are less circular. In addition, formed flakes have a large particle size; but unlike the flakes formed by current elimination, the fibers created by neutralization are more compact. [79] confirmed this statement who showed that the groups created by the suspension of charges are more stable depending on the low energy that is permanent, which shows that the groups created in -Resistance to bad medicine and does not break easily. Indeed, ligatures are strong, but they are not strong because they rely on physical bonds that are weaker than chemical bonds [6,69].

3.1.3. Interparticle Bridging

Interparticle bridging are based on polymer chains, which are long and highly reactive and hang from the surface of the particles. One part of the polymer chain is connected to the colloid, while the parts that are not connected to the polymer chain are based on the rest of the colloid and create a complex colloid-polymer-colloid that the polymer serves. Many colloid-polymer-colloid structures can aggregate and rapidly form colloidal clusters. [80] shows that the flakes form as cracks and negative spaces between the network structure because the flakes are polymer chains connected to the colloid. In contrast, the flakes produced have a small fraction of the bottom, which shows that they are not as strong as the flakes produced by other methods. In theory, low particle size results in weak particles that do not break, but strong and not easily broken into small groups, because polymers serve as enough strong bridges to chemically made enough. [72] shows that the use of natural coagulation and hybrid coagulation processes promote flake growth at least three times compared to chemical coagulation, as the polymer chains expand and bond to the maximum extent [3,6].

For example, Figure 3.1 the addition of anticoagulant is responsible for the formation of small dispersed particles that aggregate into large, stable particles. These form a solid material heavier than water that settles as sediment and can be removed. This results in 90% removal of suspended solids. Also, the coagulation step depends on the time and voltage conditions that can remove high-flow particles from sedimentation [69]. Sedimentation occurs when the physical process of excess water falls to the bottom of the surface due to gravity. Unquantified sediments are placed in the filter, which is a physicochemical process where impurities are separated from the water due to the passage of the filter [19].

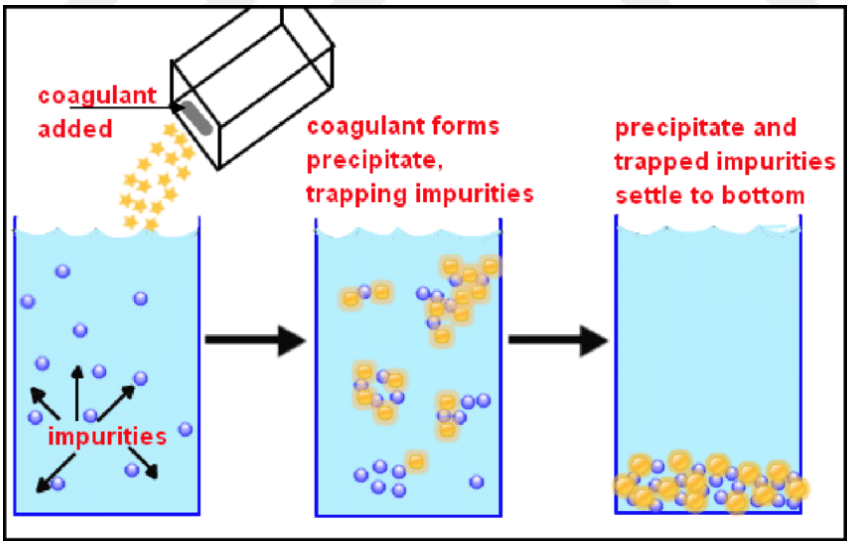


Figure 3. 1. Process of coagulation, flocculation, and sedimentation [69]

3.1.4. Sweep Flocculation

Sweep flocculation is thought of as a process used to remove colloids through binding them into a mesh-like material. The pure form includes the precipitation of amorphous iron hydroxide during hydrolysis. Analysis methods like Initial Floc Aggregation (IFA), Flocculation Index (FI), and Relative Sedimentation Factor (RSF) indicated that the lines formed through the sweeper were small and had the ability to settle well, but slowly moved. The Floc made with large broken edges, which indicates that the shells were formed strongly. In theory, a larger particle size results in stronger flow and breakage resistance, but the flow rate of the flow is only high, and the floc formation is high, and they are prone to damage. This is because of the strong prejudice that still exists between the groups. The vacuum window only binds the colloids into a mesh, but does not remove the repulsive forces between the colloids, which results in the formation of weak flakes [6,7].

3.2. FACTOR AFFECTING THE COAGULATION PROCESSES IN WASTEWATER TREATMENT

The flocculation process plays a crucial role in water and wastewater treatment and is recommended for its simplicity and efficiency. This is a common procedure in the treatment process, either pre-treatment or treatment. The efficiency of this system affects the effectiveness of the treatment, so improving the efficiency of coagulation results in improving the overall treatment results [78]. The choice of coagulant is important in different areas of water and wastewater, often due to economic considerations. This concern has been expressed in wastewater treatment practices since at least the mid-1970s [20].

Although the application of simple metal coagulants (conventional) light metals is often used for their strength and speed, they have weaknesses. These include the need to adjust the pH before or after treatment, sensitivity to temperature changes, high requirements due to complete charge reduction, sensitivity and specific sample identification, and the generation of precipitation [78]. Coagulants are used when added to water to remove colloidal particles and make them more stable in the water. In addition, the colloid will aggregate and grow, allowing the sediment to settle to the bottom and separate from the water suspension [7].

The effects of pH on anticoagulants and coagulation processes are carefully considered improving the removal of wastewater. The optimal pH value provides the best conditions for the jar test, which affects the next treatment process, including the microbiological quality, the life of the filter and the reduction of the cost of the treated water. The combination of coagulation and deposition process is important for material reduction and subsequent elimination by sedimentation under controlled time and voltage conditions [7].

As in other industries, improving wastewater treatment systems often involves improving one element while maintaining others. This system improves performance, saves energy, reduces labor, and promotes effective control and use of hydraulic equipment. Fuzzy concepts have become effective for representing treatment processes and predicting polluted water quality [21].

The effectiveness of coagulation is influenced by many factors, including the type and type and dosage rate of the coagulant, pH values, mixing rate, the specific quality of the water or wastewater to be treated, changes and temperature, and the concentration of total dissolved solids [6,15]. Contrary to the idea that these parameters work independently of the wastewater treatment and that changing the parameters affects only the variable response, things like coagulation and coagulation aid on dose and pH level greatly affect the coagulation-coagulation process [21].

3.2.1. Coagulant Dosage

Analyzing the impact of coagulant dosage on pollutant removal involves assessing three distinct scenarios: under dosage, optimum dosage, and overdosage. Under dosage occurs when there's insufficient coagulant to effectively bind with pollutants in the wastewater, necessitating additional coagulants to reach an optimal condition. Increasing the coagulant dosage provides more active sites for pollutant attraction and absorption[81]. Moreover, as coagulants are introduced, they progressively neutralize the electrical charge until the zeta potential reaches zero, facilitating the attraction and absorption of pollutants. However, exceeding the optimum dosage with excessive coagulant quantities only contaminates the wastewater. Surplus coagulant saturates colloid surfaces, leading to particle restabilization and creating repulsive forces among pollutants, hindering floc formation [6]. Economically speaking, optimizing coagulant dosage and determining the ideal amount of coagulant for scaling up and designing large-scale equipment is essential [70].

3.2.2. pH

Coagulant chemicals introduced into the water undergo hydrolysis, breaking down into various hydrolysis products that make the removal of pollutants effective. During hydrolysis, different products are produced depending on the pH value, and each product contributes to a specific type of activity. In contrast, pH's effect on natural coagulation differs depending on the anticoagulant that works in its process [82]. For example, if the active ingredient of the anticoagulant is a protein, such as the *Moringa oleifera* seeds used in the formula, pH has a significant effect. Proteins consist of polar or non-polar amino acid chains. Good amino acids, such as lysine and arginine, and bad amino acids like partic acid, play a role in this process. The pH and isoelectric points (pI) factor determine the most abundant amino acid. An optimum pH below the recorded (pI) results in a high concentration of amino acids, while a pH higher than the (pI) results in an unfavorable abundance of amino acids [6].

3.2.3. Initial Turbidity

The coagulation process depends on the relationship between impurities and coagulation required for blood clotting. In the case of high initial disturbances, there are more harmful substances, which causes an increase in the number of conflicts between coagulation and pollution. This increased number of collisions leads to larger and stronger clusters, accelerating the formation process [83]. In contrast, with low initial disturbances, the number of coincidences between coagulation and pollution is limited due to the scarcity of pollution. This leads to the formation of less liquid, which slows down the processing speed and prolongs the processing time [6]. In addition, a small initial source can contribute to the formation of particles during the coagulation-flocculation process, which can be low, worsening the coagulation efficiency and disrupting the coagulation-flocculation process. In general, these fractured structures prevent the best time for settlement.

Previous studies have shown a correlation between different initial turbidities and coagulation efficiency. For example, [84] shows turbidity removal is more effective at higher initial levels. However, [82] suggests that a deviation from the optimal initial turbidity can reduce the coagulation efficiency.

3.2.4. Rapid Mixing

Effective mixing is essential for uniform distribution of the coagulant in the wastewater during coagulation. Finding the best mixing speed and time is important to ensure uniform dispersion of the vaccine and to avoid cracking and chipping. [85] and [86] showed that the ideal mixing speed is between 40 and 200 rpm, and the perfect mixing speed is 120 rpm. A mixing speed that is too low (below 80 rpm) cannot effectively disperse the coagulant in the wastewater. On the other hand, synthetic fibers are weak and prone to cracking. Degradable particles reduce improve removal efficiency and reduce pollutant concentrations in wastewater. On the other hand, very high mixing speeds (more than 160 rpm) are also not good as they cause shear and shear flow [6].

The tearing and shearing of flocs can lead to the re-stabilization of pollutants, increasing the pollution level in wastewater. Also, the rapid mixing of high speeds results in less, more, and less water. Although these animals are small, they provide a lot of pollutants, resulting in long residence times. It is said that the formation of small flocs and the increase of the zeta potential at a high speed, which reduces the interaction between pollutants and coagulant mentioned [3]. This period should have a balance between contaminant stability and determining the best antidote to minimize the dose while ensuring that it is concentrated within the specified period. Long-term rapid mixing is not good because it is treated with water, which causes it to increase, causing water loss. In addition, long-term irritation leads to a-fold increase in the condition of flakes, increases flake damage, and inhibits flake growth [6].

3.2.5. Temperature

Temperature does not affect coagulation effectiveness as significantly as other factors. According to [87], the removal of pollutants did not change regardless of whether the wastewater was cooled or kept at room temperature. Ideally, a warm environment is best for the collection process. This is because during the process the elements are gathered and are now developing. In elevated temperatures, particles move more rapidly, resulting in frequent collisions among the particles and the contaminants, resulting in strong currents [87].

In contrast, frozen water is not suitable for coagulation as it reduces the solubility of the coagulant, increases the viscosity of the water, and reduces the kinetic energy of the particle flow. Therefore, high coagulation doses and long flow times are required to achieve optimal pollution removal, which increases treatment costs [88]. Furthermore, increasing water viscosity requires higher shear stress (stirring coefficient) during coagulation. This high pressure can disrupt the previously established transport system, resulting in pollutants to flow back entering the wastewater [89].

Although factors like coagulation factor, pH, and stirring speed have been studied, the impact of temperature has received little attention in the literature. Some researchers underestimate the importance of distance, but studies have shown differences in the effect of temperature on the elimination of pollutants. Therefore, further research is needed to better understand the role of temperature in the coagulation process [6].

CHAPTER 4

TREATMENT PROCESSES FOR TEXTILE WASTEWATER

Generally, conventional wastewater treatment involves a combination of chemical, biological, and/or physical processes to treat effluents, as outlined in various methodologies described in emerging techniques see Figure 4.1. The selection of the appropriate method depends on the specific characteristics of the wastewater. Each treatment method presents its own challenges, including cost considerations, efficiency and effectiveness in treatment, sludge generation, operational complexities, requirements for pre-treatment, reliability, environmental impact, and potential toxicity of the treated products [90].

Industrial wastewater typically exhibits high coloration, elevated COD/BOD levels, and contains significant amounts of heavy metals and salts (TDS). As a result, various treatment methods, encompassing chemical, physical, and biological approaches, have been developed to economically and efficiently treat industrial wastewater before discharge into rivers. However, due to technical and financial constraints, only a subset of these methods are currently employed in the industrial sector [90].These treatments have shown significant efficacy in managing textile wastewater, prompting ongoing research into combining cost-effective or innovative techniques. [91].

Common wastewater treatment methods include several stages: pretreatment (such as screening, flow equalization, comminution, and grit chambers), primary treatment (including oil separation, coagulation, flocculation, sedimentation, and dissolved air flotation), secondary treatment (biological), and advanced treatment processes. The conventional process involves multiple steps to effectively treat wastewater. The initial stage involves preliminary treatment, which includes physical and chemical treatment. The subsequent stage focuses on further refining the treated sewage [92].

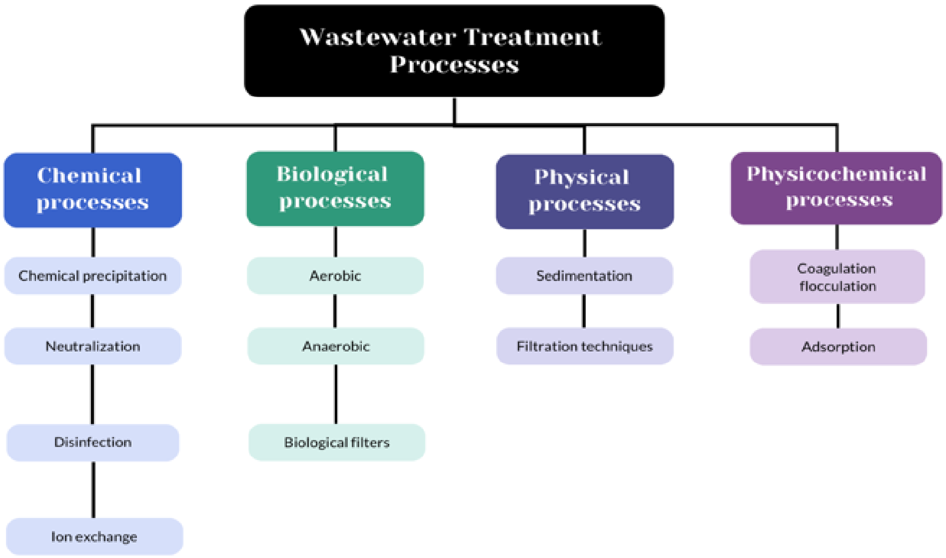


Figure 4. 1. Wastewater treatment processes.

4.1. PHYSICAL TREATMENT PROCESSES

Physical treatment methods in wastewater management do not rely on biological or chemical transformations. For instance, coarse screening removes large particles and impurities. Sedimentation and filtration are employed to eliminate finer particles, using physical processes rather than biological methods [92].

4.1.1. Sedimentation

This process separates water from solids like oil by converting liquids into a solid state, effectively reducing fine particles. Physicochemical methods have shown lower efficacy in removing total naphthenic acids compared to biological systems [93].

4.1.2. Filtration

Ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) are utilized for water recovery and reuse. The selection and installation of these filters consider the composition and temperature of the wastewater to optimize the separation process [91].

Filtration acts as an effective barrier against biosolids escaping from the system. This is unlike gravity and activated sludge systems, where biosolids can escape along with clarified effluent, leading to potential total loss of solids during process upsets caused by sludge bulking in the clarifier. Consequently, in membrane bioreactor (MBR) systems, the amount of biosolids is typically maintained at 3-4 times higher levels in terms of mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS) (~10,000 mg/l), compared to (~2,500 mg/l) measured in activated sludge systems [94].

4.2. CHEMICAL TREATMENT PROCESSES

Ultrafiltration and reverse osmosis are employed to recover and reuse water. The selection and installation of filters take into account wastewater characteristics, including its composition and temperature, to enhance separation efficiency [91]. Unlike traditional methods where biosolids can be lost during processing, filtration prevents their escape from the system [94].

4.2.1. Chemical Precipitation

Degradable inorganic substances can be eliminated by adjusting pH with acids or alkalis, altering temperature, or inducing precipitation into solid forms. Precipitates can then be removed through sedimentation, flotation, or other specialized methods [90]. While chemical precipitation (coagulation, flocculation) remains prevalent, there's a growing recommendation to replace chemical precipitation systems with phytoremediation. The trend favors the adoption of bioremediation and phytoremediation to minimize chemical use, aligning with principles of "green development." [9].

4.2.2. Neutralization

Neutralization involves regulating the pH of wastewater, whether it is acidic or alkaline, to maintain a pH around 7. When there is insufficient alkalinity, pH is adjusted to an acceptable range by adding bases such as sodium hydroxide (NaOH), sodium carbonate (Na2CO3), lime (CaO), and calcium hydroxide (Ca(OH)2), also known as soda ash. Conversely, if there is excess acidity, acids such as sulfuric acid (H2SO4) and carbonic acid (H2CO3) are used to lower the pH to a suitable level [9,92].

4.2.3. Disinfection

Wastewater treatment represents the final stage of tertiary treatment. Disinfection involves chemical treatments using specific agents to eradicate or significantly reduce pathogens. The aim is to safeguard public health by eliminating bacteria, viruses, and protozoa, thus meeting wastewater discharge regulations. Effective disinfection ensures the microbial quality of wastewater. Ideally, disinfectants should be antibacterial, cost-effective, safe, and enable accurate detection of residual traces. Common disinfectants include chlorine, ozone, ultraviolet radiation, chlorine dioxide, and bromine [9].

4.2.4. Ion Exchange

Ion exchange is a reaction where a charged ion in a solution is replaced by a similar ion bound to an immobile solid. In water treatment, one primary application of ion exchange is water softening, where polyvalent cations (like calcium and magnesium) are exchanged with sodium ions. In practice, wastewater is passed through a resin bed. This resin, created by polymerizing organic compounds within a porous matrix, facilitates the ion exchange process. Normally, cations are used to replace sodium in solution. The bed is closed when it is full of changed ions, where it will be regenerated with the sodium solution mixed with the bed [9].

4.3. BIOLOGICAL TREATMENT PROCESSES

Secondary treatment refers to the process of treating wastewater using biological treatment methods combined with advanced sedimentation. Essentially, secondary treatment primarily involves biological processes [9].

Biological processes specifically target dissolved solids in wastewater. Their effectiveness depends on factors like organic and solid content, microorganism levels, temperature, and oxygen availability. These processes are categorized into aerobic, anaerobic, and anoxic based on oxygen requirements, capacity, or combinations thereof, to meet oxygen demand efficiently [91,95].

Biological processes for removing complete bed wastewater have advantages such as: environmental friendliness, competitive cost, minimal sludge production, no hazardous metabolism or accumulation mineral and less water consumption (higher concentration or lower dilution) compared to physical/oxidation methods.

The effectiveness of biological degradation hinges on the adaptation of selected microbes and enzyme activity. Bacteria, fungi, and algae are among the organisms capable of breaking down different types of wastewater contaminants, including various colors [96].

The treated wastewater is directed into a well-designed bioreactor where microorganisms such as aerobic or anaerobic bacteria, algae, and fungi metabolize organic matter. Microbes utilize two main biological processes: biological oxidation and biosynthesis. Biological oxidation results in end products like minerals that stay dissolved and are discharged in the effluent. Biosynthesis transforms colloidal and organic matter into new molecules, forming solid biomass that can be separated from waste. Additionally, algal photosynthesis plays a crucial role in certain scenarios [9,91,92,94].

In these biological processes, microorganisms acclimate to textile dyes, and new resistant strains naturally evolve under conducive conditions, converting various dyes into less harmful forms. Enzymes like laccase, lignin peroxidase, NADH-DCIP reductase, tyrosinase, hexane oxidase, and aminopyrine-N-demethylase play pivotal roles in the enzymatic degradation process, which is crucial for breaking down dye molecules [91].

4.3.1. Aerobic

Aeration is employed to eliminate volatile organic compounds (VOCs) from water and to facilitate the transfer of substances like oxygen from air or gas into water, a process known as "gas absorption" or "oxidation." It is also utilized to remove iron and manganese. Aeration ensures the removal of dissolved gases such as CO2 and H2S from water. Additionally, aeration has proven effective in removing NH3 from wastewater and in extracting volatile compounds and other substances from water [9,91,92].

4.3.2. Anaerobic

Anaerobic treatment is employed for further treating wastewater containing high organic matter (BOD > 500 mg/L) and sewage sludge. Such wastewater originates from farms and the food industry and is challenging to treat aerobically due to the difficulty and expense of achieving the necessary oxygen concentrations for aerobic conditions. In contrast, anaerobic decomposition occurs in the absence of oxygen [91,92].

While anaerobic treatment may be time-intensive, it offers several advantages for treating animal wastewater. These benefits include high removal efficiencies, capacity to manage substantial organic loads, reduced sludge production (which is typically fine), and the generation of methane (a combustible gas) as a by-product. Anaerobic digestion is a complex process involving various chemical and microbiological processes. Organic substances decompose in an environment devoid of electron acceptors like oxygen, ultimately transforming into methane gas [6,7].

4.3.3. Biological Filters

The primary methods of biological filtration include single-pass filtration, recirculation systems, aerobic dynamic filtration (ADF), and two-stage filtration with high bioload. Various types of biological filters exist, such as soil-based air filters, also known as biological aerated filters (BAFs), which are commonly used, and percolating (trickling) filters [9,95]. Vertical flow media or upward-flowing suspended media are the most widely used designs for BAFs. When comparing biological filters with activated sludge systems, the comparison typically focuses on oxidation, which can be achieved in three ways:

I. Wastewater diffuses through a thin water film with a large surface area, facilitating oxygen supply through gas diffusion in a flow filter.
II. In the activated sludge process, aeration of wastewater occurs either through bubbling or by passing through a solid mixture.
III. Algae generate oxygen through photosynthesis, a process observed in still lakes [9].

4.4. PHYSICOCHEMICAL TREATMENT PROCESSES

Physicochemical methods in water treatment combine physical techniques like filtration and absorption with chemical methods such as ozonation and oxidation. After processing, the chemical process collects the fine materials and pours them into the bulk material to reduce flotation, sedimentation and rapid filtration [92].

4.4.1. Coagulation And Flocculation

Physically based methods are useful for purifying water with dispersive dyes [91]. This treatment serves as a pretreatment prior to membrane and biological treatments. It can also function as a final treatment to eliminate organic compounds not removed by biological methods. However, this process may not achieve complete wastewater treatment due to its limited efficiency in removing organic matter entirely [92].

4.4.2. Adsorption

Adsorption is a process in which molecules or ions remain in a gas or liquid on a surface. Here, the molecule or ion is a solid adsorbent used for diffusion, which is called an adsorbent. Liquids are sometimes used as adsorbents. Adsorption is a surface-only process where molecules adhere to the surface of the adsorbent without penetrating its structure. Conversely, the process of releasing molecules from the surface of the adsorbent is called desorption [97]. Adsorption can be categorized into two types based on how the adsorbate adheres to the surface of the adsorbent: physical adsorption, also known as physisorption, involves weak forces such as electrostatic attraction and van der Waals forces binding the adsorbate to the adsorbent surface. Chemical adsorption, or chemisorption, occurs when the adsorbate forms strong covalent bonds with the adsorbent surface [9].

Chemisorption typically occurs more slowly than physisorption and often results in a monolayer formation on the adsorbent surface, whereas physisorption tends to form multilayers on the adsorbent surface. Physisorption primarily takes place at or near the critical temperature of the adsorbate, optimizing its effectiveness at that temperature. Unlike physisorption, chemisorption usually occurs at high temperatures, with critical temperatures greater than degrees Celsius. Depending on the desired situation, both media can be displayed at the same time or alternately. Physisorption is defined by the reduction of free energy and entropy, so this diffusion is eliminated, and thus occurs faster at lower temperatures, reducing the rise in temperature. However, the chemical increases to a certain point with increasing temperature and starts to decrease [97].

These methods have attracted special attention because of their high decolorization efficiency for wastewater. High compatibility, mixing ability, and media reproducibility are the main characteristics to be considered when choosing a dye removal media. Activated carbon is highly activated and is a form of carbon that has been processed to create small pores and volumes, expanding the surface area. Because of its extensive microporosity, 1 gram of activated carbon possesses a surface area exceeding 500 square meters, as determined by gas diffusion methods. Adsorption capacity stands out as one of the most critical attributes of an adsorbent. [9,91,96].

CHAPTER 5

CHEMICAL AND NATURAL COAGULANTS

Coagulation is commonly used in primary water and wastewater to remove suspended solids from sediments. This process usually involves introducing contaminated water or waste into the pool and mixing coagulation chemicals with the body [3]. The purpose of water and wastewater treatment is to remove floating and colloidal substances, insoluble substances, microbes, and other harmful substances and to reduce turbidity. While reducing inputs, labor and maintenance costs, and environmental impact [98], coagulation followed by sedimentation, relying on gravity to remove the body [3].

The addition of coagulation is necessary to remove special contaminants from the water. Without them, colloidal or suspended matter remains stable and unstable. The addition of a coagulant reduces the repulsion between the colloidal particles, leading to the formation of flakes that settle and are removed during processing. Due to the precise filtration system, it has been a way to purify water since the 19th century [99].

Many coagulants can be used in water and wastewater, from chemical and non-chemical sources Figure 5.1 They can be a synthetic or natural coagulant with a positive charge that allows them to bind the negative material and make the solution less homogenous [98]. Chemical coagulation and natural coagulation are often used in the traditional coagulation process [6].

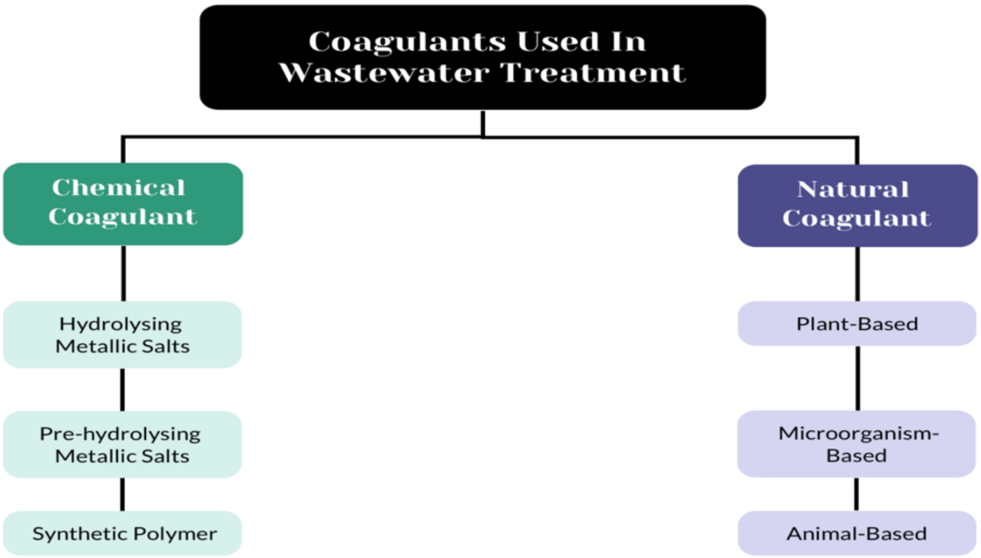


Figure 5. 1. Coagulants used in wastewater treatment.

5.1. CHEMICAL COAGULATION

Chemical coagulation in wastewater treatment involves altering the physical state of dissolved and suspended solids through the addition of chemicals, facilitating their removal via settling. The root is effective in removing suspended or colloidal impurities that are difficult to dissolve. This is the first successful treatment in water therapy [13,14].

In Figure 5.2 a chemical coagulant is introduced to counteract suspended substances in water, neutralizing the negative charges of insoluble materials like clay and organic compounds that contribute to color. This process allows small suspended particles to cluster together, forming tiny, unseen microflocs. Clear water surrounding these microflocs indicates effective coagulation, while cloudy water suggests incomplete coagulation, necessitating further chemical treatment. [14].

The most typical coagulation process involves adding benign chemical compounds like aluminum sulfate and ferric chloride. These coagulants material also have health and environmental drawbacks, with concerns about large amounts of chemical waste, toxic sludge, and potential health problems from long-term exposure [6].

These chemicals are often very expensive and are a challenge for many developing countries, who struggle to find the chemicals that are imported into their water and wastewater. researchers have raised concerns about the health effects of Alzheimer's disease due to aluminium residues in treated water. Additionally, polymeric compounds such as acrylamide are known to have neurotoxic and carcinogenic effects [18].

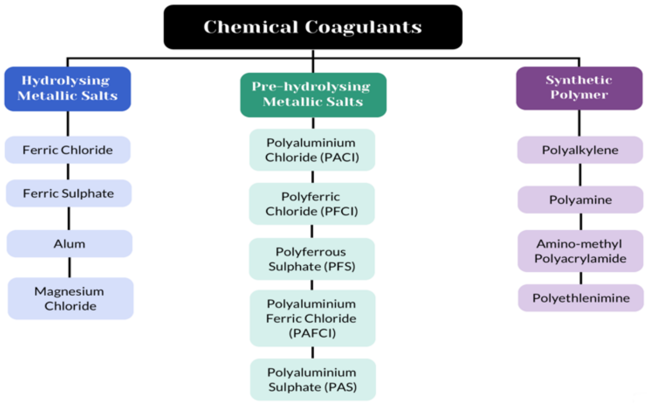


Figure 5. 2. Types of chemical coagulants.

5.2. NATURAL COAGULATION

Manufacturers have numerous applications, including disinfection and water treatment systems. Natural coagulants offer advantages such as convenience, affordability, and effectiveness as primary or supplementary treatments compared to synthetic coagulants. They can be sourced from various origins [3]. Depending on their origin, natural coagulants can be categorized into three groups: plants, microorganisms, or animals, as depicted in Figure 5.3. However, plant-based coagulants are more readily available than animal-based ones, making plant coagulants a viable alternative that has gained increasing importance over the years. [15]. However, natural coagulants from plants or animals have received attention as a safe and environmentally friendly method [6]. In the last years the researchers focused on different sources of natural coagulants, mainly wastes from plants, from the stem to the leaves [19]. Natural roots are obtained from plants and can effectively reduce turbidity and coagulation in the flow process of water treatment [3,98].

Natural preservatives of plants, including waste fruits, cactus, cereals, mushrooms, nuts, herbs and spices, have attracted great interest because of their biocompatibility and environmental friendliness. Some of these anti-inflammatory drugs eliminate common bacteria and can remove heavy metals [7,99]. Although the natural coagulant is less effective than alum, the combination of the two types can maintain the performance of water treatment and reduce dependence on chemicals. More research is needed on natural coagulants, focusing on their effectiveness, health and environmental impact, to create a sustainable alternative to chemical coagulants [7].

In response to these challenges, efforts have been made to develop new biodegradable coagulants using renewable, widely available and affordable materials. Natural polymeric compounds such as chitosan, Moringa oleifera seeds, cactus pulp and plant tannins are composed of polysaccharides and proteins [12,18].

In explaining the weaknesses related to non-synthetic and synthetic materials that contribute to global environmental issues, researchers are increasingly investigating polymers nature as producers. Antibiotics can be classified as plant-based, bio-based, or animal-based, and plant-based and other known substances for chemical coagulation [15]. Various low-cost biosorbents have been successfully tested and used as alternatives to expensive activated carbon. These include natural materials such as wood, clay and peat, agricultural materials such as stone chips and walnuts, sawdust, straw and corn, and industrial waste such as fly ash. oil dust and sewage sludge [14].

Although natural coagulation has an effective role in reducing interference, knowledge of the characteristics and characteristics of the resulting groups is limited. An understanding of these parameters, such as flow power and structure, is important for the development of effective coagulation concepts. Various microscopic techniques, such as the transmission electron microscope, can help analyses the formed flakes, providing insight into their structure and surface characteristics and improving our understanding of colloidal particles [7].

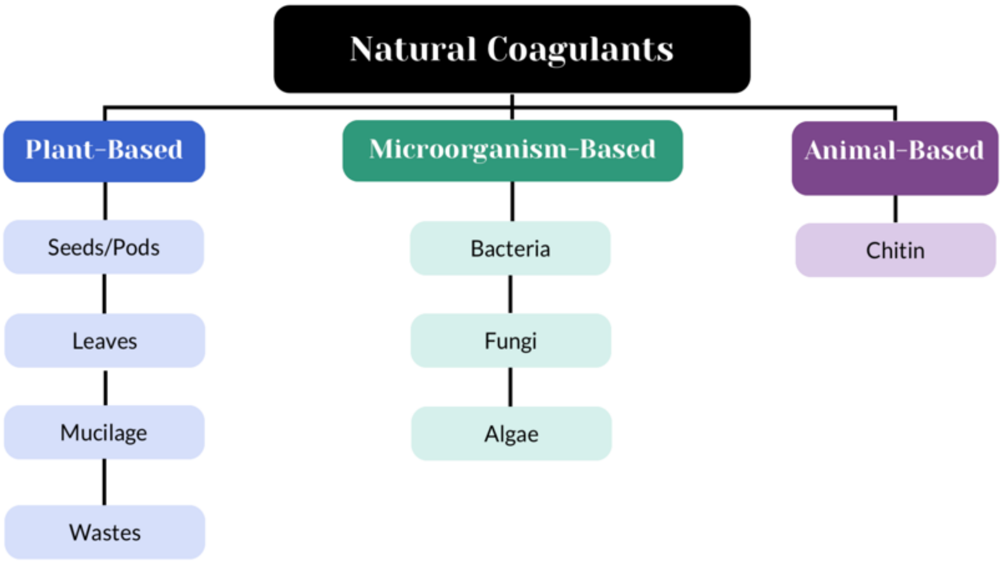


Figure 5. 3. Types of Natural Coagulants.

5.3. COMPARISON OF NATURAL AND CHEMICAL COAGULANTS

Coagulation chemicals such as alum and ferrous are commonly used, but have disadvantages such as excessive sludge. In contrast, natural coagulants from plants and sometimes microbes or animals provide an environmentally safe option. Some plants can imitate the process of coagulation, remove the charge and colloidal material that causes polymer synthesis, thus acting as coagulation [3].

The results of chemical coagulation, as shown in Figure 5.4 are serious and long-lasting, affecting the environment by producing highly toxic sludge and can affect the health of consumers in another reason for suffering and chemical poisoning. In contrast, the drawbacks associated with natural coagulation often stem from the coagulation itself, such as seasonal changes and storage effects that affect production and supply. However, ongoing research aims to reduce these delays and improve the efficiency of natural coagulation [6].

Although chemical coagulants are effective, they have disadvantages such as inactivity at low temperatures, excess aluminium residue causing health problems in water distribution, high cost, sludge formation, pH changes in treated water, and the effect on human health and harmful water. Therefore, it is desirable to replace synthetic materials with polymers and coagulants to avoid these defects and improve the environmental water treatment process [98].

In order to address the problems that cause suffering, extensive research is needed to develop new processes that are cost-effective, energy-efficient, use fewer chemicals, and have less environmental impact [3].

Switching from chemical coagulation to natural coagulation represents an alternative approach to mitigating environmental pollution and health risks linked to chemical coagulation. The adoption of natural coagulants in water treatment is crucial due to their swift effects on living organisms and the environment. [6].

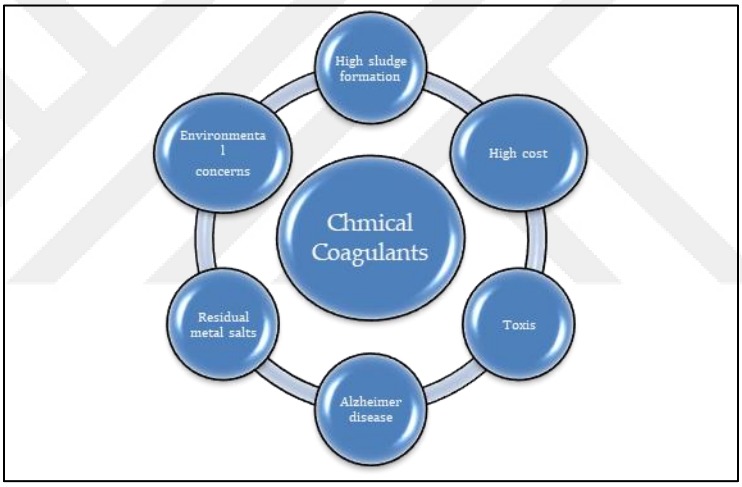


Figure 5. 4. The disadvantages of using chemical coagulants.

Compared to chemical coagulants, natural plant products offer several advantages. It is good, in a non-toxic environment [12]. Natural coagulation reducing sludge volume up to five times, while increasing the nutritional value of sludge requires a small dose of effective treatment [7]. Reducing the amount of sludge means lower costs for treatment and management, so it is a sustainable solution. Natural roots have received special attention from researchers due to their many advantages, including biodegradability, safety for human health, environmental Environmentally friendly, non-toxic, and free from secondary pollution, this coagulant material is sourced from natural origins such as microorganisms, animals, and plants [15]. Amid climate change, global resource depletion, and widespread environmental degradation, the adoption of these technologies in wastewater treatment is crucial and can significantly bolster global development initiatives. Figure 5.5 outlines the benefits of employing natural coagulants over chemical alternatives.[6].

The raw materials are often available locally, providing a cheaper alternative to chemical coagulation [12]. The advantages of plant coagulation include small doses required, small increase in water ionic load, reduced iron levels in treated water, low risk of toxicity, high biodegradability, and safety for living things in water and human health. In addition, they have little effect on global warming, do not cause secondary pollution, have good environmental qualities, the pH value of water is, they do not damage and prevent pipe erosion [15]. These products are compatible with the principles of green technology, supporting global development efforts [18].

Despite the proven coagulation characteristics of indigenous plants, many barriers to turbidity control have not been established, such as lack of funding, insufficient research and development, lack of market awareness, and legal challenges in M. oleifera produce [7]. However, plant operators present a challenge, such as a possible increase in organic load and associated microbial activity, which can lead to subsequent chlorine removal processes. In addition, the by-products of these products can contribute to the smell, color, and taste of the treated water. Despite these drawbacks, the use of plant-based coagulants to purify water is increasing due to their overall benefits and sustainable nature [70]. Raw plant material, which is easily available locally, is a cost-effective alternative to chemical coagulation. Growing attention to natural coagulation and recent studies support the urgent need to integrate low-cost natural coagulation into water treatment [15].

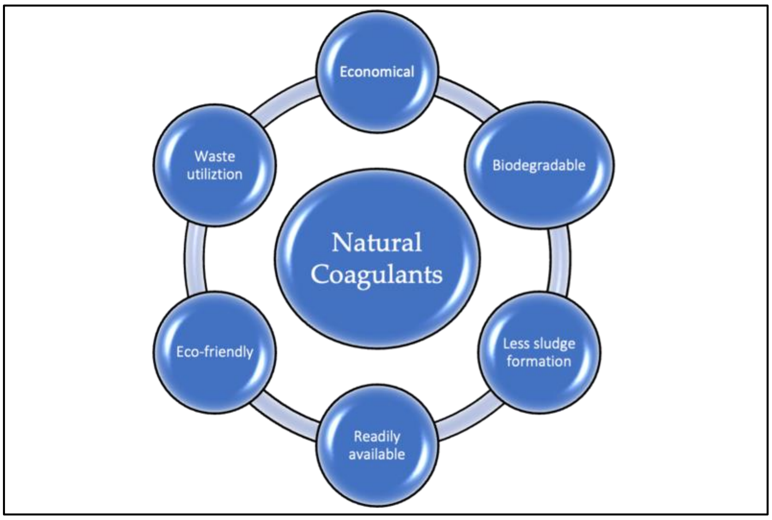


Figure 5. 5. The advantages of using natural coagulants.

5.4. PLANT-BASED COAGULANTS ON TEXTILE WASTEWATER TREATMENT

Coagulation-flocculation is especially effective in the textile industry for the removal of dyes, giving beautiful colors. Although sludge production is a concern, the cost of this process makes it attractive for water treatment. Adding certain chemicals, such as polyelectrolytes, improves coagulation by promoting the growth of large and fast clusters [14,19].

Therefore, it is urgently necessary to start using inexpensive natural polymers for water treatment. With this in mind, many researchers have evaluated the effectiveness of different natural coagulants derived from plants or animals in water treatment [6].

In recent years, the utilization of bio-based materials for wastewater treatment has proven successful, with a significant increase in published research papers. This trend is attributed to their advantages, including biodegradability, safety for human health, affordability, low toxicity, environmental friendliness, and abundance. [15].

In terms of costs and the removal of color by flocculation, it represents a promising option for liquid finishing. The use of low-cost natural polymers is essential for effective wastewater treatment, prompting researchers to explore different coagulants from plants or animals. These natural binders, mainly polysaccharides, can promote coagulation compared to synthetic agents, showing media and charge media or connection systems [14].

Verma et al. [13] investigated the use of different chemicals and natural coagulants in the treatment of textile wastewater, paying particular attention to the color of natural coagulants. It was concluded that further studies are necessary to reach clear conclusions about the effectiveness of these coagulants for removing dyes from water [18].

CHAPTER 6

EFFECT OF HEAVY METALS ON THE HUMAN, ANIMALS AND PLANT

There are different types of toxic substances in industrial effluent, which usually fall into three categories such as heavy metals, organics, and pollutants (oil). Pollutants released into waterways vary from industry, from manufacturing to mining/electricity [4]. Currently, there are many guidelines for wastewater treatment and discharge into water sources in many countries; Unfortunately, these recommendations or guidelines might not be reviewed or put into practice [4,100,101].

The publication of industrial wastewater into the environment leads to aesthetic issues, because the color in bodies of water like lakes and rivers that have changed following the discharge of industrial wastewater is not acceptable to the residents. In addition, the buildup of color prevents light penetration, disturbing the organisms in the water. However, water sources that undergo industrial wastewater can be polluted and pose a health hazard when used for irrigation or drinking. The main pollutants from industrial and household pollution are heavy metals (Cd, Hg, Cr, Zn, Pb, Cd), light metals (like Se, F, CN, S), derivatives (changed benzene, phenols, alkanes, phthalate esters, PAHs, volatile carbon, dyes) inorganic compounds (chlorides, sulfides, nitrogen-containing solids and compounds) and microorganisms (pathogenic bacteria, bacteria, viruses) [4,102,103].

Wastewater textile processing at various stages contains numerous pollutants, which harm the environment if not properly treated. The textile industry provides a living to farmers, cotton producers, carding, spinning, weaving, cutting, manufacturing, sewing, and packaging workers, which can affect the reduction of the value of the environment and the construction of the role of aquatic ecosystems in human health [4,36,104]. Wastewater from the textile industry is often contaminated with nonrecyclable or harmful organic substances like organic pollutants (POPs), dyes, salts metals, and crusts [15,105].

Mettal et al.(2010) [106] It has been reported that azo dyes are extensively utilized in textile, leather, rubber, and food industries. Abu et al.(2021) [16] said that The discharge of color in organisms has both toxicological and aesthetic implications. These colorants pose a great pose a threat to both the environment and human health [107], so the removal of dyes and heavy metals is important. Heavy metals, whether in complexed or free ion forms, present a threat to the environment in textile wastewater [16,108].

Pollution from heavy metals is a significant contributor to poses severe health risks and environmental issues. Elements such as Zn^{2+}, Pb^{2+}, $Cr^{6+,}$ Cu^{2+}, and Cd^{2+}, Heavy metals, which typically have an atomic density greater than 6 g/cm^3, are common pollutants found in wastewater [16]. The efficient the recovery of heavy metals from wastewater is seen as crucial because these metals have toxic properties. This large atomic density is due to the large number of industrial activities and expansion. In addition, elevated levels of heavy metals above the normal range are dangerous for living organisms [109]. Once it interferes with cardiovascular systems and the nervous, it causes death [16,109].

Very low levels of heavy metals have beneficial effects on maintaining health. However, they can damage the function of vital organs such as the lungs brain and kidneys and decrease energy levels, due to the high toxicity from prolonged exposure. The toxicity of metals depends on the concentration, route and duration of exposure [16,110]. Groundwater systems are also affected by these pollutants as they leach through the soil [111,112]. In addition, several colors and distributions of species have been demonstrated to be harmful to aquatic life, including (organisms, water plants, mammals and fish) [13,113].

6.1. EFFECTS OF HEAVY METALS ON HUMAN

Exposure of humans to heavy metals occurs to some extent through oral (ingestion) inhalation (espiration), dermal, and parenteral routes [16,114,115]. Currently, two types of azo, dyes and dispersed dyes, are globally acknowledged as triggers for allergic dermatitis and potentially cancer [116]. In addition, it can slowly speed up the processes of the body, nerves and muscles that mimic conditions like Alzheimer's disease, Parkinson's disease muscular dystrophy and multiple sclerosis [110]. Some reports also link high selenium levels to skeletal harm (osteoporosis) in humans [16,117].

They can be broken down by skin bacteria, skin cells, or chemical processes into aromatic amines that have negative toxic properties, mainly due to the ability of carcinogenic or allergenic [15,118,119].Besides can enter through the skin and reach the body, and they are able to damage other types of external tissues. Possible adverse Effects can include pancreatic issues, kidney, DNA damage, potentially cancer and nervous system damage [15,120].

According to [121], Heavy metal ions have emerged as significant disorders to humans, posing serious health risks and environmental concerns. In this decade, the impact of heavy metals on humans is the primary concern, because they can cause chronic diseases and death. Because of the detrimental effects of heavy metals on human health, the rehabilitation of our water environment requires knowledge of the correct methods for effective treatment [16].

For example, arsenic is a prominent human poison [122]. Long-term exposure to As3+ can cause cancer, non-cancerous neurological, tissue diseases, damage to reproductive cells and spleen cardiovascular, and lung problems [123]. According to [124], Exposure to arsenic during childhood or in the womb has significant pulmonary effects, contributing to increased mortality rates in young adults from both benign and malignant diseases [16].

High levels of exposure to heavy metals can cause damage impact various systems and organs through weight loss, circulatory system diseases, liver and kidney damage, and also, abnormal neurological behavior and animal death [16,125]. These heavy metals can lead to serious effects like damage and vital organs, reduced growth, brain damage and cancer. The health risks associated with heavy metal poisoning are not novel [18].

In addition, accurate and rapid studies estimate that such allergens can occur in a chemical and biological mixture, causing eutrophication, consuming dissolved oxygen, preventing the prevent reoxygenation in receiving streams, and produces metal ions that cause genotoxicity and rapid micro toxicity [126,127]. Broadly speaking, excessive and excessive exposure to colored liquids waste causes various types of immunosuppression, central nervous system, circulatory, respiratory and nervous system diseases such as allergies, leukemia, autoimmune diseases, vomiting, myeloma, appetite. Insomnia, severe quadriplegia, salivation, diarrhea, eye (or skin), jaundice, cyanosis, tissue necrosis, disease, irritability, and even pulmonary edema [13,127,128].

6.2. EFFECTS OF HEAVY METALS ON ANIMALS

The textile industry discharges large amounts of water into the aquatic environments, which can directly or indirectly affect the organisms in the water through the trophic chain or recycling, allowing pollutants to reach the organisms and human beings. If the wastewater is not treated properly or not at all, it can create a thin film of color on the water's surface and also reduce the oxygen dissolved in the water, which affects aquatic animals and increase the BOD value of the polluted water [15,129,130]. In addition, many dyes The decomposition byproducts have proven harmful to aquatic life, including algae, microorganisms, and fish [131] [15,132].

Heavy metals can affect organisms living in the aquatic environment. They can prevent the growth of living things in water and cause serious interference in non-living water treatment plants [16,117]. In addition, animals in the environment and contaminants have experience health issues when consuming vegetation near the drinking water system. Food can make animals sick from heavy metals [16].

It was found that the water content is very dangerous due to metal contamination, which occurs due to the occurrence of heavy metals in the water system in their ionic form. Heavy metals are a serious pollutant that kills fish. In addition, harmful pollution that affects the aquatic environment is classified according to treatment methods [16,133]. Research conducted on various fish species has indicated that heavy metals can alter biochemical and physiological functions in tissues and blood [16,115]. Effects of heavy metals in animals include slowed growth and development, cancer, organ damage, mortality, and nervous system impairment [117]. According to [134], the aquatic environment interacts with many heavy metals that are toxic and resistant to chemicals and can have strong oxidative stress [16]. Therefore, Regular monitoring is essential to prevent harmful metals from accumulating in humans through food. This result also shows the importance of eliminating heavy metals from the aquatic environment [101].

6.3. EFFECTS OF HEAVY METALS ON PLANTS

Heavy metals have a toxic impact on agricultural soils via wastewater, which presents certain risks to consumers of crops in polluted areas. Heavy metals can affect plants in both their root and leaf systems. Heavy metals persist in entering plants and leaves, leading to their inhibition and death. If crops are harvested in areas where water is not polluted, farmers suffer losses due to damage to their crops, which reduces their income [16].

Agricultural crops suffer from severe biotic stress, including stresses like heavy metal pollution, drought, and salinity [135]. The harmfulness of heavy metals in plants destroys the plant's growth and reduces its value. Plants are responsive to both low and high levels of certain heavy metal ions. $Cu^{2+,}$ Mn^{2+}, and Zn^{2+} ions are crucial micronutrients, while Cd2+ and Pb2+ ions are non-essential. These metals are crucial for the synthesis of photosynthetic pigments, nucleic acids, and proteins; they also contribute to the structure and function of cell membranes [16,135].

Water that seeps into the ground can add to underground aquifers, causing pollution. Soil pollution also affects crop quality [16]. Metal toxicities in plants disrupt nuclear functions, decrease cell division, and impair leaf development [136]. Research indicates that cadmium can diminish nutrient decrease hinder chlorophyll production, carbon assimilation, absorption, disrupt photosynthesis, impede plant growth, and induce oxidative stress. Moreover, elevated levels of heavy metals can adversely affect soil biological properties while also being toxic to plants [16,137].

In general, it can be said that inorganic compounds and Heavy metals do not exhibit toxic effects. This is because metals are unable to. Since metals cannot be destroyed, and when the damage in the plant exceeds the optimal level, they impact the plant either directly or indirectly [10].

CHAPTER 7

SODIUM LIGNOSULFONATE (SLS)

The largest renewable resource in the world is biomass (wood and plants), consisting primarily of lignin, cellulose, and hemicellulose. The most important biopolymer in wood biomass is cellulose, next is lignin, comprising 15-40% of wood weight. Lignin is additionally an important source of flavor. However, Annually, 50-70 million tons of lignin are produced, only 1 to 2% is used to make value-added products, meaning it is a waste material. Today, lignin serves mainly utilized to provide energy by burning. Therefore, it is very important to identify and encourage the manufacture of high-value products. Therefore, it is a reliable source for new industrial materials [25,138].

Lignin comes from many sources and is renewable. in the world Lignin is the largest reservoir of aromatic compounds and has great potential for use in many industrial applications. LS are a by-product of the pulping industrially produced, inexpensive and widely distributed chemicals and it can be used as concrete admixtures [25,28].

Efforts have been made for decades to increase the utilization of lignin as a raw material, but there is still a large gap between concept and implementation, that is, between technical feasibility and economic feasibility. Recently, the increase in energy demand has led scientists to search for new sources [28].

sulfite pulping and Pulping are recognized as efficient methods to extract lignin derived from wood and therefore utilized globally. Kraft lignin was extracted from wood using NaOH and Na2S. Lignin obtained from sulfites is processed as LS and produced using sulfuric sulfite and/or acid containing calcium, magnesium, ammonium or sodium at different pH levels. Currently, LS accounts for 90% of the total commercial lignin market, and the total production of LS worldwide is 1.8 million tonnes [17,27].

AL and SLS are residues of the paper industry. AL and SLS are waste products from the production of alkaline pulp for paper and kraft pulp. During fermentation, lignin is converted to low molecular weight, hydrothermally degraded by high temperatures and various chemicals, resulting in AL and SLS. Paper mills (PMS) are produced in large quantities (about 5.38 million tons per year, dry weight) in China and can pollute soil and groundwater because of uncontrolled discharges. Traditional treatments for PMS, such as disposal and burning, face limitations due to the secondary pollution they generate [26].

Commercially available lignin is divided into two types. The first type contains lignins that are common or sulfur-containing, including Kraft lignin and LS. These products have existed for many years. LS is available in significant amounts (about 1 million solid tons per year), Kraft lignin in medium size (about 100,000 solid tons per year). The most common lignins used in the industry are softwood. The second group contains non-sulfur lignins acquired through various processes, many have not currently been commercialized: (organic, soda, steam cracking, hydrolysis (mainly for biofuel production) and oxygen delignification) lignins. In this last group, only soda lignite can be found in the industry for a short period of time. Hydrolysis of lignins provides new opportunities important for industrial production in situations like the manufacture of bioethanol as a substitute for fossil fuels. They can be from forest or non-forest. Lignin from lignocellulosic materials derived from the (P&P) industry is used for almost all energy production and chemical extraction purposes. In the P&P industry, only a small amount (1-2%) is used to trade in most items. Several of these uses are car brake phenolic resins, wood products, materials, bio dispersants, polyurethane foams, epoxy resins used in printed circuit boards, and surfactants. Due to the presence of sulfonated groups, LS has an anionic charge and is water soluble [25].

LS is a by-product of the crude alcohol of the tube sulfite process or the sulfonated product of soda ash [22]. During the sulfite knocking process, the lignin of the soil is degraded by the destruction of randomly distributed r-O-4 ether bonds; The molecules are made water-soluble by introducing a sulfone group. Thus, LS molecules contain a hydrophobic aromatic skeleton and a hydrophilic sulfone group. Its lip hydrophilic nature gives LS outstanding performance and physicochemical properties such as water, adsorption and dispersibility, making it an effective admixture in many industrial areas. SL belongs to macromolecular surfactants, which have a hydrophobic core and a hydrophilic sulfone group. Like surfactants, SL molecules agglomerate immediately when exposed to a large solution [138]. Lignin from alcohols used in distillation or distillation can give LS. SLS can be utilized to promote SLS can be employed as a surfactant in the enzymatic saccharification of lignocellulosic biomass. can inhibit the non-lignin attachment of cellulase to solids [139].

The science of SLS is old, but the subject continues to show an increasing interest in the exploitation of natural resources such as wood and its parts, commonly called "biorefinery" [22].

In the past years, lignin and its production have turned into other useful products because they are non-toxic, environmentally friendly, biodegradable and renewable resources. In addition to the inorganic composition, using lignin sulfonate as a surfactant offers direct impact on the size and structure of nanomaterials [28,29]. Due to their special properties and the properties of water nutrients determined by sulfonic acids, LS is used in many ways, SLS is water-soluble, so it is -used as a spread of agrochemicals, coal-water-coal, paint. Cements and ceramics [22,24]. In contrast, LS is attracting more attention due to its good stability, dispersion, reproducibility and non-polluting properties [140]. LS is utilized in diverse manufacturing processes. One of its applications of LS is the mixing plant, where it is used as a distributor and processor. There are numerous other uses of LS, including partial replacement of phenol in resin production, oil additives, paint dispersants, and cleaners [24].

Like sulfites and paper production fluids, SLS is treated as a cheap waste with limited economic viability. Today, the majority of lignin applications rely on bulk lignin (such as LS), which is often extracted during the pulping process. Millions of tons SLS are generated annually, but only a minor portion is recycled [29]. LS is a by-product of the crude alcohol derived from sulphite pulp. According to Xiao's report, in 2001, the annual global lignin production in the pulp industry was 50 million tons. However, in

2005, only about 1 million tons were used [24]. Others produce 40-50 million tons of technical lignin per year, only 3 million tons of LS are used for other purposes [28]. Lignin is often referred to as a non-burning plant for energy recovery, but most of the studies on lignin are focused on exploring other useful properties of lignin, such as fuel [24].

Lignin is a naturally occurring polymer composed of phenylpropane. Like collagen, it plays a crucial role in plant walls as the microfibrillar matrix of cells. Lignin and its components, LS and kraft lignin, were well researched decades ago have received little scientific attention since then [141]. Although acidification is becoming increasingly popular with other environmentally friendly methods, it cannot be accomplished overnight. Additionally, alkaline lignin and kraft lignin are converted to LS during sulfonation [29]. The structure of lignin and lignin sulfonate (LS) is intricate. Lignin constitutes 30% of wood tissue and plays a role in transporting water inside wood. It provides protection against fungal and bacterial attacks and is also a crucial structural component of wood. Lignin forms a bond with cells in wood, which this explains the challenge in isolating pure lignin [141]. Therefore, the development of lignin-sulfonate products and the expansion of their applications are beneficial from the point of view of saving resources and protecting the environment and bringing other economic benefits [29].

Due to highly effective flocculation and dispersion, LS is anticipated to be utilized in production of microspheres and significant metals in water treatment, etc. Undoubtedly, LS's use provides important environmental, economic and social benefits [29]. Lignosulfonic acid is a by-product of the sulfite industry, and it has coagulation, dispersion, and transparency properties. Wood lignin in sulfite alcohol is made from water by the addition of a sulfonate group to the molecular structure [142]. SLS is a complex of soluble sulfites and anionic surfactants. This is because SLS has many polar anionic groups (such as phenolic, aliphatic hydroxyl, carbon and sulfonic acid groups). It is molecules compound of amphiphilic. Moreover, SLS has the advantages of being cheap and environmentally friendly [143].

Surfactants are known to have both hydrophobic and hydrophilic characteristics. They can facilitate the elimination of hydrophobic compounds by decreasing the surface tension between two water systems and altering the surface and structure of the biomolecule, making it more hydrophilic [139]. LS has both and hydrophobic group (carbon chain) and hydrophilic group (phenyl hydroxyl, alcohol hydroxyl and sulfonic acid), as shown in Figure 7.1. [23,24]. It is a surfactant with anionic properties a high activity which can facilitate diffusion up and the dispersal of the other body, forms a thin layer on the metal and thus can be applied to corrosion and scaling prevention. It is expected that SLS can serve as an alternative water treatment agent through chemical alteration guided by structural analysis [24].

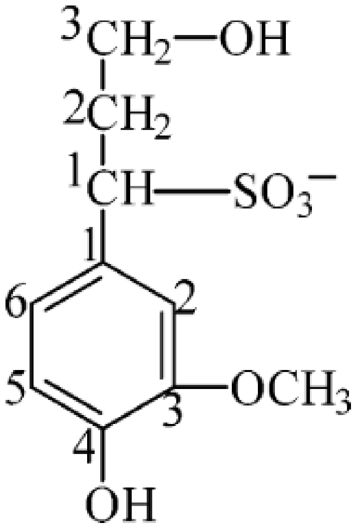


Figure 7. 1. Typical structural unit of lignosulfonate [24].

LS extraction occurs during the sulfite pulping of wood chips. LS is a type of polyelectrolyte of a single charge composed of a carboxylic acid and a sulfonic acid. In strong alkaline solutions (pH > 10), phenolic OH groups also accumulate, by increasing the charge density. Unlike kraft lignin, LS is easily soluble in water. Observed a characteristic increase and viscosity decrease at lower concentrations of polyelectrolytes. This rise in viscosity characteristic of polyelectrolyte and correlates with the expansion of the polyelectrolyte macromolecule. Particularly notable is the slight rise in viscosity reduction during mixing seen in LS compared to other high molecular weight polyelectrolytes. [141] concluded that LS has a high charge density when studying the composition of LS. This indicates that the polyelectrolyte's limited diffusion is due to its restricted molecular geometry [141]. The greater molecular weight of SLS leads to a reduced size of the dye, indicating that higher molecular weight SLS has better diffusion characteristics at room temperature and high temperature [140].

In the aqueous system groups of LS make the color more attractive, while the hydrophilic groups make the water flow and make the fragrance more attractive through creating steric or electrostatic repulsion through adsorption onto the dye's surface. Although LS has been extensively utilized as a paint, it has some disadvantages. On the other hand, lignin's colorless catholic structure is prone to oxidation, which intensifies its color, making pollution by lignin sulfonate (LS) particularly concerning for fibers, depending on LS's color and chemical composition. Additionally, LS can reduce azo dyes by cleaving their azo bonds. Previous research indicates that LS's structural characteristics, especially its molecular weight and degree of sulfonation, influence its dispersing properties and ability to reduce the impact of azo dyes on dyeing effects. Higher sulfonation of LS enhances surfactant dispersal but reduces hydrophobic interactions with dyes.

LS is a chemically complex compound, consisting of phenylpropane units linked by various bonds to form a branched structure with diverse functional groups. One drawback of LS as a surfactant is its odor on textile fibers, which varies depending on the lignin's color. The predominant reason for lignin's dark color is its quinonoid structure, with the intensity of light absorption by lignin at 450 nm primarily attributed to the number of quinonoid structures. UV absorbance of LS is typically tested at 450 nm to determine its color. [27,140].

It has also been Studies have indicated that SLS with low molecular weight and high sulfonation level can promote the enzymatic saccharification of cellulose, and the lignin structure of seeds clearly affects the efficiency of SLS during enzymatic hydrolysis [139].

The global paper industry generates 50 million tons of lignin waste annually, keeping the price of lignin relatively low at about $400 USD per ton [23,24,26,27]. Lignin contains both hydrophilic groups (such as sulfonic, hydroxyl, and phenyl) and hydrophobic groups (like carbon chains). As an anionic surfactant, it exhibits surface activity and can facilitate the adsorption on surfaces and subsequent dispersion of particles, potentially forming a thin film on metal surfaces. This characteristic suggests potential applications in corrosion and scale inhibition.

SLS is anticipated to serve as a versatile water treatment agent through chemical modifications guided by its structural analysis. [26,28]. The hydrophilic property makes have obvious surface activity and physicochemical properties such as testability, adsorption and dispersion ability, so it can be used as an additive. Effective surface treatment in many industrial fields [23,25].

CHAPTER 8

EXPERIMENTAL STUDIES

8.1. MATERIALS

8.1.1. Sodium Lignosulfonate (SLS) Powder

Commercial Sodium lignosulfonate (SLS), a yellow-brown dry water-soluble powder, was obtained from Ankarain company, Ankara, Turkey, and stored in the Karabuk University, Engineering Faculty, Environmental Engineering Department laboratory at room temperature for future use [28]. To eliminate potential moisture from storage, the (SLS) underwent an eight-hour drying process in an oven at 50 °C [144]. This procedure aimed to prevent any moisture-related issues from arising. Following the drying, the material was sifted to ensure uniformity of molecules, confirming the absence of agglomerates that could impede dissolution to be used as a coagulant in the experiments later, as shown in Figure 8.1.

Figure 8. 1. Sodium lignosulfonate (SLS) powder.

8.1.2. Sample Collection

Textile industrial wastewater samples were obtained from a textile plant in Gerede / Bolu, Turkey. These samples were subsequently transferred to the laboratory in a cooling box. Since they were not immediately utilized, the samples were stored in polyethylene (HDPE) containers within the laboratory refrigerator at the Department of Environmental Engineering, Faculty of Engineering, Karabuk University. The industrial wastewater samples were maintained at a temperature of 4°C until employed in the subsequent treatment procedure.

8.2. METHODOLOGY

8.2.1. Analytical Analysis

All analytical procedures were conducted according to the Standard Method of Water and Wastewater, as detailed in Table 8.1 Throughout the tests, the pH of the samples was modified using a 1 M H_2SO_4/NaOH solution [145].

Table 8. 1. Characterization Parameters and Methods.

Parameters	**Method**
pH	pH meter
Color	SM 2120 C
TSS	SM 2540 D
NH3-N	TS EN ISO 11732
COD	ASTM D1252-A
Aluminium "Al"	TS EN ISO 11885
Phosphorus "P"	SM 4500 P-I
Iron "Fe"	TS EN ISO 11885
Zinc "Zn"	TS EN ISO 11885
Sodium "Na"	TS EN ISO 11885
Copper "Cu"	TS EN ISO 11885
Nickel "Ni"	TS EN ISO 11885
Boron "B"	TS EN ISO 11885
Lead "Pb"	TS EN ISO 11885

8.2.2. Experimental Procedures

The test method to determine the coagulation/flocculation efficiency of given water depends on the type (or types) of the main coagulant, the method of coagulation, the best method of coagulation (s), and the pH of the coagulation that works best very well. The following test method is called the jar test method [146]. The instrument used to evaluate coagulation efficiency is the jar test equipment. The rotation speed of the stirrer can vary with the jar test since the speed of the stirrer is used in the coagulation mixture and the slow speed is for the flocculation phase.

The coagulation and flocculation experiments were conducted under specified operational conditions using a jar test of type (Velp) Figure 8.2. The timing and speed of fast and slow mixing were adjusted through the automatic control unit [147].

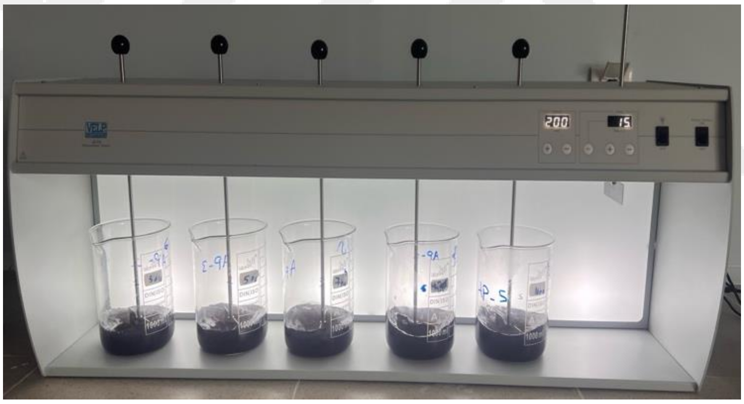


Figure 8. 2. Jar test device used in the experiments.

A literature review was undertaken to determine the operational parameters for the impact of coagulation velocity. However, it proved inadequate in addressing the subject of research, which is textile industrial wastewater. Hence, experiments were conducted to establish the appropriate optimum dosage. Each experiment involved placing a 200 ml sample of industrial water in 1000 ml, with Fast mixing was determined as 200 rpm in 15 minutes following by slow mixing was 90 rpm in 30 minutes and the settling time was set at 60 minutes for the 200 ml sample [148].

After the 60-minute sedimentation period, the samples were filtered using white/ash strip filter paper in the Whatman circuit to ensure clarity and remove impurities. This was followed by additional testing by sending the samples to the Kocaeli Municipal Center laboratory (ISU) in Kocaeli to assess the removal efficiency of COD, TSS, NH_3–N, color, heavy metals (Cu, Fe, Zn, Al), and other pollutants B, Na, P at the original pH of 11.9 from the textile industry wastewater sample.

Equation (1) was used to calculate the percentage removal of the respective parameters by considering the initial concentration of raw industrial wastewater sample and the final concentration of industrial wastewater.

$$Removal\ efficiency(\%) = \left[1 - \left(\frac{C_f}{C_i}\right)\right] * 10 \qquad (1)$$

where C_i and C_f refer the original and the obtained levels of each parameter.

CHAPTER 9

RESULTS AND DISCUSSION

The purpose of this study is to evaluate the effectiveness of SLS powder as a natural agent in textile wastewater treatment, and to determine the best coagulate parameter, especially for the removal of COD, TSS, color, ammonia-nitrogen NH3- N and heavy metals. Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) to define the chemical structure, thermal stability and structure of SLS powder. In addition, the study aims to investigate the effect of pH on the textile wastewater treatment process and to characterize it using SLS. This study was carried out to evaluate the performance of SLS in the coagulation-flocculation process of the wastewater of textile industry.

9.1. SODIUM LIGNOSULFONATE POWDER CHARACTERIZATION

9.1.1. Scanning Electron Microscopy (SEM)

Before the coagulation process, the surface morphological structure of the Sodium Lignosulfonate (SLS) powder was examined. Scanning electron microscopy (SEM) analysis shows a description of the morphology of SLS. SLS powder has a brick-shaped condensed crystal structure, The analysis included images from several dimensions as shown in Figure 9.1. The irregular shapes and surface roughness of the molecules contribute to flocculation and sedimentation during the coagulation process. The surface of SLS powder particles has varying degrees of roughness, high roughness indicates more active sites for reactions with contaminants and facilitates the coagulation process. In addition to the porous surface structure, it promotes the absorption of contaminants on the coagulant molecules [140]. The structure acted as a binding point for suspended particles and cations [149]. The coagulant is expected to the agglomerates of SLS molecules to facilitate the formation of larger clumps and thus stabilize them and improve coagulation efficiency and sedimentation later. SEM images show that this powder may be the secret to SLS remarkable clotting ability [149–151].

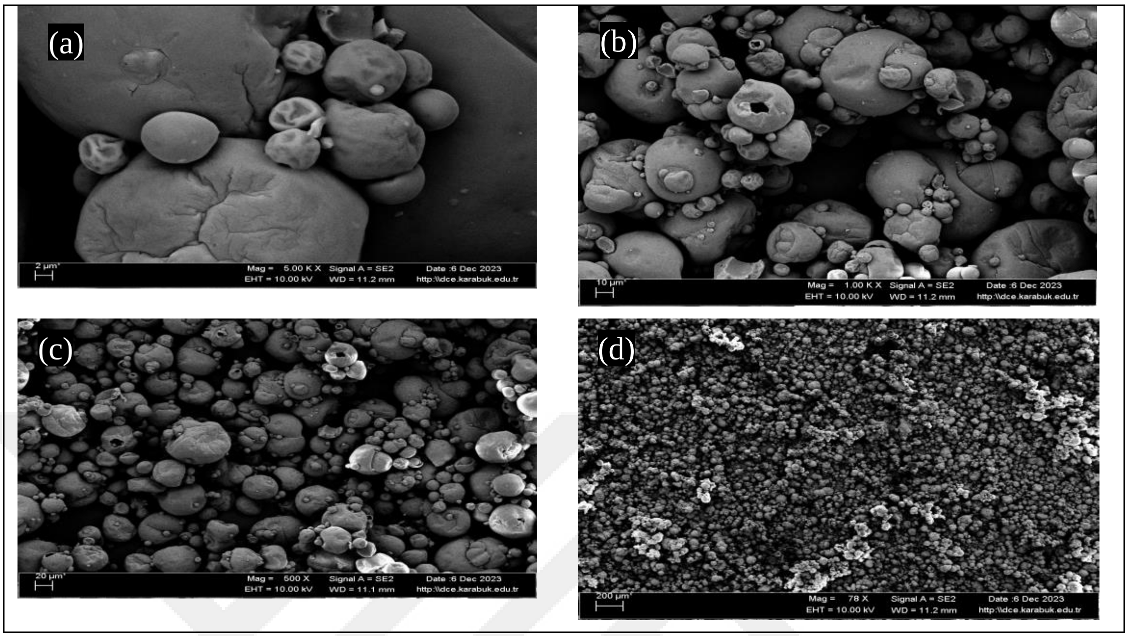
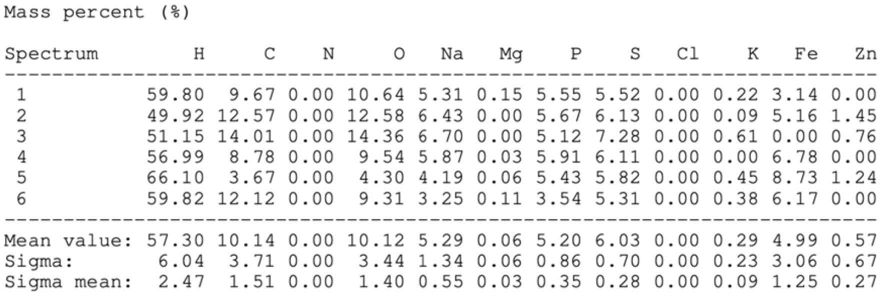


Figure 9. 1. Microscopic image for SLS powder before coagulation process observed by scanning electron microscopy: a) 2 µm b) 10 µm c)20 µm d)200 µm.

Table 9. 1. Mass % of SLS.



```
Mass percent (%)

Spectrum        H     C    N     O   Na   Mg    P    S   Cl    K   Fe   Zn
---------------------------------------------------------------------------
 1          59.80  9.67 0.00 10.64 5.31 0.15 5.55 5.52 0.00 0.22 3.14 0.00
 2          49.92 12.57 0.00 12.58 6.43 0.00 5.67 6.13 0.00 0.09 5.16 1.45
 3          51.15 14.01 0.00 14.36 6.70 0.00 5.12 7.28 0.00 0.61 0.00 0.76
 4          56.99  8.78 0.00  9.54 5.87 0.03 5.91 6.11 0.00 0.00 6.78 0.00
 5          66.10  3.67 0.00  4.30 4.19 0.06 5.43 5.82 0.00 0.45 8.73 1.24
 6          59.82 12.12 0.00  9.31 3.25 0.11 3.54 5.31 0.00 0.38 6.17 0.00
---------------------------------------------------------------------------
Mean value: 57.30 10.14 0.00 10.12 5.29 0.06 5.20 6.03 0.00 0.29 4.99 0.57
Sigma:       6.04  3.71 0.00  3.44 1.34 0.06 0.86 0.70 0.00 0.23 3.06 0.67
Sigma mean:  2.47  1.51 0.00  1.40 0.55 0.03 0.35 0.28 0.00 0.09 1.25 0.27
```

9.1.2. Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

The corresponding infrared (IR) spectrum was obtained using (FTIR) to further investigate the presence of the main possible functional groups in powdered SLS. The FTIR analysis was suitable for simplifying and highlighting the most important functional groups. FT-IR spectra show that SLS mainly bears hydroxyl and carboxyl functional groups (e.g. hydroxyl and carboxyl functional groups), in addition to aromatic rings and phenolic hydroxyls, which contribute to the adsorption of a variety of pollutants [152]. As shown in Figure 9.2 the FTIR spectra of the SLS used in this study are shown. This indicates that the wide range extending from 3250 cm^{-1} to 3417 cm^{-1} belongs to O-H stretching phenolic group, followed by 2924 cm^{-1} belongs to C-H stretching methyl and methylene groups, 1620 cm^{-1} belongs to C=O stretching, the peak at 1515 cm^{-1}belongs to C-C stretching for the aromatic skeleton, range extending from 1315 cm^{-1} to 1371 cm^{-1} belongs to S=O stretching sulfonic groups group, the peak at 1043 cm^{-1} and 621 cm^{-1} belongs to anti-symmetry and symmetry stretching vibrations of sulfonic group [151], the peak at 1250 cm^{-1} belongs to C-O stretching for aromatic ester [24,153]. The presence of these active groups (O-H, C-H, C=O) indicates their participation on the surface of SLS in removing chemical oxygen demand (COD) from textile wastewater [29].

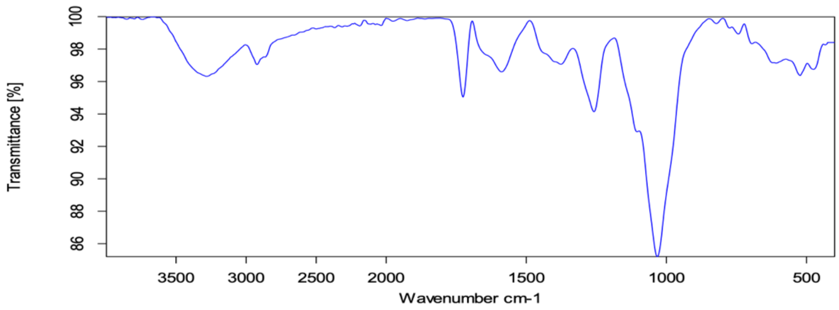


Figure 9. 2. FT-IR spectrum of SLS used in this study.

9.2. CHARACTERIZATION OF TEXTILE WASTEWATER

The wastewater from the textile factory exhibited diverse characteristics, as presented in Table 9.2 The pH level was notably high at 11.9, suggesting alkaline conditions. The color, measured in Pt-Co units, reached 1572.44, indicating a substantial presence of colored substances. Total Suspended Solids (TSS) were measured at 159 mg/L, suggesting a considerable load of solid particles. The Chemical Oxygen Demand (COD) was remarkably high, recording 3305.72 mg/L, indicative of the organic pollutants' strength in the effluent. Ammonia-nitrogen (NH_3–N) content was measured at 6.33 mg/L, while the concentrations of metal ions varied. Copper (Cu) was found at 0.025 mg/L, iron (Fe) at 0.666 mg/L, zinc (Zn) at 0.119 mg/L, aluminium (Al) at 0.600 mg/L, nickel (Ni) at 0.038 mg/L, boron (B) at 0.357 mg/L, and phosphorus (P) at 18.38

mg/L. Sodium (Na) exhibited a concentration of 605.481 mg/L, indicating the presence of salts. The concentration of lead (Pb) is 0.075 mg/L. The results underscore the complex composition of the industrial wastewater, with elevated levels of pH, COD, and various metals. These findings align with previous studies on textile industry effluents [154]. The high pH and COD levels may pose environmental challenges, emphasizing the need for effective treatment methods to mitigate the impact on receiving water bodies.

Table 9. 2. Characteristics of industrial (Textile Factory) wastewater.

Industrial wastewater parameters	**Unit**	**Results**
pH	-	11.9
Color	Pt-Co	1572.44
TSS	mg/L	159
COD	mg/L	3305.72
Ammonia-nitrogen (NH_3–N)	mg/L	6.33
Copper Cu	mg/L	0.025
Iron (Fe)	mg/L	0.666
Zinc (Zn)	mg/L	0.119
Aluminium (Al)	mg/L	0.600
Boron (B)	mg/L	0.357
Phosphorus (P)	mg/L	18.38
Sodium (Na)	mg/L	605.481

9.3. EXPERIMENTS OF COAGULATION AND FLOCCULATION TO DETERMINE THE OPTIMUM DOSAGE

The following parameters were measured using different concentrations (0.25, 0.125, 0.1, 0.05, 0.025, 0.016 and 0.0125 g/l) to find the best concentration required to obtain the best possible removal yield: % heavy metal (Al, Cu, Zn, Fe) and other elements (B, Na, P) and removal as shown in Table 9.3 and % COD, % Color, % TSS, % Ammonium-nitrogen presented in Table 9.4.

Figure 9. 3. Determination of optimum coagulant concentration for heavy metals (Al, Cu, Zn,Fe, B) and Na, P.

Dose (g/L)	**Al %**	**Cu %**	**Zn %**	**Fe %**	**B %**	**Na %**	**P %**
0.25	98	60	85.7	92.2	95.2	86.3	89.7
0.125	87	60	90	93.1	95.2	87.7	89.6
0.1	95.3	60	85.7	94	95.2	88.2	89.1
0.05	97.7	60	82.4	95.2	95.2	87.4	88.4
0.025	87.3	76	51.3	89.2	93.8	98.8	90.4
0.016	90.8	76	77.3	89.8	93.6	98.8	90.6
0.0125	95	76	89.1	91.3	93.8	98.8	90.4

The efficiency of the wastewater coagulation and flocculation process depends on many variable factors, such as the type of coagulant used, the coagulant dose, the type and concentration of ions in the water, the temperature, the pH of the medium, and rotation speed. There appears to be a very complex relationship between these factors [155,156].

Bratby (2006) also mentioned that the best way to determine the parameters of experimental or pilot tests is to conduct coagulation [146]. Therefore, we conducted jar tests with different concentrations, this test represents an ideal tool for improving coagulation processes. In this study, we carried out a series of tests to determine the optimal dose of SLS on the removal efficiency of heavy metals and other pollutants from textile wastewater. In addition, studying the factor of the pH with the optimum concentration and the corresponding rotation speed on the removal efficiency.

To determine the effectives of SLS powder in terms of coagulation, it is added to the wastewater solution through a series of experiments with different doses and change in experimental condition (rotation speed and time) by using jar test. The surface charge due to the mass of the coagulant can have a significant impact on coagulation function [151]. There is a need for economic development between coagulation dosages and the much-needed coagulation mass for expansion of activity. Therefore, the effect of SLS powder dose on the removal performance of COD, TSS, color, ammonia-nitrogen $NH_3 – N$ and heavy metals was studied, at the original pH of textile industrial wastewater which has a value of (11.9).

Rapid mixing distributes the coagulant in the wastewater. On the other hand, slow mixing is an essential part of the flocculation phase to achieve the best performance [158].

Table 9. 3. Determination of optimum coagulant concentration for COD, TSS, color and NH_3-N.

Dose (g/L)	Tss %	Color %	NH3-N %	COD %
0.25	88.1	83.6	69.8	87.1
0.125	84.3	85.6	64.8	89.2
0.1	88.7	86.6	68.1	90.3
0.05	90	86.9	43.6	90.8
0.025	96.2	91	88	90.6
0.016	89.9	89.3	88.8	90.4
0.0125	96.2	90.4	89.6	90.6

9.3.1. Effect of Coagulant Concentration on Removal of Heavy Metals, COD, TSS, Color and NH_3-N

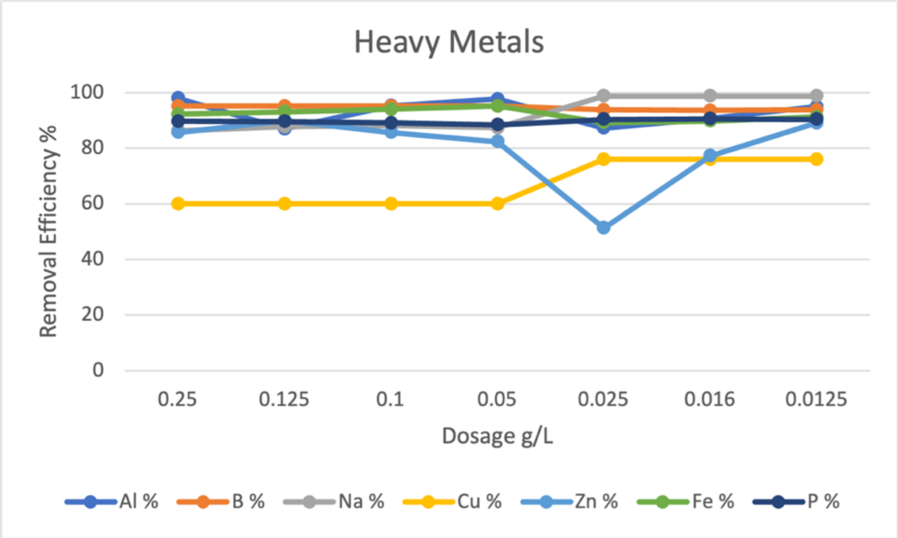


Figure 9. 4. Effect of Coagulant Concentration on Heavy Metals Removal.

Different concentration of SLS (0.25 to 0.0125 g/L) was used to investigate the best dosage in satisfying the heavy metals, the results are tabulated in Figure 9.3 in addition, for COD, TSS, Color and NH_3-N the results presented in Figure 9.4.

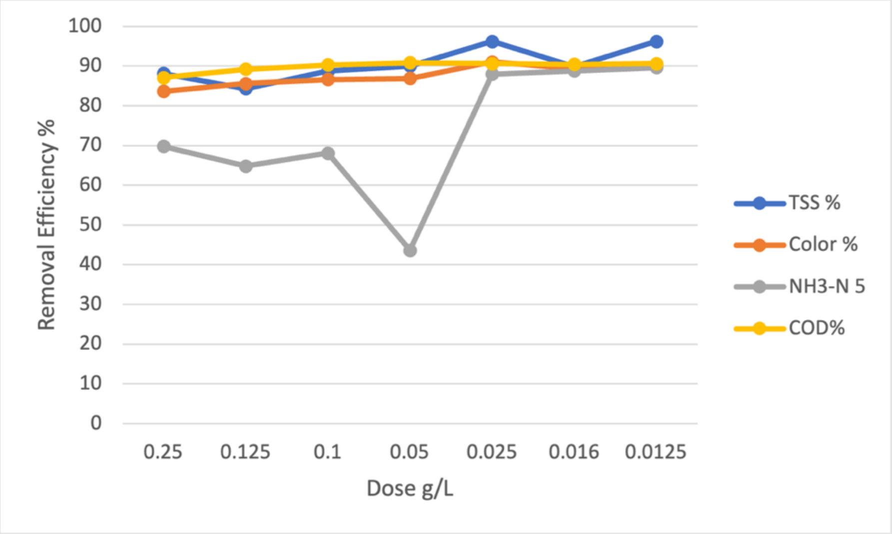


Figure 9. 5. Effect of Coagulant Concentration on COD, TSS, COLOR, NH3-N Removal from Textile Wastewater.

Notably, at 0.125 g/L, substantial removal rates were observed for (Fe), (Na), and (Zn), with percentages of 93.1%, 87.7%, and 90%, respectively. Conversely, at 0.25 g/L, removal rates for these elements decreased to 92.2%, 86.3%, and 85.7%, respectively. For Aluminium (Al), higher removal rates were noted at 0.25 g/L compared to 0.125 g/L, with percentages of 98% and 87%, respectively. In Figure. 9.3 concerning Total (TSS) and (NH3–N), the total removal efficiency at 0.125 g/L was low (84.3% and 64.8%, respectively). However, an increase in total color removal efficiency and the (COD) (85.6% and 98.2%, respectively) was observed. At 0.25 g/L, total removal efficiency for TSS and NH3–N increased to 88.1% and 69.8%, respectively. while decolorization and COD ratios decreased to 83.6% and 87.1%, respectively.

The use of (SLS) as natural coagulant for the removal of heavy metals from industrial wastewater was investigated, the experimental conditions involved agitation at 200 RPM for 15 minutes and 90 RPM for 30 min. The dose-response relationship at different concentrations, 0.25, 0.125, 0.1, 0.05, 0.025, 0.016 and 0.0125 g/L demonstrated varying heavy metal removal efficiency. At a concentration of 0.05 g/L, significant removal percentages were observed for various heavy metals. (Al) exhibited an impressive removal efficiency of 97.7%, while (B) and (Zn) removal percentages were 95.2%, 82.4% respectively. In Fig. 9.3 at 0.05 g/L the removal efficiency for (TSS), Color, (NH3-N), and (COD) was also notable, with percentages ranging from 86.9% to 90.8%.

From the factors on which the efficiency of the coagulation and flocculation process depends is the coagulant dose. Therefore, we still need a more in-depth study with lower doses.

Moreover, at 0.025 g/L increased improvements in removal efficiency were observed across lower doses for elements like (Na), (Cu) and (P), with removal ratios ranging from 76% to 98.8%. Lower doses exhibited high and consistent removal efficiency for (B), and (P), with constant removal ratios at 0.025 g/L and 0.0125 g/L (93.8%, 90.4%) and (93.6%, 90.6%), respectively, while at 0.016 g/L, the removal rates were (93.6%, 90.6%), respectively. Total removal efficiency of (TSS) and (COD) remained high and consistent at concentrations of 0.025 g/L and 0.0125 g/L, with removal rates of 96.2% for TSS and 90.6% for COD. However, at a concentration of 0.016 g/L, removal decreased to (89.9%, 90.4%), respectively. Additionally, there was a slight increase in removal efficiency with lower doses for (NH3–N), with removal rates of 88% at 0.025 g/L, 88.8% at 0.016 g/L, and 89.6% at 0.0125 g/L. In general, the dose (0.0125 g/L) shows excellent and optimum efficiency for removing heavy metals.

9.3.2. Effect of Coagulant Concentration on COD Removal

Table 9. 4. Effect of Coagulant Concentration on COD Removal.

Dose (g/L)	**COD %**
0.25	87.1
0.125	89.2
0.1	90.3
0.05	90.8
0.025	90.6
0.016	90.4
0.0125	90.6

Different concentration of SLS (0.25 to 0.0125 g/L) was used to investigate the best dosage in satisfying the chemical oxygen demand. The results are tabulated in Table 9.5.

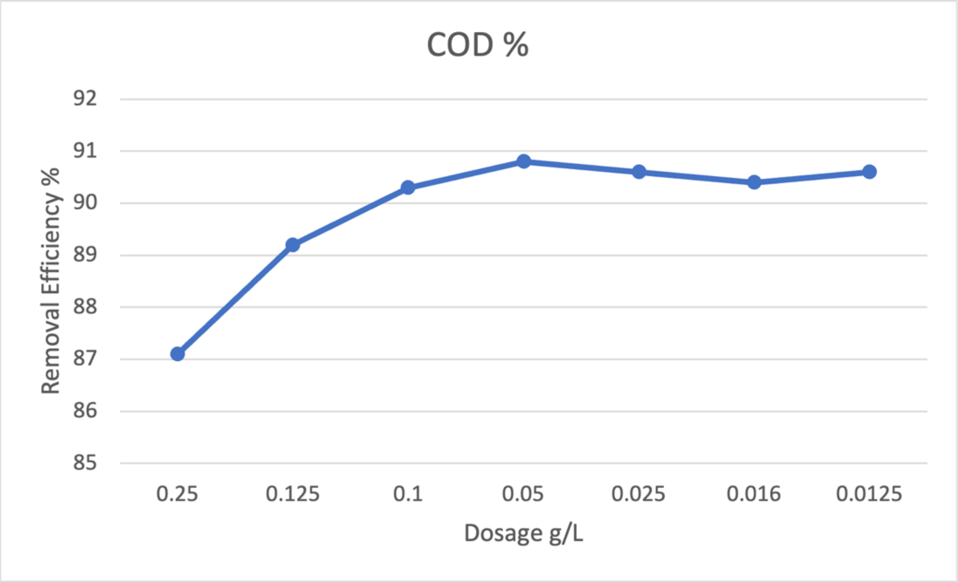


Figure 9. 6. Effect of Coagulant Concentration on COD Removal.

9.3.3. Effect of Coagulant Concentration on Color

Different concentration of SLS (0.25 to 0.0125 g/L) was used to investigate the best dosage in satisfying the color. The results are tabulated in Table 9.6.

Table 9. 5. Effect of Coagulant Concentration on Color Removal.

Dose (g/L)	Color %
0.25	83.6
0.125	85.6
0.1	86.6
0.05	86.9
0.025	91
0.016	89.3
0.0125	90.4

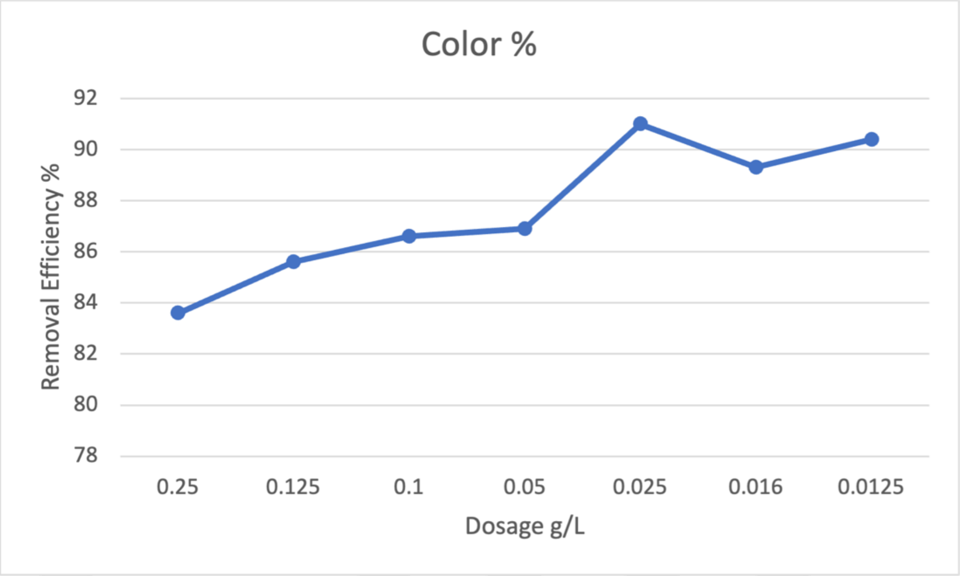


Figure 9. 7. Effect of Coagulant Concentration on Color Removal.

9.3.4. Effect of Coagulant Concentration on TSS

Different concentration of SLS (0.25 to 0.0125 g/L) was used to investigate the best dosage in satisfying the TSS. The results are tabulated in Table 9.7.

Table 9. 6. Effect of Coagulant Concentration on TSS Removal.

Dose (g/L)	**Tss %**
0.25	88.1
0.125	84.3
0.1	88.7
0.05	90
0.025	96.2
0.016	89.9
0.0125	96.2

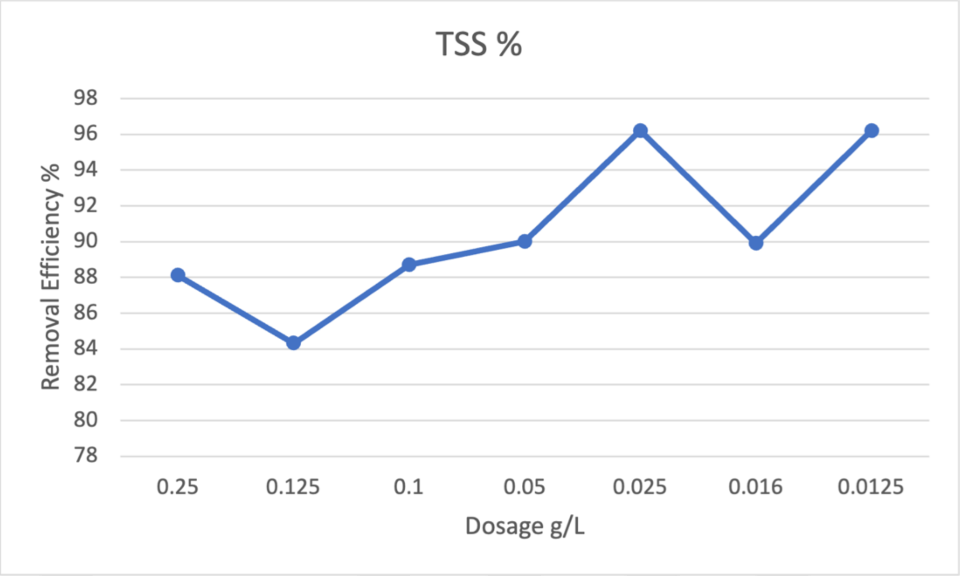


Figure 9. 8. Effect of Coagulant Concentration on TSS Removal.

9.3.5. Effect of Coagulant Concentration on NH3-N Removal

Different concentration of SLS (0.25 to 0.0125 g/L) was used to investigate the best dosage in satisfying the NH_3-N. The results are tabulated in Table 9.8.

Table 9. 7. Effect of Coagulant Concentration on NH_3-N Removal.

Dose (g/L)	**NH_3-N %**
0.25	69.8
0.125	64.8
0.1	68.1
0.05	43.6
0.025	88
0.016	88.8
0.0125	89.6

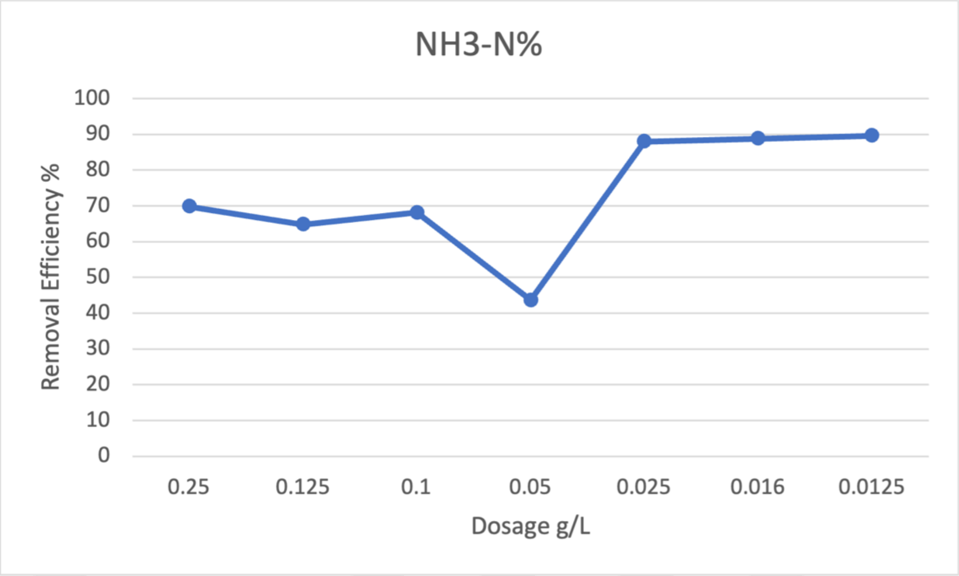


Figure 9. 9. Effect of Coagulant Concentration on NH3-N Removal.

9.4. DETERMINATION OF OPTIMUM PH AT OPTIMUM COAGULANT CONCENTRATION

Coagulant samples with a concentration of 0.0125 g/l at different pH values of 3, 5, 7, 9 and 11 were used to determine the pH required to ensure the best possible removal and the following parameters were measured: COD, COLOR, TSS, NH_3-N, and heavy metals.

Table 9. 8. Determination of Optimum pH at Optimum (0.0125 g/l) Coagulant Concentration for heavy metals.

Dose	**Al %**	**B %**	**Na %**	**Cu %**	**Zn %**	**Fe %**	**P %**
3	91.5	95.2	87.8	68	60.5	85.9	87.9
5	92.3	96.6	86.9	68	60.5	85.9	87.5
7	93	96.6	87.6	68	60.5	85.9	90.6
9	83.8	96.4	86.7	68	60.5	85.9	92.1
11	94	95.8	87.2	68	60.5	85.9	89.2

Table 9. 9. Determination of Optimum pH at Optimum (0.0125 g/l) Coagulant Concentration for COD, TSS, COLOR and NH_3-N.

Dose	**TSS %**	**Color %**	**NH3-N %**	**COD %**
3	90.6	95.2	90.4	91.9
5	91.2	91.4	94.3	91
7	94.3	91.8	95.6	91.5
9	91.2	90.5	95.9	90.5
11	88.1	90.9	95.3	90.9

9.5. THE EFFECT OF OPTIMUM DOSE FOR HEAVY METALS, COD, TSS, COLOR AND AMMONIA-NITROGEN NH3–N REMOVAL EFFICIENCY

To determine the effectives of SLS powder in terms of coagulation, it is added to the wastewater solution through a series of experiments with different doses by using jar test. The surface charge due to the mass of the coagulant can have a significant impact on coagulation function [151].There is a need for economic development between coagulation dosages and the much-needed coagulation mass for expansion of activity. Therefore, the effect of SLS powder dose on the removal performance of COD, TSS, color, ammonia-nitrogen NH3 – N and heavy metals was studied, at the original pH of textile industrial wastewater which has a value of (11.9).

At dose (0.25g/l) of SLS powder shows a reduction in the removal efficiency of COD, and SLS powder has shown efficacy when used as a coagulant at the lowest dose (0.0125g/L) with a maximum removal rate of 90.6% it is caused by excess coagulant limiting the amount of adsorption that can be achieved to prevent colloidal particles from covering the surface of the native coagulant [151,157].The presence of these active groups (O-H, C-H, C=O) indicate their participation on the surface of SLS in removing (COD) from textile wastewater [29].

The results of the analysis of the jar show the effect of the coagulation SLS powder on the ability to remove ammonia-nitrogen NH3 – N, the best removal efficiency at dose (0.0125g/l) was found to have a good rate of 89.6%.

Economically and to reduce sludge resulting from the process, a lower concentration indicated greater removal efficiency this is consistent with previous research [144]. Moreover, when the ratio increased to (0.05g/L), the removal rate was very low (43.6%).

On the other hand, jar test studies have shown that TSS removal performance is similar for all dosages. Due to neutral electricity charge, the particles have a strong coagulation capacity at pH levels of (7 to 9). This means that the adsorption capacity of COD, ammonia-nitrogen NH3 – N and TSS will be high. Although TSS removal performance is similar for all dosages, it can be said that the best dose (0.0125g/L) shows 96.2% removal.

The results also showed the effect of SLS powder as a coagulant on the color removal efficiency. A slight decrease in removal was observed with higher doses, however, SLS remained effective, as the reduction was not significant. Due to the presence of hydrophobic bonds, it contributes to the removal of color [159].

The ability of SLS powder, composed of natural polyphenols, to adsorb organic and metal ions improved the removal of pollutants [160]. The improvement in the removal of organics and ammonia can be attributed to the electric double layer’s activity produced by carbohydrates, phenols and amino acids [161]. Removal efficiency decreased when large amounts of SLS powder (>0.0125 g) were used. Essential amino acid groups in SLS powder increased the bridging mechanism of the particles and colloids in the wastewater, which aided in flocculation [162]. SLS powder has a high molecular weight and has never been converted into liquid. A large amount of SLS powder will cause the powder to settle quickly, which may reduce the agglomeration efficiency [163]. The larger dose shows less removal, and this is what the results showed, where the removal of Na at a dose of 0.25 g/L were low compared to the removal efficiency at a dose of 0.0125 g/L.

9.6. THE EFFECT OF PH FOR HEAVY METALS, COD, TSS, COLOR AND AMMONIA-NITROGEN NH3–N REMOVAL EFFICIENCY AT OPTIMUM DOSE

Table 9. 10. Effects of pH on heavy metals removal at optimum (0.0125g/l) coagulant concentration and 200RPM / 15min, 90RPM / 30min at room temperature 25 ˚C.

Dose	Al %	B %	Na %	Cu %	Zn %	Fe %	P %
3	91.5	95.2	87.8	68	60.5	85.9	87.9
5	92.3	96.6	86.9	68	60.5	85.9	87.5
7	93	96.6	87.6	68	60.5	85.9	90.6
9	83.8	96.4	86.7	68	60.5	85.9	92.1
11	94	95.8	87.2	68	60.5	85.9	89.2

The pH value of the wastewater influences both the surface charge of the coagulant and the degree of stability. The effect of pH of wastewater on the removal of heavy metals and other pollutants was investigated [70]. The investigation into heavy metals removal from textile factory wastewater using the natural coagulant SLS at different pH levels, as presented in Table 9.11 reveals valuable insights into the impact of pH on removal efficiency. The experiments were conducted at pH values of 3, 5, 7, 9, and 11, with an optimal coagulant concentration of 0.0125 g/L and agitation at 200 RPM for 15 minutes followed by 90 RPM for 30 minutes at room temperature (25 °C). The results demonstrate the sensitivity of heavy metal removal to pH variations. At pH 7, the highest removal percentages were observed for most heavy metals, including Aluminum (Al), Boron (B), Sodium (Na), Copper (Cu), Zinc (Zn), phosphorus (P) and Iron (Fe). The removal efficiencies ranged from 60.5% to 96.6% However, at pH 9, a decrease in removal efficiency was noted, especially for Aluminum (Al).

In Figure 9.9 These findings align with studies on the influence of pH on coagulation processes [164]. The optimal pH range for heavy metal removal is crucial, as it influences the surface charge of coagulants and particles, affecting coagulation and precipitation reactions. In this context, the pH of 7 appears to provide an optimal environment for SLS-induced coagulation in removing heavy metals from the textile factory wastewater, However, the result contradicts the observation in the literature that higher pH values are optimal for natural coagulation factors [165–167]. This discrepancy can be explained by differences in experimental conditions and the source of the coagulant.

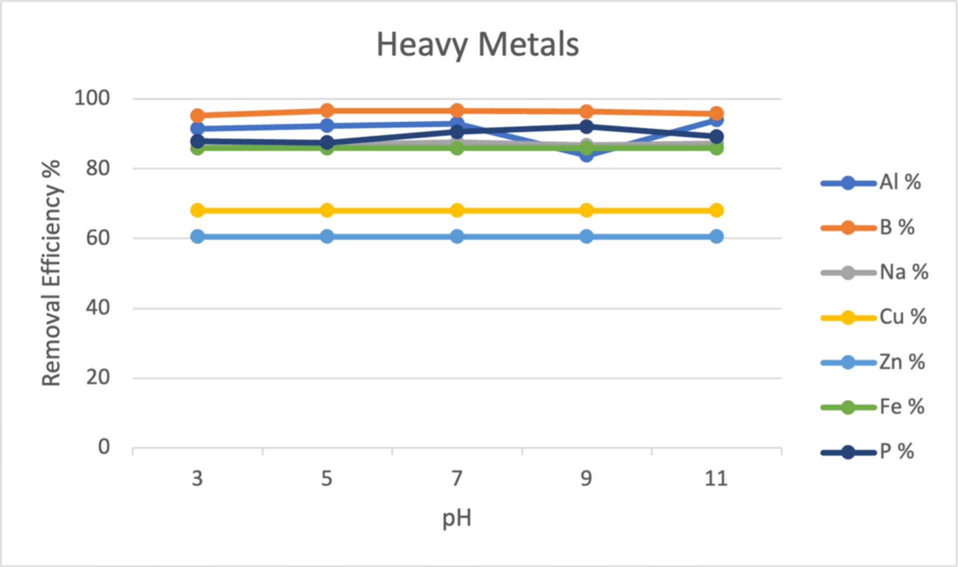


Figure 9. 10. Effects of pH on heavy metals removal at optimum (0.0125g/l) Coagulant Concentration and 200RPM / 15min, 90RPM / 30min at room temperature 25 ˚C.

Table 9. 11. Effects of pH on COD, TSS, COLOR and ammonia-nitrogen NH_3–N removal at optimum (0.0125g/l) Coagulant Concentration and 200RPM / 15min, 90RPM / 30min at room temperature 25 ˚C.

Dose	TSS %	Color %	NH3-N %	COD %
3	90.6	95.2	90.4	91.9
5	91.2	91.4	94.3	91
7	94.3	91.8	95.6	91.5
9	91.2	90.5	95.9	90.5
11	88.1	90.9	95.3	90.9

Furthermore, the removal efficiencies for Total Suspended Solids (TSS), Color, Ammonia-nitrogen NH3-N, and Chemical Oxygen Demand (COD) remained consistently high across different pH levels, in Table 9.12 indicating the robust performance of SLS in addressing various wastewater parameters. This is consistent with [70] results as it stated that the maximum COD removal occurs at pH below 8, as the results of his study at pH 7 showed a removal rate of 88.9% of COD from textile wastewater, which is a lower percentage little less than the results of our study as shown in Figure 9.10.

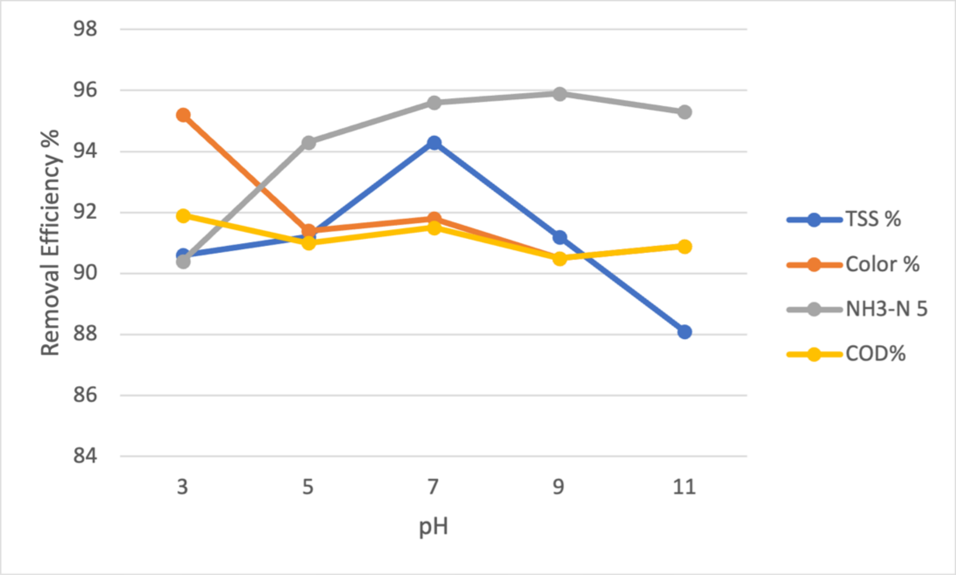


Figure 9. 11. Effects of pH on COD, TSS, COLOR and ammonia-nitrogen NH3–N removal at optimum (0.0125g/l) Coagulant Concentration and 200RPM / 15min, 90RPM / 30min at room temperature 25 ˚C.

CONCLUSION

In this work, the treatment of textile wastewater with the natural coagulant SLS was investigated and the influence of the dose, rotation speed and pH on the removal efficiency of heavy metals and other pollutants (TSS, COD, Color and ammonia nitrogen NH3–N) was also investigated. Through FT-IR and SEM analysis of SLS, the results showed that the composition of SLS and its content of functional groups such as (hydroxyl group, carboxyl group, aromatic group and phenolic groups) confer its ability to coagulate and enhance interactions with pollutants and make disposal from wastewater easier.

The optimal concentration of the coagulant SLS was (0.0125 mg/L) at a rotation speed of 200 rpm for 30 minutes, followed by 90 rpm for one hour. The pH of the medium was also examined at the optimal concentration, which was the optimal pH (7) at which the greatest removal of heavy metals and other contaminants occurred. The heavy metal removal efficiency was as follows: aluminum (Al) 93%, copper (Cu) 68%, zinc (Zn) 60.5%, (iron Fe) 85.9% and boron (B) 96.6%, sodium (Na) 87.6%, phosphorus (P) 90.6%. While the removal efficiency of other pollutants such as TSS was 94.3%, color was 91.8%, ammonia nitrogen was 95.6% and COD was 91.5 %.

The treatment of textile wastewater by coagulation and flocculation using SLS enable effective removal of pollutants. These results indicate that SLS has great potential for use in wastewater treatment in the textile industry and it can be recommended to use SLS for wastewater treatment. The use of natural coagulants can reduce financial costs because they are widely available and provide greater public health safety due to their biodegradability. In addition, they can serve as nutrients for microorganisms. A first experiment was carried out to determine two important parameters for defining the wastewater treatment efficiency of SLS coagulant, the optimal dose coagulant and optimal pH.

REFERENCES

1. Sharma, S. and Bhattacharya, A., "Drinking water contamination and treatment techniques", ***Applied Water Science***, 7 (3): 1043–1067 (2017).

2. O. B., A., "Wastewater Management, Recycling and Discharge", ***Hydrology***, 3 (3): 33 (2015).
Panwar, K., Dadhich, I., Dave, M., Sharma, Y., and Shaik, N., "Effective Waste Water Treatment by the Application of Natural Coagulants", ***Advances In Materials Science And Engineering***, 2022: (2022).

4. Chowdhary, P., Bharagava, R. N., Mishra, S., and Khan, N., "Role of Industries in Water Scarcity and Its Adverse Effects on Environment and Human Health", ***Environmental Concerns And Sustainable Development***, (Dm): 235–256 (2020).

5. Qamar, K., Nchasi, G., Mirha, H. T., Siddiqui, J. A., Jahangir, K., Shaeen, S. K., Islam, Z., and Essar, M. Y., "Water sanitation problem in Pakistan: A review on disease prevalence, strategies for treatment and prevention", ***Annals Of Medicine And Surgery***, 82 (June): 104709 (2022).

6. Bahrodin, M. B., Zaidi, N. S., Hussein, N., and Sillanpää, M., "Recent Advances on Coagulation-Based Treatment of Wastewater : Transition from Chemical to Natural Coagulant", (2021).

7. Kumar, V., Othman, N., and Asharuddin, S., "Applications of natural coagulants to treat wastewater− a review", (2017).

8. Chai, W. S., Cheun, J. Y., Kumar, P. S., Mubashir, M., Majeed, Z., Banat, F., Ho, S. H., and Show, P. L., "A review on conventional and novel materials towards heavy metal adsorption in wastewater treatment application", ***Journal Of Cleaner Production***, 296: 126589 (2021).

9. Samer, M., "Biological and chemical wastewater treatment processes", Wastewater Treatment Engineering, 150 (10.5772): 61250 (2015).

10. Bharagava, R. N., Saxena, G., and Mulla, S. I., "Introduction to industrial wastes containing organic and inorganic pollutants and bioremediation approaches for environmental management", Bioremediation of Industrial Waste for Environmental Safety, ***Springer***, 1–18 (2020).

11. Jiang, C., Wang, X., Wang, G., Hao, C., Li, X., and Li, T., "Adsorption performance of a polysaccharide composite hydrogel based on crosslinked glucan / chitosan for heavy metal ions", ***Composites Part B***, 169 (March): 45–54 (2019).

12. Choy, S. Y., Murthy, K., Prasad, N., Wu, T. Y., Raghunandan, M. E., and Ramanan, R. N., "ScienceDirect Invited article Utilization of plant-based natural coagulants as future alternatives towards sustainable water clarification", ***JES***, 26 (11): 2178–2189 (2014).

13. Verma, A. K., Dash, R. R., and Bhunia, P., "A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters", ***Journal Of Environmental Management***, 93 (1): 154–168 (2012).

14. Wakkel, M., Khiari, B., and Zagrouba, F., "Journal of the Taiwan Institute of Chemical Engineers Textile wastewater treatment by agro-industrial waste : Equilibrium modelling , thermodynamics and mass transfer mechanisms of cationic dyes adsorption onto low-cost lignocellulosic adsorbent", ***Journal Of The Taiwan Institute Of Chemical Engineers***, 96: 439–452 (2019).

15. Karoliny, T., Souza, F., and Almeida, C. A., "Review of Utilization Plant-Based Coagulants as Alternatives to Textile Wastewater Treatment List of Abbreviations", (2018).

16. Abu, N., Othman, N., Murni, Z., and Ali, W., "Environmental Technology & Innovation An insight review of lignocellulosic materials as activated carbon precursor for textile wastewater treatment", ***Environmental Technology & Innovation***, 22: 101445 (2021).

17. Zhang, F., Wang, B., Jie, P., Zhu, J., and Cheng, F., "Preparation of chitosan / lignosulfonate for effectively removing Pb (II) in water", ***Polymer***, 228 (May): 123878 (2021).

18. Tripathi, A. and Rawat Ranjan, M., "Heavy Metal Removal from Wastewater Using Low Cost Adsorbents", ***Journal Of Bioremediation & Biodegradation***, 06 (06): (2015).

19. Theodoro, J. D. P., Lenz, G. F., Zara, R. F., and Bergamasco, R., "Coagulants and natural polymers: perspectives for the treatment of water", ***Plastic And Polymer Technology***, 2 (3): 55–62 (2013).

20. Tetteh, E. K., Rathilal, S., and Robinson, K., "Treatment of industrial mineral oil wastewater – effects of coagulant type and dosage", ***Water Practice And Technology***, 12 (1): 139–145 (2017).

21. Fard, M. B., Hamidi, D., Yetilmezsoy, K., Alavi, J., and Hosseinpour, F., "Utilization of Alyssum mucilage as a natural coagulant in oily-saline wastewater treatment", ***Journal Of Water Process Engineering***, 40 (October): 101763 (2021).

22. Li, R., Yang, D., Guo, W., and Qiu, X., "The adsorption and dispersing mechanisms of sodium lignosulfonate on Al 2 O 3 particles in aqueous solution", 67 (4): 387–394 (2013).

23. Duan, J., Litwiller, E., Choi, S., and Pinnau, I., "Evaluation of sodium lignin sulfonate as draw solute in forward osmosis for desert restoration", ***Journal Of Membrane Science***, 453: 463–470 (2014).

24. Ouyang, X., Qiu, X., Lou, H., and Yang, D., "Corrosion and Scale Inhibition Properties of Sodium Lignosulfonate and Its Potential Application in Recirculating Cooling Water System", 5716–5721 (2006).

25. Aro, T. and Fatehi, P., "Production and application of lignosulfonates and sulfonated lignin", .

26. Wang, W., Hou, Y., Huang, W., Liu, X., Wen, P., and Wang, Y., "Bioresource Technology Alkali lignin and sodium lignosulfonate additives promote the formation of humic substances during paper mill sludge composting", ***Bioresource Technology***, 320 (PA): 124361 (2021).

27. Geng, J., Gu, F., and Chang, J., "Fabrication of magnetic lignosulfonate using ultrasonic-assisted in situ synthesis for e ffi cient removal of Cr (VI) and Rhodamine B from wastewater", ***Journal Of Hazardous Materials***, 375 (March): 174–181 (2019).

28. Yang, D., Qiu, X., Zhou, M., and Lou, H., "Properties of sodium lignosulfonate as dispersant of coal water slurry", 48: 2433–2438 (2007).

29. Wang, Y., Wang, X., Ding, Y., Zhou, Z., Hao, C., and Zhou, S., "Novel sodium lignosulphonate assisted synthesis of well dispersed Fe 3 O 4 microspheres for ef fi cient adsorption of copper (II)", ***Powder Technology***, 325: 597–605 (2018).

30. Bharagava, R. N., Saxena, G., Mulla, S. I., and Patel, D. K., "Characterization and identification of recalcitrant organic pollutants (ROPs) in tannery wastewater and its phytotoxicity evaluation for environmental safety", ***Archives Of Environmental Contamination And Toxicology***, 75: 259–272 (2018).

31. Chandra, R., Saxena, G., and Kumar, V., "Phytoremediation of environmental pollutants: an eco-sustainable green technology to environmental management", ***Advances In Biodegradation And Bioremediation Of Industrial Waste. CRC Press, Boca Raton***, 1–30 (2015).

32. Chandra, R., Bharagava, R. N., and Rai, V., "Melanoidins as major colourant in sugarcane molasses based distillery effluent and its degradation", ***Bioresource Technology***, 99 (11): 4648–4660 (2008).

33. Maszenan, A. M., Liu, Y., and Ng, W. J., "Bioremediation of wastewaters with recalcitrant organic compounds and metals by aerobic granules", ***Biotechnology Advances***, 29 (1): 111–123 (2011).

34. Megharaj, M., Ramakrishnan, B., Venkateswarlu, K., Sethunathan, N., and Naidu, R., "Bioremediation approaches for organic pollutants: a critical perspective", ***Environment International***, 37 (8): 1362–1375 (2011).

35. Chandra, R., "Environmental Waste Management", ***CRC Press***, (2016).

36. Mani, S. and Bharagava, R. N., "Exposure to crystal violet, its toxic, genotoxic and carcinogenic effects on environment and its degradation and detoxification for environmental safety", ***Reviews Of Environmental Contamination And Toxicology Volume 237***, 71–104 (2016).

37. Khan, S. and Malik, A., "Environmental and health effects of textile industry wastewater", ***Environmental Deterioration And Human Health: Natural And Anthropogenic Determinants***, 55–71 (2014).

38. Abubacker, M. N. and Mehala, T., "Physico-chemical analysis of textile dye effluent using microbial consortia mediated degradation process", ***Biolife***, 5 (1): 60–67 (2017).

39. Lee, Y. H., Matthews, R. D., and Pavlostathis, S. G., "Biological decolorization of reactive anthraquinone and phthalocyanine dyes under various oxidation–reduction conditions", ***Water Environment Research***, 78 (2): 156–169 (2006).

40. Jadhav, J. P., Parshetti, G. K., Kalme, S. D., and Govindwar, S. P., "Decolourization of azo dye methyl red by Saccharomyces cerevisiae MTCC 463", ***Chemosphere***, 68 (2): 394–400 (2007).

41. Shi, B., Li, G., Wang, D., Feng, C., and Tang, H., "Removal of direct dyes by coagulation: the performance of preformed polymeric aluminum species", ***Journal Of Hazardous Materials***, 143 (1–2): 567–574 (2007).

42. Anouzla, A., Abrouki, Y., Souabi, S., Safi, M., and Rhbal, H., "Colour and COD removal of disperse dye solution by a novel coagulant: application of statistical design for the optimization and regression analysis", ***Journal Of Hazardous Materials***, 166 (2–3): 1302–1306 (2009).

43. El-Gohary, F. and Tawfik, A., "Decolorization and COD reduction of disperse and reactive dyes wastewater using chemical-coagulation followed by sequential batch reactor (SBR) process", ***Desalination***, 249 (3): 1159–1164 (2009).

44. Lau, W.-J. and Ismail, A. F., "Polymeric nanofiltration membranes for textile dye wastewater treatment: preparation, performance evaluation, transport modelling, and fouling control—a review", ***Desalination***, 245 (1–3): 321–348 (2009).

45. Ciabatti, I., Tognotti, F., and Lombardi, L., "Treatment and reuse of dyeing effluents by potassium ferrate", ***Desalination***, 250 (1): 222–228 (2010).

46. Debik, E., Kaykioglu, G., Coban, A., and Koyuncu, I., "Reuse of anaerobically and aerobically pre-treated textile wastewater by UF and NF membranes", ***Desalination***, 256 (1–3): 174–180 (2010).

47. Phalakornkule, C., Polgumhang, S., Tongdaung, W., Karakat, B., and Nuyut, T., "Electrocoagulation of blue reactive, red disperse and mixed dyes, and application in treating textile effluent", ***Journal Of Environmental Management***, 91 (4): 918–926 (2010).

48. Gupta, V. K., Tyagi, I., Agarwal, S., Singh, R., Chaudhary, M., Harit, A., and Kushwaha, S., "Column operation studies for the removal of dyes and phenols using a low cost adsorbent", ***Global Journal Of Environmental Science And Management***, 2 (1): 1–10 (2016).

49. Wong, S., Ngadi, N., Inuwa, I. M., and Hassan, O., "Recent advances in applications of activated carbon from biowaste for wastewater treatment: a short review", ***Journal Of Cleaner Production***, 175: 361–375 (2018).

50. Akpor, O. B., Ohiobor, G. O., and Olaolu, D. T., "Heavy metal pollutants in wastewater effluents: sources, effects and remediation", ***Advances In Bioscience And Bioengineering***, 2 (4): 37–43 (2014).

51. Kamaruddin, M. A., Yusoff, M. S., Aziz, H. A., and Akinbile, C. O., "Recent developments of textile waste water treatment by adsorption process: a review", ***International Journal Of Scientific Research In Knowledge***, 1 (4): 60–73 (2013).

52. Birame, C. S., "Development of a Low-Cost Alternative for Metal Removal from Textile Wastewater", ***CRC Press/Balkema***, (2012).

53. Krika, F., Azzouz, N., and Ncibi, M. C., "Adsorptive removal of cadmium from aqueous solution by cork biomass: Equilibrium, dynamic and thermodynamic studies", ***Arabian Journal Of Chemistry***, 9: S1077–S1083 (2016).

54. Rajasulochana, P. and Preethy, V., "Comparison on efficiency of various techniques in treatment of waste and sewage water–A comprehensive review", ***Resource-Efficient Technologies***, 2 (4): 175–184 (2016).

55. Maria, F., Chequer, D., Dorta, D. J., and Oliveira, D. P. De, "Azo Dyes and Their Metabolites : Does the Discharge of the Azo Dye into Water Bodies Represent Human and Ecological Risks ?", (2011).

56. Uday, U. S. P., Bandyopadhyay, T. K., and Bhunia, B., "Bioremediation and detoxification technology for treatment of dye (s) from textile effluent", ***Textile Wastewater Treatment***, 75–92 (2016).

57. De Moraes, S. G., Freire, R. S., and Duran, N., "Degradation and toxicity reduction of textile effluent by combined photocatalytic and ozonation processes", ***Chemosphere***, 40 (4): 369–373 (2000).

58. Dellamatrice, P. M., Monteiro, R. T. R., and Balan, D. de S. L., "Capítulo 14-Biodegradação de corantes têxteis", ***Microbiologia Ambiental***, 647 (2008).

59. Bisschops, I. and Spanjers, H., "Literature review on textile wastewater characterisation", ***Environmental Technology***, 24 (11): 1399–1411 (2003).

60. Dos Santos, A. B., Cervantes, F. J., and Van Lier, J. B., "Review paper on current technologies for decolourisation of textile wastewaters: perspectives for anaerobic biotechnology", ***Bioresource Technology***, 98 (12): 2369–2385 (2007).

61. Industry, T., "Profile of the Textile Industry", (1997).

62. Papić, S., Koprivanac, N., Božić, A. L., and Meteš, A., "Removal of some reactive dyes from synthetic wastewater by combined Al (III) coagulation/carbon adsorption process", ***Dyes And Pigments***, 62 (3): 291–298 (2004).

63. Riera-Torres, M., Gutiérrez-Bouzán, C., and Crespi, M., "Combination of coagulation–flocculation and nanofiltration techniques for dye removal and water reuse in textile effluents", ***Desalination***, 252 (1–3): 53–59 (2010).

64. Husain, Q., "Potential applications of the oxidoreductive enzymes in the decolorization and detoxification of textile and other synthetic dyes from polluted water: a review", ***Critical Reviews In Biotechnology***, 26 (4): 201–221 (2006).

65. Hai, F. I., Yamamoto, K., and Fukushi, K., "Hybrid treatment systems for dye wastewater", ***Critical Reviews In Environmental Science And Technology***, 37 (4): 315–377 (2007).

66. Gupta, V. K., "Application of low-cost adsorbents for dye removal–a review", ***Journal Of Environmental Management***, 90 (8): 2313–2342 (2009).

67. Malik, A., "Metal bioremediation through growing cells", ***Environment International***, 30 (2): 261–278 (2004).

68. Choy, S. Y., Prasad, K. M. N., Wu, T. Y., Raghunandan, M. E., and Ramanan, R. N., "Utilization of plant-based natural coagulants as future alternatives towards sustainable water clarification", ***Journal Of Environmental Sciences (China)***, 26 (11): 2178–2189 (2014).

69. Buckner, C. A., Lafrenie, R. M., Dénommée, J. A., Caswell, J. M., Want, D. A., Gan, G. G., Leong, Y. C., Bee, P. C., Chin, E., Teh, A. K. H., Picco, S., Villegas, L., Tonelli, F., Merlo, M., Rigau, J., Diaz, D., Masuelli, M., Korrapati, S., Kurra, P., Puttugunta, S., Picco, S., Villegas, L., Tonelli, F., Merlo, M., Rigau, J., Diaz, D., Masuelli, M., Tascilar, M., de Jong, F. A., Verweij, J., and Mathijssen, R. H. J., "We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %", ***Intech***, 11 (tourism): 13 (2016).

70. Ramavandi, B. and Farjadfard, S., "Removal of chemical oxygen demand from textile wastewater using a natural coagulant", ***Korean Journal Of Chemical Engineering***, 31 (1): 81–87 (2014).

71. Meijerink, M., “Flocculation and filtration of sludge”, Master Thesis, Chemical Engineering at the University of Groningen, Groningen, 123 (2013).

72. Choy, S. Y., Prasad, K. N., Wu, T. Y., Raghunandan, M. E., and Ramanan, R. N., "Performance of conventional starches as natural coagulants for turbidity removal", ***Ecological Engineering***, 94: 352–364 (2016).

73. Chitra, D. and Muruganandam, L., "Performance of natural coagulants on greywater treatment", ***Recent Innovations In Chemical Engineering (Formerly Recent Patents On Chemical Engineering)***, 13 (1): 81–92 (2020).

74. Jahn, S. A. I. A., "Drinking water from Chinese rivers: challenges of clarification", ***Journal Of Water Supply: Research And Technology—AQUA***, 50 (1): 15–27 (2001).

75. Simate, G. S., Iyuke, S. E., Ndlovu, S., Heydenrych, M., and Walubita, L. F., "Human health effects of residual carbon nanotubes and traditional water treatment chemicals in drinking water", ***Environment International***, 39 (1): 38–49 (2012).

76. Asrafuzzaman, M., Fakhruddin, A. N. M., and Hossain, M. A., "Reduction of turbidity of water using locally available natural coagulants", ***International Scholarly Research Notices***, 2011: (2011).

77. Choy, S. Y., Prasad, K. M. N., Wu, T. Y., Raghunandan, M. E., and Ramanan, R. N., "Utilization of plant-based natural coagulants as future alternatives towards sustainable water clarification", ***Journal Of Environmental Sciences***, 26 (11): 2178–2189 (2014).

78. Tzoupanos, N. D. and Zouboulis, a I., "Coagulation-Flocculation Processes in Water / Wastewater Treatment : the Application of New Generation of Chemical Reagents", ***6th IASME/WSEAS International Conference On HEAT TRANSFER, THERMAL ENGINEERING And ENVIRONMENT***, (May 2014): 309–317 (2008).

79. Huang, C., Lin, J.-L., Lee, W.-S., Pan, J. R., and Zhao, B., "Effect of coagulation mechanism on membrane permeability in coagulation-assisted

microfiltration for spent filter backwash water recycling", ***Colloids And Surfaces A: Physicochemical And Engineering Aspects***, 378 (1–3): 72–78 (2011).

80. Lek, B. L. C., Peter, A. P., Chong, K. H. Q., Ragu, P., Sethu, V., Selvarajoo, A., and Arumugasamy, S. K., "Treatment of palm oil mill effluent (POME) using chickpea (Cicer arietinum) as a natural coagulant and flocculant: Evaluation, process optimization and characterization of chickpea powder", ***Journal Of Environmental Chemical Engineering***, 6 (5): 6243–6255 (2018).

81. Choy, S. Y., Prasad, K. M. N., Wu, T. Y., and Ramanan, R. N., "A review on common vegetables and legumes as promising plant-based natural coagulants in water clarification", ***International Journal Of Environmental Science And Technology***, 12: 367–390 (2015).

82. Abidin, Z. Z., Ismail, N., Yunus, R., Ahamad, I. S., and Idris, A., "A preliminary study on Jatropha curcas as coagulant in wastewater treatment", ***Environmental Technology***, 32 (9): 971–977 (2011).

83. Amran, A. H., Zaidi, N. S., Muda, K., and Loan, L. W., "Effectiveness of natural coagulant in coagulation process: a review", ***Int J Eng Technol***, 7 (3): 34–37 (2018).

84. Rajput, S. K., Bapat, K. N., and Choubey, S., "Bioremediation-natural way for water treatment", ***J. Biol. Chem. Research***, 29: 86–99 (2012).

85. Ramphal, S. and Sibiya, S. M., "Optimization of time requirement for rapid mixing during coagulation using a photometric dispersion analyzer", ***Procedia Engineering***, 70: 1401–1410 (2014).

86. Ding, Y., Zhao, J., Wei, L., Li, W., and Chi, Y., "Effects of mixing conditions on floc properties in magnesium hydroxide continuous coagulation process", ***Applied Sciences***, 9 (5): 973 (2019).

87. He, J., Liu, F., Ouyang, L., and Kang, X., "Optimum Operating Conditions Confirmation and Effectiveness Analysis Based on Research of the Coagulation and Precipitation Integrated Process", ***Procedia Environmental Sciences***, 10: 541–548 (2011).

88. Katayon, S., Noor, M. J. M. M., Asma, M., Ghani, L. A. A., Thamer, A. M., Azni, I., Ahmad, J., Khor, B. C., and Suleyman, A. M., "Effects of storage conditions of Moringa oleifera seeds on its performance in coagulation", ***Bioresource Technology***, 97 (13): 1455–1460 (2006).

89. Warrier, R. R., Singh, B. G., and Balaji, C., "Storage duration and temperature effects of Strychnos potatorum stock solutions on its coagulation efficiency", (2014).

90. Crini, G. and Lichtfouse, E., "Advantages and disadvantages of techniques used for wastewater treatment", ***Environmental Chemistry Letters***, 17 (1): 145–155 (2019).

91. Holkar, C. R., Jadhav, A. J., Pinjari, D. V., Mahamuni, N. M., and Pandit, A. B., "A critical review on textile wastewater treatments: Possible approaches", ***Journal Of Environmental Management***, 182: 351–366 (2016).

92. Shuokr, Q. and Sazan, M., "Characteristics, treatment techniques, and operational limitations for refinery wastewater: Review", ***Reciklaza I Odrzivi Razvoj***, 14 (1): 19–30 (2021).

93. Wang, Y., Wang, Q., Li, M., Yang, Y., He, W., Yan, G., and Guo, S., "An alternative anaerobic treatment process for treatment of heavy oil refinery wastewater containing polar organics", ***Biochemical Engineering Journal***, 105: 44–51 (2016).

94. Lakatos, G., "Biological wastewater treatment", Wastewater And Water Contamination: Sources, Assessment And Remediation, 105–128 (2018).

95. Ng, M., Dalhatou, S., Wilson, J., Kamdem, B. P., Temitope, M. B., Paumo, H. K., Djelal, H., Assadi, A. A., Nguyen-tri, P., and Kane, A., "Characterization of Slaughterhouse Wastewater and Development of Treatment Techniques: A Review", ***Processes***, 10 (7): 1–28 (2022).

96. Siddique, K., Rizwan, M., Shahid, M. J., Ali, S., Ahmad, R., and Rizvi, H., "Textile wastewater treatment options: A critical review", ***Enhancing Cleanup Of Environmental Pollutants***, 2 (11): 183–207 (2017).

97. Rathi, B. S. and Kumar, P. S., "Application of adsorption process for effective removal of emerging contaminants from water and wastewater", ***Environmental Pollution***, 280: 116995 (2021).

98. Prakash, N. B., Sockan, V., and Jayakaran, P., "Waste Water Treatment by Coagulation and Flocculation", ***Certified International Journal Of Engineering Science And Innovative Technology***, 9001 (2): 2319–5967 (2014).

99. Mohd-Asharuddin, S., Othman, N., Zin, N. S. M., and Tajarudin, H. A., "A chemical and morphological study of cassava peel: A potential waste as coagulant aid", (2017).

100. Goutam, S. P., Saxena, G., Singh, V., Yadav, A. K., Bharagava, R. N., and Thapa, K. B., "Green synthesis of TiO2 nanoparticles using leaf extract of Jatropha curcas L. for photocatalytic degradation of tannery wastewater", ***Chemical Engineering Journal***, 336: 386–396 (2018).

101. Binti Norarmi, N. F., Binti Tajudin, N. H., Binti Hafizo, N. S. H., Binti Wan Mohd Luzi, W. N. S., Binti Md. Amin, N. A., Binti Aziz, S. N. F., and Binti Haji Musa, A., "A Review on Textile and Clothing Industry Impacts on The Environment", ***International Journal Of Academic Research In Business And Social Sciences***, 12 (10): 2137–2146 (2022).

102. Yadav, A., Chowdhary, P., Kaithwas, G., and Bharagava, R. N., "Toxic metals in the environment: threats on ecosystem and bioremediation approaches", Handbook of Metal-Microbe Interactions and Bioremediation, ***CRC Press***, 128–141 (2017).

103. Mishra, S. and Bharagava, R. N., "Environmental Carcinogenesis and Ecotoxicology Reviews Toxic and genotoxic effects of hexavalent chromium in environment and its bioremediation strategies", ***Journal Of Environmental Science And Health, Part C***, 34 (1): 1–32 (2016).

104. Mani, S., Chowdhary, P., and Bharagava, R. N., "Textile wastewater dyes: toxicity profile and treatment approaches", ***Emerging And Eco-Friendly Approaches For Waste Management***, 219–244 (2019).

105. Valh, J. V., Le Marechal, A. M., Vajnhandl, S., Jerič, T., and Šimon, E., "Water in the textile industry", (2011).

106. Mittal, A., Mittal, J., Malviya, A., and Gupta, V. K., "Journal of Colloid and Interface Science Removal and recovery of Chrysoidine Y from aqueous solutions by waste materials Structure of Chrysoidine Y", ***Journal Of Colloid And Interface Science***, 344 (2): 497–507 (2010).

107. Saravanan, R., Gupta, V. K., Prakash, T., Narayanan, V., and Stephen, A., "Synthesis , characterization and photocatalytic activity of novel Hg doped ZnO nanorods prepared by thermal decomposition method", ***Journal Of Molecular Liquids***, 178: 88–93 (2013).

108. Singh, A. L., Chaudhary, S., and Yadav, A., "Decolourization, degradation and removal of heavy metals of textile effluent with the help of mixed bacterial consortium", (2017).

109. Ali, A., Saeed, K., and Mabood, F., "Removal of chromium (VI) from aqueous medium using chemically modified banana peels as efficient low-cost adsorbent", ***Alexandria Engineering Journal***, 55 (3): 2933–2942 (2016).

110. Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., and Beeregowda, K. N., "Toxicity , mechanism and health effects of some heavy metals", 7 (2): 60–72 (2014).

111. Namasivayam, C. and Sumithra, S., "Removal of direct red 12B and methylene blue from water by adsorption onto Fe (III)/ Cr (III) hydroxide , an industrial solid waste", 74: 207–215 (2005).

112. Khaled, A., Nemr, A. El, El-sikaily, A., and Abdelwahab, O., "Treatment of artificial textile dye effluent containing Direct Yellow 12 by orange peel carbon", ***DES***, 238 (1–3): 210–232 (2009).

113. Georgiou, D., Melidis, P., Aivasidis, A., and Gimouhopoulos, K., "Degradation of azo-reactive dyes by ultraviolet radiation in the presence of hydrogen peroxide", 52: 69–78 (2002).

114. Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., and Sutton, D. J., "Heavy metal toxicity and the environment", ***Molecular, Clinical And Environmental Toxicology: Volume 3: Environmental Toxicology***, 133–164 (2012).

115. Pandey, G. and Madhuri, S., "Heavy metals causing toxicity in animals and fishes", ***Research Journal Of Animal, Veterinary And Fishery Sciences***, 2 (2): 17–23 (2014).

116. Gupta, N., Yadav, K. K., Kumar, V., Krishnan, S., Kumar, S., Nejad, Z. D., Majeed Khan, M. A., and Alam, J., "Evaluating heavy metals contamination in soil and vegetables in the region of North India: Levels, transfer and potential human health risk analysis", ***Environmental Toxicology And Pharmacology***, 82 (November 2020): 103563 (2021).

117. Akpor, O. B., Ohiobor, G. O., and Olaolu, T. D., "Heavy metal pollutants in wastewater effluents : Sources , effects and remediation 2 . Sources of Heavy Metals in", 2 (4): 37–43 (2014).

118. Platzek, T., "Thomas Platzek Federal Institute for Risk Assessment, Thielallee 88-92, D-14195 Berlin, Germany", 1169–1183 (2010).

119. Muralt, L. and Nyfeler, E., "Identification of non-regulated aromatic amines of toxicological concern which can be cleaved from azo dyes used in clothing textiles", (May): (2014).

120. Morais, D., Augusto, G., Oliveira, R. De, Meireles, G., Cristina, T., Valnice, M., Zanoni, B., Palma, D., and Oliveira, D., "Toxicology in Vitro Genotoxicological assessment of two reactive dyes extracted from cotton fibres using artificial sweat", ***TOXICOLOGY IN VITRO***, (2013).

121. Mostafa, M., "Waste water treatment in textile Industries-the concept and current removal technologies", ***Journal Of Biodiversity And Environmental Sciences***, 7 (1): 501–525 (2015).

122. Sajib, M. A. M., Hoque, M. M., Yeasmin, S., and Khatun, M. H. A., "Minerals and heavy metals concentration in selected tropical fruits of Bangladesh.", ***International Food Research Journal***, 21 (5): (2014).

123. Cu, P. and Pisang, B., "ADSORPTION OF Cu , As , Pb AND Zn BY BANANA TRUNK", 20 (1): 187–196 (2016).

124. Smith, A. H., Marshall, G., Yuan, Y., Ferreccio, C., Liaw, J., Ehrenstein, O. Von, Steinmaus, C., Bates, M. N., and Selvin, S., "Research | Children ’ s Health Increased Mortality from Lung Cancer and Bronchiectasis in Young Adults after Exposure to Arsenic in Utero and in Early Childhood", 114 (8): 1293–1297 (2006).

125. Fiati Kenston, S. S., Su, H., Li, Z., Kong, L., Wang, Y., Song, X., Gu, Y., Barber, T., Aldinger, J., and Hua, Q., "The systemic toxicity of heavy metal mixtures in rats", ***Toxicology Research***, 7 (3): 396–407 (2018).

126. Walsh, G. E., Bahner, L. H., and Horning, W. B., "Toxicity of textile mill effluents to freshwater and estuarine algae, crustaceans and fishes", ***Environmental Pollution Series A, Ecological And Biological***, 21 (3): 169–179 (1980).

127. Foo, K. Y. and Hameed, B. H., "Decontamination of textile wastewater via TiO2/activated carbon composite materials", ***Advances In Colloid And Interface Science***, 159 (2): 130–143 (2010).

128. Anliker, R., "Organic colorants-, interpretation of mammalian, geno-and ecotoxicity data in terms of potential risk", ***Toxic Hazard Assessment Of Chemicals. London: Royal Society Of Chemistry***, 166–187 (1986).

129. Ali, H., "Biodegradation of Synthetic Dyes — A Review", (February): 251–273 (2010).

130. Annuar, M. S. M., Adnan, S., Vikineswary, S., and Chisti, Y., "Kinetics and Energetics of Azo Dye Decolorization by Pycnoporus sanguineus", 179–188 (2009).

131. Bae, J. and Freeman, H. S., "Aquatic toxicity evaluation of new direct dyes to the Daphnia magna", 73: 81–85 (2007).

132. Dyes, T., Toxicity, I., Zebrafish, O. N., and Life, E., "TEXTILE DYES INDUCE TOXICITY ON ZEBRAFISH EARLY LIFE STAGES", 35 (2): 429–434 (2016).

133. Ghaedi, M., Hajjati, S., Mahmudi, Z., Tyagi, I., Agarwal, S., Maity, A., and Gupta, V. K., "Modeling of competitive ultrasonic assisted removal of the dyes – Methylene blue and Safranin-O using Fe 3 O 4 nanoparticles", ***CHEMICAL ENGINEERING JOURNAL***, 268: 28–37 (2015).

134. Singh Jiwan, S. J. and Ajay, S. K., "Effects of heavy metals on soil, plants, human health and aquatic life.", (2011).

135. Adrees, M., Ali, S., Rizwan, M., Ibrahim, M., Abbas, F., Farid, M., and Zia-ur-rehman, M., "The effect of excess copper on growth and physiology of important food crops : a review", 8148–8162 (2015).

136. Nawaz, H., Akhtar, J., Anwar-ul-Haq, M., Arfan, M., Ullah, A., Iftikhar, I., Awais, M., and Nadeem, M., "Wastewater induced manganese toxicity affects growth and bioavailability in spinach (spinacia oleracea)", ***Int. J. Agric. Biol.***, 21 (1): 135–139 (2019).

137. Xie, Y., Hu, L., Du, Z., Sun, X., Amombo, E., Fan, J., and Fu, J., "Effects of cadmium exposure on growth and metabolic profile of bermudagrass [Cynodon dactylon (L.) Pers.]", ***PloS One***, 9 (12): e115279 (2014).

138. Qiu, X., Kong, Q., Zhou, M., and Yang, D., "Aggregation Behavior of Sodium Lignosulfonate in Water Solution", 15857–15861 (2010).

139. Xu, H., Yu, G., Mu, X., Zhang, C., Deroussel, P., Liu, C., Li, B., and Wang, H., "Effect and characterization of sodium lignosulfonate on alkali pretreatment for enhancing enzymatic saccharification of corn stover", ***Industrial Crops & Products***, 76: 638–646 (2015).

140. Taylor, P. and Yang, D., "Journal of Dispersion Science and Technology Structure and Properties of Sodium Lignosulfonate with Different Molecular Weight Used as Dye Dispersant Structure and Properties of Sodium Lignosulfonate with Different Molecular Weight Used as Dye Dispersant", (June 2015): 37–41 (2014).

141. Vainio, U., Lauten, R. A., and Serimaa, R., "Small-Angle X-ray Scattering and Rheological Characterization of Aqueous Lignosulfonate Solutions", 24 (18): 7735–7743 (2008).

142. Gopinatha, G., Adhikari, B., and Zisu, B., "Recovery of proteins and lipids from dairy wastewater using food grade sodium lignosulphonate", ***Water Resources And Industry***, 22 (March): 100114 (2019).

143. Yao, M., Liu, L., Qin, C., Qin, B., Deng, N., Liang, C., and Yao, S., "Mechanism and Characteristics of Oil Recovery from Oily Sludge by Sodium Lignosulfonate Treatment", (2021).

144. Shadi, M., Abujazar, S., Ugurlu, S., Ramadan, H., Abu, S. S., and Alazaiza, M. Y. D., "Application of pinecones powder as a natural coagulants for sustainable treatment of industrial wastewater", 269: 57–64 (2022).

145. Veli, S., Arslan, A., Isgoren, M., Bingol, D., and Demiral, D., "Experimental design approach to COD and color removal of landfill leachate by the electrooxidation process", ***Environmental Challenges***, 5 (November): 100369 (2021).

146. Bratby, J., "Coagulation and Flocculation in Water and Wastewater Treatment", Water 21, 25–27 (2006).

147. Ndabigengesere, A. and Subba Narasiah, K., "Quality of water treated by coagulation using Moringa oleifera seeds", ***Water Research***, 32 (3): 781–791 (1998).

148. S, A. A. S., Abujazarm, S. S., Karaağaç, S. U., Mehdi, K. K., Alazaiza, M. Y. D., Bashir, M. J. K., Fatihah, S., and Vakili, A. H., "Factorial design and optimization of date stone as a natural coagulant for organic and heavy metals removal from industrial wastewater", 25 (1): 99–107 (2023).

149. Salehizadeh, H. and Shojaosadati, S. A., "Extracellular biopolymeric flocculants: recent trends and biotechnological importance", ***Biotechnology Advances***, 19 (5): 371–385 (2001).

150. He, N., Li, Y., Chen, J., and Lun, S. Y., "Identification of a novel bioflocculant from a newly isolated Corynebacterium glutamicum", ***Biochemical Engineering Journal***, 11 (2–3): 137–148 (2002).

151. Ramavandi, B. and Farjadfard, S., "Removal of chemical oxygen demand from textile wastewater using a natural coagulant", ***Korean Journal Of Chemical Engineering***, 31: 81–87 (2014).

152. Chua, S. C., Malek, M. A., Chong, F. K., and Sujarwo, W., "Red Lentil (Lens culinaris) Extract as a Novel Natural Coagulant for Turbidity Reduction : An Evaluation , Characterization and Performance Optimization Study", (Iii): 1–19 (2019).

153. Sun, S., Li, M., Yuan, T., Xu, F., and Sun, R., "Effect of ionic liquid / organic solvent pretreatment on the enzymatic hydrolysis of corncob for bioethanol production . Part 1 : Structural characterization of the lignins", ***Industrial Crops & Products***, 43: 570–577 (2013).

154. Smith, A., et al., "Environmental Impact of Textile Industry Wastewater", ***Journal Of Environmental Chemistry***, 25(3): 145-162. (2018).

155. Kawamura, S., "Considerations on Improving Flocculation", (1976).
156. Dotto, J., Fagundes-Klen, M. R., Veit, M. T., Palácio, S. M., and Bergamasco, R., "Performance of different coagulants in the coagulation/flocculation process of textile wastewater", ***Journal Of Cleaner Production***, 208: 656–665 (2019).

157. Fard, M. B., Hamidi, D., Alavi, J., Jamshidian, R., Pendashteh, A., and Mirbagheri, S. A., "Saline oily wastewater treatment using Lallemantia mucilage as a natural coagulant: Kinetic study, process optimization, and modeling", ***Industrial Crops And Products***, 163: 113326 (2021).

158. Aragaw, T. A. and Bogale, F. M., "Role of coagulation / fl occulation as a pretreatment option to reduce colloidal / bio-colloidal fouling in tertiary fi ltration of textile wastewater : A review and future outlooks", (April): (2023).

159. Black, P. and Hannah, S. A., "Electrophoretic Studies of Turbidity Removal by Coagulation With Aluminum Sulfate", 438–452 .

160. Palma, G., Freer, J., and Baeza, J., "Removal of metal ions by modified Pinus radiata bark and tannins from water solutions", ***Water Research***, 37 (20): 4974–4980 (2003).

161. Schofield, P., Mbugua, D. M., and Pell, A. N., "Analysis of condensed tannins: a review", ***Animal Feed Science And Technology***, 91 (1–2): 21–40 (2001).

162. Palma, G., Freer, J., and Baeza, J., "Removal of metal ions by modified Pinus radiata bark and tannins from water solutions", ***Water Research***, 37 (20): 4974–4980 (2003).

163. Mangrich, A. S., Doumer, M. E., Mallmannn, A. S., and Wolf, C. R., "Green chemistry in water treatment: use of coagulant derived from Acacia mearnsii tannin extracts", ***Revista Virtual De Quimica***, 6 (1): 2–15 (2014).

164. Brown, C., & Johnson, E., "No TitleAnalysis of Industrial Wastewater Parameters in Textile Factories.", ***Environmental Science Reports***, 42(2),: 201–215 (2019).

165. Diaz, A., Rincon, N., Escorihuela, A., Fernandez, N., Chacin, E., and Forster, C. F., "A preliminary evaluation of turbidity removal by natural coagulants indigenous to Venezuela", 35: 391–395 (1999).

166. Okuda, T., Baes, A. U., and Nishijima, W., "ISOLATION AND CHARACTERIZATION OF COAGULANT EXTRACTED FROM MORINGA OLEIFERA SEED BY SALT SOLUTION", 35 (2): 405–410 (2001).

167. Sanghi, R., Bhatttacharya, B., Singh, V., and Testing, A., "Cassia angustifolia seed gum as an effective natural coagulant for decolourisation of dye solutions Green Context", (2002).

CURRICULUM VITAE

I obtained a bachelor's degree in water and environment management / Faculty of Natural Resources and Environment, with an excellent grade from the Hashemite University in Jordan in 2017. During my studies, I received training in:1) Ministry of Water and Irrigation laboratories for drinking water and wastewater tests. 2) A private contracting company in drinking water and wastewater treatment plants of various technologies. 3) Administrative and field training of the Water Authority. After graduation, I worked in a contracting and construction company specialized in water networks for 4 years. In 2022 I started studying for a master's degree at the Karabuk University Institute of Graduate Studies, Department of Environmental Engineering.