Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Environmental Engineering Post Graduate Program

Removal of river water pollutants using indigenous bio coagulants: optimization by central composite design (CCD).

By: Sebilewongel Milargh

A thesis submitted to the Faculty of Civil and Environmental Engineering of Jimma University Jimma Institute of Technology in Partial Fulfillment of the Requirements for the degree of Masters of Science in Environmental Engineering.

January, 2019

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Advisor: Prof., Dr.-Ing Esayas Alemayehu.

Co-advisor: Dr.P. Asaithambi

January, 2019

Jimma, Ethiopia

DECLARATION

I, Sebilewongel Milargh declare that, this thesis is my original work and it is not presented previously published by another person or which has not been accepted for the award of any other academic degree of the University, except I have been used their materials as a reference and cite in the reference part of this document.

	Signature	Date
Sebilewongel Milargh	__________	_________

This research has been submitted for examination with my approval as university supervisors

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Advisor: Prof., Dr.-Ing Esayas Alemayehu.	____________	__________
Co-advisor: Dr.P. Asaithambi	___________	_________

ABSTRACT

Water is one of the most precious natural resource, it is very extensively used by mankind. It is an important and essential component of this universe and plays a vital role in the proper functioning of the Earth's ecosystems. In an era of increasing environmental concerns, water scarcity admits the draw backs of chemical coagulants and poor sanitary facilities in lowest income earning countries, the need to further develop natural coagulants as alternative environmentally favorable water treatment chemicals. Therefore, this study was conducted to investigate the surface water treatment potentiality of two natural coagulants, cactus(beles) and Moringa stenopetala (seed of shiferaw). To conduct this study natural coagulants were collected from local areas and grab or hand sampling technic was used to collect surface water sample from awetu river. Based on this, coagulation and flocculation treatment process were applied by using jar test apparatus to simulate the results. Design expert (11.0) was used for statistically analyzing the experimental data with ANOVA and to evaluate the optimum condition or value of both process factors with respective responses. So according to the experimentally analyzed result, the optimum conditions and responses obtained from the numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 2.5, 1.17g, 83.19rpm and 42.1min respectively when cactus powder was used as a natural coagulant. Under this optimum conditions, about 70.22%, 47.10 % and 83.80% for color, COD and turbidity removal efficiency was obtained respectively. And also in the same manner when Moringa stenopetala used as a natural coagulant, the optimum conditions and responses obtained from numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 10, 0.602g, 30.00rpm and 36.56 minute respectively. Then under this optimum condition, about 99.40%, 56.13%, and 96.56%, for color, COD and turbidity removal efficiency was obtained respectively. The effective results were found using moringa stenopetala.

Keywords: Coagulation and Flocculation, Bio coagulants, Color, COD and Turbidity removal, Central composite design, Optimization, Surface water.

ACKNOWLEDGEMENTS

First of all, I would like to thank my Almighty GOD as he made all things are possible to me throughout my life.

I would like to express my deepest gratitude to my advisors Professor Doctor Engineer Esayas Alemayehu and Doctor Asaithambi Peruma for their permission to complete this study in this title and their well-organized advice throughout the study.

And also, I would like to say thanks for all my best friends those support, advice and encourage me to do and accomplish this work at this time.

My next gratitude goes to Jimma University, Jimma institute of Technology for allowing me to take part in the Graduate Study Program of Environmental Engineering

Finally, I would like to thank all my families who always being in the side of me next to GOD by giving moral encouragement and by sharing my stress.

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ACRONYEMS

ANOVA	Analysis of Variance
APHA	American Public Health Association
BBD	Box-Behnken Design
BOD	Biochemical Oxygen Demand
CCD	Central Composite Design
COD	Chemical Oxygen Demand
DoE	Design of Expert
EPA	Environmental Protection Agency
FAS	Ferrous Ammonium Sulphate
MCL	Maximum Contamination Level
NOM	Natural Organic Matter
NTU	Nepheloturbidity Unit
PCP	Personal Care Products
RSM	Response Surface Methodology
TDS	Total Dissolved Solid
TS	Total Solid
TSS	Total Suspended Solid
UV/V	Ultraviolet Visible
WHO	World Health Organization
WW	Waste Water

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Water is one of the most precious natural resource, it is very extensively used by mankind. It is an important and essential component of this universe and plays a vital role in the proper functioning of the Earth's ecosystems (Alemayehu and Lennartz, 2009). Water covers 75% of the blue planet, it is distributed in the form of oceans, rivers, lakes. In spite of that, only a small part of this water – in the order of 113 trillion m3 is available to life on Earth (Thakur and Choubey, 2014). Water is the elixir of life as there is no life without water and the rivers are the life line of our economy and culture (Panda *et al*., 2018).

Water is needed for meeting consumptive demands, which include agricultural, domestic and industrial use and no consumptive demands which comprise in-stream use (navigation, fisheries, salinity control and dilution of pollution) and water required for ecological protection and wetland preservation (Nadira and Shixiang, 2018). Water is one of the most vital natural resources for all life on Earth. Water is also considered to be one of the most abundant commodities in nature but also misuse one (Zandagba *et al*., 2017). However, water can be problematic if it is not available in the right conditions. Water is used by human for various purposes; therefore, the cleanliness of water consumed is very important since water is known to affect the health (Hendrawati *et al*., 2016).

Coagulation is one of the most common ways to reduce the pollutant contents in the water body that are present as turbidity, color and organic matters. Coagulation is also used to reduce the metal ion content in water. Separation of these colloids can be done by the addition of synthetic coagulant or bio coagulant followed by slow agitation (flocculation) that causes coagulation of colloidal particles so they can be separated by sedimentation. Coagulation happens when coagulant reduces repulsive force of electrical double layers on colloids surface that it is function to push between one and another, furthermore, it cause the particles join to form a larger floc(Abd Wahid *et al*., 2016).The significance of coagulation – flocculation in the area of water and wastewater treatment is reviewed and evaluated, emphasizing on the series of applications employed, including destabilization of colloids, removal of inorganic and organic matter (particulate and/or dissolved), removal of metals and anions (arsenic, phosphate etc.), as well as removal of pathogen microorganisms(Tzoupanos and Zouboulis, 2008).

The coagulation activity is studied using four parameters: pH, dosage, COD and turbidity and the effect of variation of dosage and pH were studied on turbidity and COD. Turbidity and COD of all samples were studied and the efficiency of all the coagulants was recorded (Muruganandam *et al*., 2017). Coagulation and flocculation is simple and rapid technique. This is most often used pretreatment technique to treat the effluent. Coagulation/flocculation process has been found to be cost effective, easy to operate and energy saving treatment alternatives. Coagulant dosages vary in a wide range aiming at maximum removal efficiency of pollutants using minimum doses at optimum pH (Amuda *et al*., 2006).

The coagulation process proves a high removal efficiency of different parameters, mainly chemical oxygen demand (COD) and suspended solids (Guida *et al*., 2007). Coagulation is a process for combining particles (colloidal and suspended) and/or dissolved organic matter into large aggregates, thereby facilitating their removal in subsequent sedimentation/flotation and filtration stages (Zhou *et al*., 2008). Coagulation is the destabilization of a colloid from neutralization of the electric charge and aggregation of fine particles in suspension. Flocculation involves an increase in the contact among fine particles to form flocs that settle easily. These processes are carried out by means of chemical compounds that are added to the WW (Carpinteyro-Urban, and Torres, 2013). Coagulation–flocculation is widely used for wastewater treatment, as it is efficient and simple to operate. In this process, many factors can influence its efficiency, such as the type and dosage of coagulant/flocculent, pH, mixing speed and time, temperature and retention time (Fendri *et al*., 2013). The optimization of these factors may significantly increase the process efficiency. Coagulation is a common process used for removing suspended matter from water. The physical phenomenon of destabilization of colloids is induced by several chemical agents. However, this process is normally very slow, so some chemical products (usually synthetic polyelectrolytes like polyacrylamides) are added to water in order to accelerate the coagulation Process by increasing floc size (Sánchez - Martín *et al*., 2012).

The common methods of water purification using synthetic materials such as aluminum sulfate (alum) and calcium hypochlorite are not efficient, because these materials are imported and thus make the water cost becomes relatively expensive in most economically developed countries and is not affordable for most rural population (Hendrawati *et al*., 2016).Besides synthetic chemicals, there are natural ingredients that can be derived from tropical plants which can be used as coagulants, including Moringa seeds (*Moringa oleifera*). The use of natural ingredients from local indigenous plants to clear muddy water is not a new idea. The effectiveness of coagulation depends on the coagulating agent used, the dosage, the solution pH, the concentration and the nature of the organic compound present in water.

The widely used coagulants are iron and alum salts (Sher *et al*., 2013). The aluminum salts are commonly used coagulants for water and wastewater treatment. One of the most widely used coagulants is aluminum sulphate (alum), due to its low cost, ease of use, handling, storage and mixing properties. The coagulation process with alum as the sole coagulant is capable of achieving significant organic removal. The pH of the water during coagulation has profound influences on effectiveness of coagulation for organic removal (Sahu and Chaudhari, 2013). Iron compounds possess pH coagulation ranges and floc characteristics similar to aluminum sulfate. The cost of iron compounds may often be less than that of alum.

However, the iron compounds are generally corrosive and often present difficulties in dissolving, and their use may result in high soluble iron concentration in process effluents. The most commonly used method for evaluating and optimizing the coagulation flocculation processes is the jar test. This study consists of a series of simultaneous batch experiments involving three stages, namely, rapid mixing, slow mixing, and sedimentation (Muruganandam *et al*., 2017). Jar testing is a pilot-scale test of the treatment chemicals used in a particular water plant. It simulates the coagulation/flocculation process in a water treatment plant and helps operators determine if they are using the right amount of treatment chemicals, and, thus, improves the plant's performance (Zane Satterfield, 2005). Another important reason to perform jar testing is to save money. One of the common problems in water treatment is overfeeding or overdosing, especially with coagulants. This may not hurt the quality of water, but it can cost a lot of money. One of the easiest things an operator can do for optimization of the plant is jar testing, and jar testing is a must when looking at best available technologies.

Majority of the wastewater treatment processes are multi-variable and optimization through the classical method is inflexible, unreliable and time-consuming. Thus, an alternative method which will be more effective and can be adapted for parameter optimization of various wastewater treatment processes is favored (Bashir Mohammed *et al*., 2015). Optimizing refers to improving the performance of a system, a process, or product in order to obtain the maximum benefit from it. The term optimization has been commonly used in chemistry as a means of discovering conditions at which a procedure produces the best possible response (Azami *et al*., 2012).

The central composite design (CCD) for the response surface methodology (RSM) approach is used to develop a mathematical model and to optimize the parameters of the flocculation process in terms of optimal removal of chemical oxygen demand (COD), total suspended solids (TSS), and turbidity. The RSM is a statistical technique for designing experiments, building models, evaluating the effects of several factors and searching optimum conditions for desirable responses. With RSM, the interactions of possible influencing parameters on treatment efficiency can be evaluated with a limited number of planned experiments (Khannous *et al*., 2011).

RSM has been proposed to determine the influence of individual factors and their interactive influence. It uses an experimental design such as the central composite design (CCD) in order to fit a modeling by the least squares technique, and the adequacy of the proposed model is then revealed using the diagnostic checking tests (Birjandi *et al*., 2016). One of the main objectives of RSM is the determination of the optimum settings of the control variables that result in a maximum (or a minimum) response over a certain region of interest, R. This requires having a 'good' fitting model that provides an adequate representation of the mean response because such a model is to be utilized to determine the value of the optimum. Optimization techniques used in RSM depend on the nature of the fitted model (Morshedi and Akbarian, 2014).

1.2 Statement of the problem

Surface water that we endowed from our natural water resources including streams, rivers, lakes, oceans and ponds are mostly seen as contaminated. This mainly as a result of both directly and indirectly by manmade and naturally occurring activity. And also these surface water used us for a recreation, as a water supply for different purposes. Due to its application increase time to time as industrialization and population increament, it must be clean for those applications in order to be safe for human health as well as for proper ecological functioning.

Among the pollution results that contributed from different sources to surface water pollution are color, turbidity and COD. So unless these pollutants reduced from surface water it causes cloudy color due to the presence of colloidal particles and colorfulness due to releasing of different types of wastes from different sources. Generally, all these leads to make surface water unsafe for the users. It also contains organic pollutants that if it is not reduced that disturb aquatic life and making the surface water unsafe for the whole ecosystem.

Treating such type of surface water by chemical coagulants such as alum (aluminum sulfate), synthetic organic polymers, ferric chlorides are effective but it has some limitations such as cost, have residual effects on treated water, secondary pollution on the environment since it results non degradable sludge and are suspected to induces Alzheimer's diseases, carcinogenetic and neurotoxic effects. As a study conducted by Yongabi (Yongabi, 2010) states that, in an era of increasing environmental concerns, water scarcity admist the draw backs of chemical coagulants and poor sanitary facilities in lowest income earning countries, the need to further develop natural coagulants as alternative environmentally favorable water purifying chemicals is exigent.

Ecologically, the use of synthetic coagulant produces a certain amount of sludge sediment that is a pollutant for environment because the sludge is relatively difficult to degrade and can change the component of soil and water minerals from normal condition (Hendrawati, 2015). In addition, the use of such coagulant in continuous manner leads to dependency on the producers of synthetic coagulant.

In addition to all, it is important to improve the performance of the systems and to increase the yield of the processes without increasing the cost. The method used for this purpose is called optimization. In general, coagulation and flocculation with the use of natural coagulants for the removal of pollutants from water were encouraged by different investigators and confirmed in terms of their efficiency. Therefore, this study was try to investigate the effectiveness of cactus and Moringa powder by conducting preliminary experiments on color, COD and turbidity reduction efficiency by optimize the process using RSM in order to determine the optimum condition of the factors and value of the response, this important to reduce over dosage or under dosage problems, finally implies well performance of the process and economical safety was achieved.

1.3 Objectives

1.3.1 General objective

The general objective of this study was to investigate the application of indigenous bio coagulants for the removal of surface water pollutants by optimizing the process using central composite design (CCD).

1.3.2 Specific objectives

The specific objectives of this study were to:

1. Characterize specific parameters of surface water sample in terms of color, COD and turbidity.

2. Optimize pollutants removal efficiency at optimum condition of design parameters.

3. Determine the interactive effect of design parameters using RSM.

4. Compare the efficiency of selected natural coagulants in terms of each response using both experimental and optimized value.

1.4 Research questions

1. Why specific parameters of surface water sample were characterized in terms of color, COD and turbidity?

2. How pollutants removal efficiency was optimized at optimum condition of design parameters?

3. What are the design parameters and how their interactive effect was determined?

4. How the efficiency of selected natural coagulants was compared and which one is more effective?

1.5 Significance of the study

Several studies indicated that bio coagulants are locally available and environmental friendly so it is sustainable for the environment. So this study confirms the effectiveness of selected natural coagulants for surface water color, COD and turbidity reduction. This leads us to have a confidence on natural coagulants in order to treat water by coagulation flocculation process. And also I can say, using natural coagulants for surface water treatment encourage the investigator weather to investigate another natural coagulant or initiate to go ahead on another water/ waste water pollutant parameter using cactus and moringa. And also since optimization was considered in this study, the optimum condition and value of both process factors and responses determined, so no dosage problem, well performance of the process and production of more sludge was reduced. Generally using natural coagulants are sustainable in terms of cost reduction, health benefits and environmentally sustainable.

1.6 Scope of the study

Color, COD and turbidity are the most common surface water constituents even if there are many types of physical, chemical and biological parameters. Therefore, this study was limited to analyzing the potentiality of selected natural coagulants and conformation of their effectiveness by conducting preliminary experiment on color, COD and turbidity removal efficiency, optimizing the process and determination of the more efficient one, showing the interactive effect of process parameters on the response using three dimensional (3D) surface based on RSM.

CHAPTER 2

LITRATURE REVIEW

2.1. Introduction

Coagulation which is a part of the water treatment process nowadays still depends on alum as the coagulation agent due the economical and the availability. Coagulation process is the first step to destabilize the particle's charge. Coagulants with charge opposites to those of the suspended particles are added to the water to neutralize the negative charges on dispersed on-settle able solids. The neutralization assists by high energy rapid mixing promotes particle collision and thus causes the small suspended particles to stick together (Abidin *et al*., 2014). Coagulation is an essential process for the removal of suspended and colloidal material from water and wastewater. However, no comprehensive or universally accepted mathematical description of the process has been developed so far. Therefore, process optimization and control is usually based on data from jar tests and simple flow proportional dosing concepts, while more accurate concepts based on water quality parameters that can be measured online are emerging (Ratnaweera and Fettig, 2015).

Coagulants are used that added to the water to withdraw the forces that stabilizes the colloidal particles and causing the particles to suspend in the water. Once the coagulant is introduced in the water, the individual colloids must aggregate and grow bigger so that the impurities can be settled down at the bottom of the beaker and separated from the water suspension. Various types of coagulants show potential application in treating water and wastewater. It ranges from chemical to non-chemical coagulant. The coagulant also could be synthetic material or natural coagulant with the properties of coagulant having +vecharge, these positive charge proteins would bind to the -ve charged particles in the solution that cause turbidity (Kumar *et al.*, 2017).

2.2. Critique of existing literature review relevant to the study

Surface water, the water obtained from streams, rivers, lakes, ponds etc., requires treatment to make it safe for human consumption. Surface water is almost always contaminated by people and animals who defecate in or near the water (Yongabi, 2010). The quality of surface waters is a very sensitive issue. Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, and weathering of crustal materials) degrade surface waters and impair their use for drinking, industrial, agricultural, recreation or other purposes. Due to spatial and temporal variations in water chemistry a monitoring program that will provide a representative and reliable estimation of the quality of surface waters is necessary (Simeonov *et al*, 2003).

Chemical coagulants such as aluminum sulphate, Synthetic organic polymers, Ferric chloride used in water treatment process it induces Alzheimer's diseases, carcinogenic and neurotoxic effects. However, the application of these treatment processes has been found to be sometime restricted because of expensive investment operational costs potential generation of secondary pollution and its disposal is not ecofriendly. One possible solution to these problems which are preferably extracted from natural and renewable sources such as microorganisms, animals or plants (Sasikala and Muthuraman, 2015).

In many developing countries, access to clean and safe water is a major problem. Poor water quality is a key cause of poor livelihood and poor health. Surface water either from rivers or rain fed ponds and lakes has become one of the main sources of water supply. This water is vulnerable to various forms of pollution generated from different sources mainly households and agriculture (Pastay *et al*., 2017). Securing safe water and reducing the unregulated discharge of wastewater are among the underlying concept of wastewater management (WHO, 2008). Unmanaged wastewater has far reaching implications for the health of all aquatic ecosystems, which threatens to demine the resilience of biodiversity and ecosystem services on which human wellbeing depends (Corcoran *et al*., 2010). In an era of increasing environmental concerns, water scarcity admist the draw backs of chemical coagulants and poor sanitary facilities in lowest income earning countries, the need to further develop natural coagulants as alternative environmentally favorable water purifying chemicals is exigent (Yongabi, 2010).

Pollution of water streams causes due to by different inorganic, organic and biological contaminates, among which pesticides are very common and introduced due to agriculture source, represents a serious environmental problem (Turkar *et al*., 2011). Nowadays, the quality of drinking water is degrading due to large scale application of agrochemicals, direct pollution by untreated sewage and infiltration of effluent from sewage treatment plants and storage pits. However, the efficiency of existing water treatment systems to remove potential pollutants from the above sources in different seasons was not clearly known (Sisay *et al*., 2017).

Natural coagulants are mostly carbohydrates (polysaccharides) and proteins (Yin, 2010). They are polymeric compounds that can have even ionic or no ionic character (cations or anions), where the ionic ones are commonly known as polyelectrolytes. The principal advantages of the implementation of natural coagulants are the following: Organic and inorganic turbidity removal, reduction of true and apparent color, production of easy to deal with sludge, destruction of pathogens, algae and planktons, as well as the elimination of substances imparting odor and flavor (Rodiño-Arguello *et al*., 2015).

The long-term viability of the natural environment should be maintained to support long term development by supplying resources and taking up emissions. This should result in protection and efficient utilization of environmental resources (Balkema *et al*., 2002). Wastewater reuse is an integral part of water demand management, promoting the protection of high quality fresh water and reducing both environmental pollution and overall supply costs (Shakir *et al*., 2017). Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrient and toxic compounds (Singh *et al*., 2011).The presence of high concentrations of these pollutants above the critical value stipulated by national and international regulatory bodies is considered unacceptable in receiving water bodies (Akpor and Muchie, 2011).The major concern with color is its aesthetic character at the point of discharge with respect to the visibility of the receiving waters (Solmaz *et al*., 2006). Pollution and over-extraction have placed the world's freshwater resources in a state of crisis, and the discharge of polluted and nutrient-laden freshwater to the sea is putting marine systems, particularly coastal waters, under significant stress (Hamilton *et al*., 2006).

High level of COD indicates the presence of chemical oxidants in the effluent. This process would likely cause nutrient fixation in the soil as well and could result to reduced rate of nutrient availability to plants (Chukwu, 2008). In addition, chemical oxidation affects water treatment plants by causing rapid development of rust. This would reduce the service life of the plant. Disposal of such waste into water could reduce the level of oxygen thereby threatening aquatic lives. The technology of using natural coagulants for treatment of water is most appropriate in developing countries, especially in rural areas, where they cannot afford the high cost of conventional coagulants (Bodlund, 2013). Removal of suspended and colloidal material from water and wastewater requires the application of inorganic or organic coagulants for destabilization and subsequent flocculation and separation (Ratnaweera and Fettig, 2015).

The physiochemical principle behind coagulation is the reduction of the repulsive electrical potential between typically electronegative colloidal particles in water, such as color, NOM, microorganisms, clays, etc., in such a way that the coagulant causes these suspended, dispersed particles to destabilize and agglomerate to form large, dense structures (flocs) that will precipitate and sediment (Abebe *et al.*, 2016).

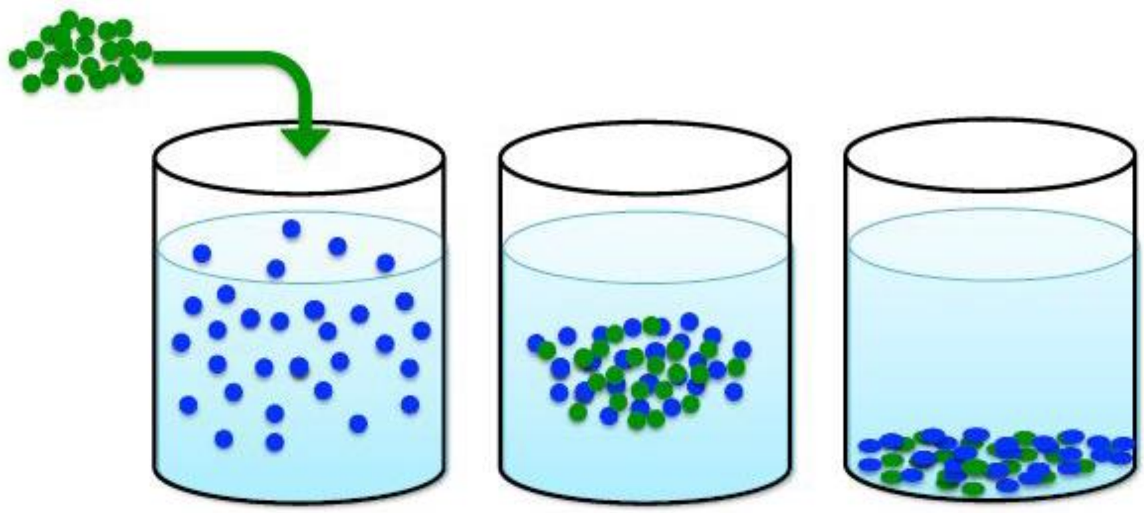


Figure 2.1 Coagulation and flocculation mechanism with coagulants (Bodlund, 2013).

As figure 2.1 shows that the first beaker filled by sample water with any pollutant particles indicated by blue color and the above green arrow inters in to this beaker show the coagulant needed to be dosed for treatment of the sample water using coagulation flocculation process. The second beaker show when coagulants added it makes dispersion with pollutant particles and make floc formation and agglomeration due to the presence of opposite ions between the coagulant particle and the pollutant particle. The third beaker indicates the sedimentation of flocs at the bottom of the container in the form of sludge and the formation of the supernatant.

2.3 Comparative study of bio coagulants with synthetic coagulants

The comparation of bio coagulants with chemical coagulants were in terms of their respective advantage and dis advantage. This comparation involves the availability, cost of coagulants, ecofriendly conditions, sludge productions and degradability, residual effects on human health as well as on the environment.

2.3.1 Advantage of bio coagulants over synthetic coagulant

The choice of natural bio-coagulants over the chemical – based coagulants such as: aluminum sulphate, ferric chloride, polyaluminum chloride and synthesis polymers stem from the fact that they are cost effective, abundance in availability, environmentally friendly, biodegradable, medically potent, low sludge productivity and increased pH (Agunwamba *et al.*, 2016). Natural coagulants have bright future and are concerned by many researchers because of their abundant source, low price, environment friendly, multifunction, and biodegradable nature in water purification (Asrafuzzaman *et al*., 2011).

Synthetic polyelectrolytes are cuestionated due to the toxicity and carcinogenetic potential of the mono- mers used for their synthesis. Therefore, it is need to progressively replacement of these inorganic and organic coagulants with alternative natural coagulants. Natural coagulants (bio-polymers) would be of great interest since they are natural low cost products, characterized by them environ-mentally friendly behavior, and presumed to be safe for human health (Thakur and Choubey, 2014). The merits of natural coagulant over chemical coagulant are illustrated in the figure given below.

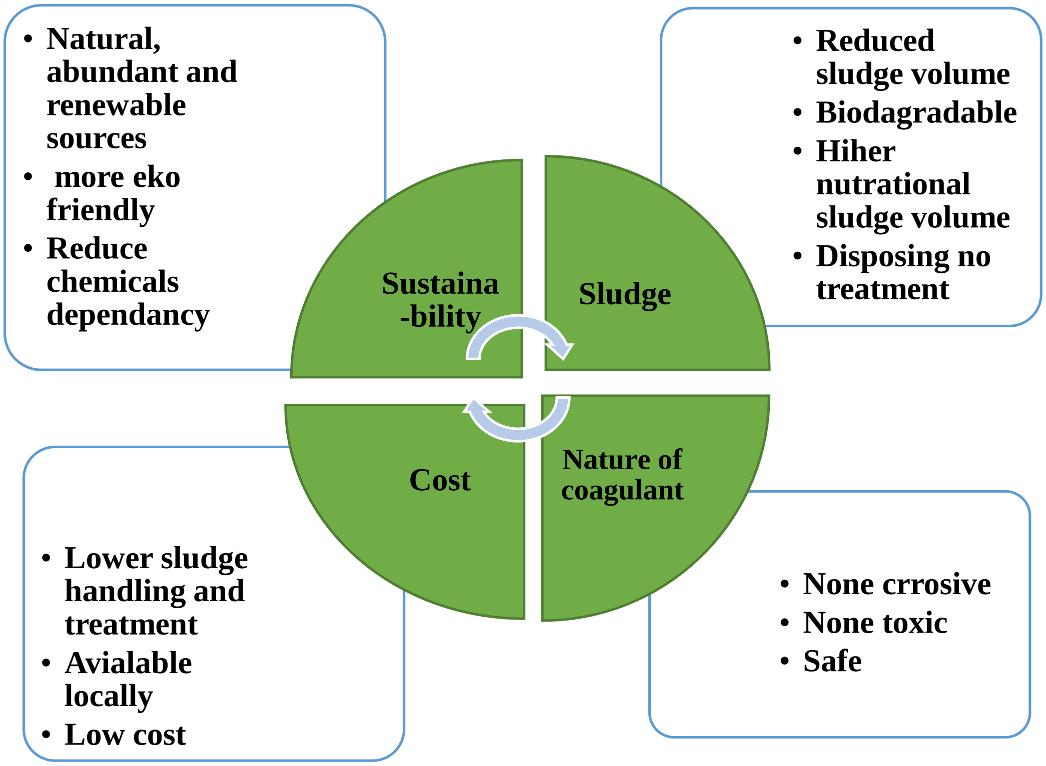


Figure 2.2 Advantages of natural coagulants over chemical coagulants (Nandini and Sheba, 2016).

Utilization of alum has raised a public health concern because of the large amount of sludge produced during the treatment and the high level of aluminum that remains in the treated water. The intake of large quantity of alum salt may cause Alzheimer disease. For these reasons, and also due to others advantages of natural coagulants/flocculants over chemicals, developing countries adopted the use of natural polymers in the treatment of surface water for the production of drinking water (Shilpa *et al*., 2012).

Chemical coagulants are used for the treatment of wastewater from various industries like tannery, textile, and meat processing, and so on. But the disadvantages associated with usage of these chemical coagulants, such as high operation costs, ineffectiveness in low temperature water and large sludge volume, significantly affect the pH of the treated water and considerable effects on human health like Alzheimer's disease. To overcome these difficulties, the desirable alternate for this chemical coagulant is natural, plant-based coagulants. The main advantages of using this are the following: material is eco-rich, cost effective, highly biodegradable and toxic-free treated water and low sludge volume (Vishali and Karthikeyan, 2014). Natural coagulants have been reported to have several advantages compared to Alum. Natural coagulants produce much lower sludge volume, the natural alkalinity is not consumed during the treatment process, they are biodegradable, safe to human health, cost effective since they can be locally grown and have a wider effective dosage range for flocculation of various colloidal suspensions (Abatneh *et al.*, 2014). These merits underscore the environmental and sustainability gains that would be made upon embracing natural coagulants in treating wastewater. The study concludes that natural coagulants are equally effective in treating water and are also unlikely to alter the pH of treated water (Karanja, et al, 2017).

2.3.2 Disadvantage of bio coagulants

Beyond their advantages over Alum, natural coagulants have also limitation. For instance, they increase organic load in the water which tend destabilization to occur (Megersa *et al.*, 2014). In addition, water treated with natural coagulants (e.g. Moringa) was reported only used for 24 hours and inefficiency of treating low turbid water is another problem. One of the problems in the use of plant-based coagulants is the substantial increase in the organic load of the treated water, which may result in undesired and increased microbial activities, having serious implications on subsequent disinfection processes using chlorine. Organic matter is regarded as the source of odor, color, and taste (Choy *et al*., 2014; Oladoja 2015). These organic matters might act a precursor of trihalomethanes (THMs), of which many are carcinogenic and also require chlorine treatment (Anastasakis *et al*., 2009).

2.4 Coagulation and flocculation process for pollutant removal technology

Research and practical applications have shown that coagulation will lower the pollution load and could generate an adequate water recovery (Fendri *et al*., 2013).Coagulation/flocculation is a commonly used process in water and wastewater treatment in which compounds such as coagulant are added to wastewater in order to destabilize the colloidal materials and cause the small particles to agglomerate into larger settle able flocs (Daud *et al*., 2015).Although the terms coagulation and flocculation are often used interchangeably, or the single term "flocculation" is used to describe both; they are, in fact, two distinct processes (Jagaba *et al*., 2016).

The coagulation process proves a high removal efficiency of different parameters, mainly chemical oxygen demand (COD) and suspended solids (Guida *et al*., 2007). Coagulation and flocculation is simple and rapid technique. This is most often used pretreatment technique to treat the effluent (Rao *et al*., 2015). Coagulation Flocculation in general is a two phase process aimed at removing stable particles by forming larger aggregates that can be separated from the aqueous phase by a subsequent separation step (Harif *et al*., 2012). Among the various physicochemical and biological methods of textile wastewater treatment, coagulation flocculation is considered as an attractive and favorable technique because of its low cost, easy operation and high efficiency (Amini *et al*., 2017).

Physico- chemical methods are effective when pollution level is low but depend upon the chemical used (Anteneh and Sahu, 2014). The coagulation is widely used in wastewater treatment and the operating cost is low (Daud *et al*., 2016). Rapid mixing is practiced during coagulation; a unit process, whereby chemical coagulants are mixed with raw water to facilitate particle destabilization (Ramphal and Sibiya, 2014). From the historical point of view, the processes of coagulation were designed primarily for reducing turbidity, and then the reduction of organic matter was a goal of coagulation because organic constituents have on water bio stability (Radhi *et al*., 2017). This technology is used as primary treatments for removal of particulate matter and organic matter effectively. The process is very efficient in removal of total solids (TS), Total suspended solids (TSS), total dissolved solids (TDS) and chemical oxygen demand (COD), Color (Borchate *et al*., 2014).

The major advantage of chemical treatment is that most of the COD and TSS are being reduced during this process therefore it can lead to make it more cost effective before secondary treatment as well as removal of color for effluent (Irfan *et al*., 2017).The cost of chemical coagulation is low, cheapness and widely used in treating wastewater (Han W.Q *et al*., 2008).Coagulation/flocculation process may be used as a pretreatment prior to biological treatment in order to enhance biodegradability of the wastewater during the biological treatment (Amuda and Amoo, 2006). Coagulation and flocculation process can remove COD, turbidity, color and metals with high efficiencies depending on contaminant and coagulant/flocculants type (Vermaa *et al*., 2016). The inherent disadvantage to this process is the generation of large quantities of chemical sludge and its classification as hazardous waste, necessitating the need for secured land filling of hazardous solid waste (Sahu and Chaudhari, 2013).

2.5 Natural coagulants used for this study

2.5.1 Cactus

Cactus is one of the drought tolerant species and has a number of applications. It is used as a source of food, forage, soil conservation purpose. Cactus serves as raw material for cosmetic products like shampoo, soap, and cream and body lotion. Adhesive and glues, pectins, fibers for hand crafts and papers can be made from cactus; the vegetative material is used with bovine manure as an anaerobic digestion accelerator to produce biogas (Belay, 2015). The multi-purpose uses of cactus empower the rural population to better face the challenges of living in low-rainfall areas. Cactus pear is adapted to many parts of Northern Ethiopia. Farmers maintain cactus backyards but most of the fruit harvest comes from the wildly growing cactus plantation (Welderufael, 2015).

Cactus pear was introduced to Tigray region of northern Ethiopia between 1846 and 1887 by missionaries (Bariagabr *et al*., 2016). Several studies demonstrate that cactus is potentially an effective natural coagulant that is also responsive to environmental and sustainability concerns (Karanja *et al*., 2017). Cactus is used as a natural coagulant in water treatment via adsorption, neutralization, formation of hydrolyzed species of positive charge in the compound, and destabilization of the particle suspension. This attraction may result from interactions of hydrogen bonding, coordination reaction, covalent reaction, and ion exchange process. The main functional groups such as carboxyl and hydroxyl groups could be contributed by the protein portion of the material to bind the suspended particles by their pores (Beyene *et al.,* 2016).

Water scarcity encourages researchers to keep working on natural coagulant agents such as Moringa oleifera seed extract that could be used even in developing countries (Sánchez-Martín, *et al.,* 2012). Natural coagulants have been the focus of research of many investigators through the last decade owing to the problems caused by the chemical coagulants (Sarith *et al.,* 2017). Natural coagulants are biodegradable and present low toxicity and low levels of residual sludge production besides being considered health friendly (Valverde *et al.,* 2018). Natural coagulants (bio-polymers) would be of great interest since they are natural low cost products, characterized by them environ-mentally friendly behavior, and presumed to be safe for human health (Thakur and Choubey, 2014). Natural macromolecular coagulants show bright future and are concerned by many researchers because of their abundant source, low price, innocuity, multifunction and biodegradation (Shilpa *et al.*, 2012).

Recently, many research activities have demonstrated the possibility of the use of cactus as a promising natural flocculants/coagulant to substitute synthetic polymers, for wastewater treatment (Rebah and Siddeeg, 2017). Various studies pointed out the importance of using cactus as flocculants, coagulant or coagulant/flocculants aid for the removal of turbidity, COD and heavy metal. Cactus is native to Kenya making it readily available, which indicates that it bears significant promise as a natural coagulant to address the problem faced in potable water supply and sustainable wastewater treatment in the country (Karanja *et al.*, 2017).

Mucilage in some types of Cactus contains carbohydrates, such as L-arabinosa, D-galactose, L-ramnosa, D-xilosa and galacturonic acid (Yin, 2010). (Miller., et al, 2008) informed that the galacturonic acid is the active ingredient that offers the coagulant capacity acting predominantly through a transition mechanism of coagulation, where the solution particles do not get in contact between them, but are linked to a polymeric material that is generated from the cactus species. The presence of carbohydrates as polysaccharides, glucose, xylose, galactose, arabinose, cactus pectin constituents, would be related to their viscous consistency (mucilage) and these substances in aqueous solution generate the suspension of other insoluble substances that induce the colloidal particles coagulation.

It is hypothesized that the predominant coagulation mechanism for Opuntia is adsorption and bridging, wherein particles which because turbidity is directly not in contact one another but are bound to a polymer like material from Opuntia. There is a high probability that adsorption may occur through hydrogen bonding or dipole interactions. It is likely that natural electrolytes from within the Opuntia pad, specifically the divalent cations, which are known to be important for coagulation with anionic polymers, facilitate adsorption. Literature, cactus opuntia contained 2.3% nitrogen, 29.4% carbon and 1.7% hydrogen (Ayelech and Worku, 2015).

2.5.2 *Moringa stenopetala* (seed of Shiferaw)

Moringa is a tropical plant belonging to the family Moringaceae that grows throughout the tropics and *M. stenopetala* seeds are triangular, have three wings, and are covered with a spongy, thick yellowish seed coat. The kernel has a whitish-grey color and oval shape, and its thickness decreases from the center towards either end along the length of the seed (Seifu, 2014). And also moringa is a multipurpose tree with considerable economic and social potential and its cultivation is currently being actively promoted in many developing countries. Seeds of this tropical tree contain water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment. (Abiyu *et al.,* 2018).

Based on a review of the literature concerning *M. oleifera*, a project was developed to investigate the traditional uses of *M. stenopetala*, a species that grows widely in southern parts of Ethiopia. As well as being eaten, *M. stenopetala*, also known as aleko or shiferaw among local communities, has a variety of uses, many of them medicinal (Mekonen, 1999). *Moringa oleifera* and *Moringa stenopetala* are the two most common species among the 13 species of the Moringa family. Both species have many characteristics in common. For both species the use as a vegetable and water purifier are similar. They share several medicinal uses and both have high contents of oil in the seeds: between 32 - 42 %. Moringa oleifera has a faster development and yields fruits and seeds quickly. Moringa stenopetala is better suited to a drier climate; yields of seeds are higher and they have a higher coagulant content. While *Moringa oleifera* originates from the Himalaya, *Moringa stenopetala* is endemic to East Africa, where it occurs in northern Kenya and in Ethiopia. The two most common English vernacular names for the tree are ‘drumstick’ describing the shape of its pods) and ‘horseradish’ (describing the taste of its roots. In Ethiopia it is widely cultivated (Schneemann, 2011).

Among various types of Moringa species, Moringa stenopetala (*M. stenopetala*) is native to Ethiopia, Northern Kenya and Eastern Somali and is the most economically important species after *M. oleifera* (Melesse *et al.,* 2011). One of the most promising potential uses of M. stenopetala is to purify turbid water. The seeds of this and some other species of the *Moringaceae* have flocculating and anti-microbial properties. The active substances are found only in the cotyledons of the seeds (Orwa *et al.,* 2009).

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study area

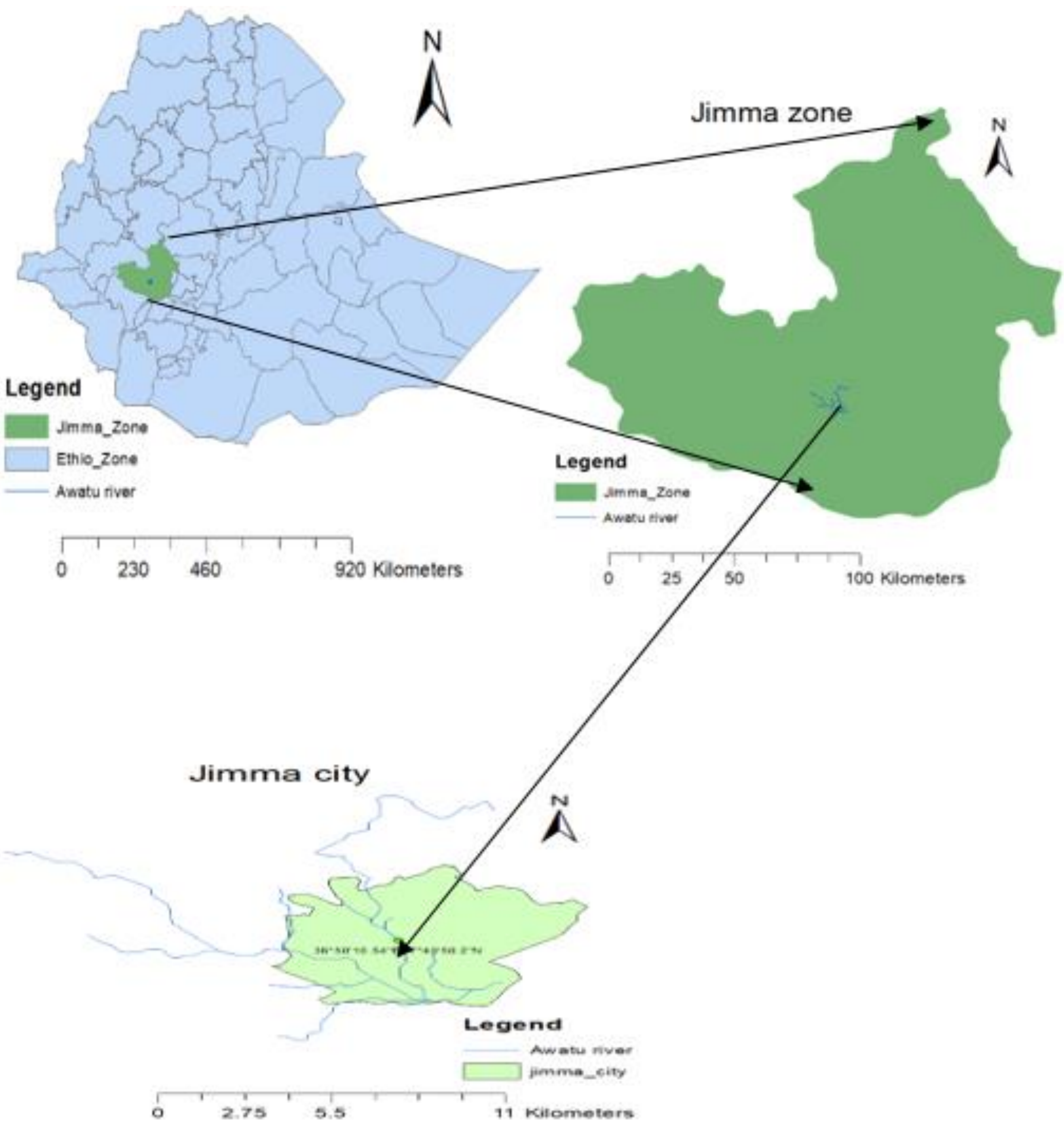


Figure 3.1 Map of study area

As shown in figure 3.1 Awetu river is located in Jimma town that far 352km from Addis Abeba and the laboratory study was conducted in Jimma university, Jimma institute of technology. Awetu river is one of the most polluted surface water since many pollutant contributors and users are available around it such as car washing activity at the downstream part, waste water dischargers.

3.2 Experimental Procedures

3.2.1 Preparation of bio coagulants

Plant material was selected considering the information of previous studies where they have shown good properties such as: coagulant activity, availability and nutrient composition, especially the content of protein and carbohydrates (Rodiño-Arguello *et al.,* 2015). In this study matured moringa stenopetala seed, indicated with white and dry fruits, locally named as seed of shiferaw and cactus pod powder were used as natural coagulant. The *moringa stenopetala* seeds were collected locally from Arbaminch town. They were sundried for 7 days. the chaff surrounding the seed kernel was removed and the kernels was ground finely to powder form by using pestle and mortar and sieved to size 600μm. This was the coagulant prepared from *moringa stenopetala* seed.

Figure 3.2 coagulation flocculation processes for surface water treatment using moringa stenopetala powder

The fresh cactus pear (*opuntia ficus indica*) pods, locally known as beles used for this study was collected from local area specifically available from Jimma town. Then by removing its pad fresh cactus was sliced or cutting in to small pieces to facilitate drying and wash by tap water followed by distilled water to remove unnecessary dirties and air borne pollutants then the sliced was dried for 9 hours at 80°C.The dried cactus was ground into fine powders using pestle and mortar and subsequently sieved to size 600μm in order to remove large particles then the powder was stored at room temperature until final analysis.

Figure 3.3 Coagulation flocculation technology for surface water treatment using cactus powder

3.2.2 Collection of surface water sample

Surface water samples were collected from awetu river in Jimma town from downstream parts of the river for better representativeness of the sample. The sample point was selected based on three reasons, the pollution load is high at the downstream part of the river, moderate flow velocity of the point and the sample area is point of use. The methods used to collect surface-water samples depend not only on flow characteristics of the surface-water body but also on the following considerations: safety of field personnel, suitability of the equipment with regard to the analysts of interest as well as that of the anticipated hydraulic conditions, field-measurement profiles, temporal and spatial heterogeneity; physical setting; ecological characteristics; weather conditions, fluvial-sediment transport, point and nonpoint sources of contamination; and study objectives, including data-quality requirements. Each sampling site needs to be selected and sampled in a manner that minimizes bias caused by the collection process and that best represents the intended environmental conditions at the time of sampling (USGS, 2006). In this study grap/hand sampling technique was used to take samples from the sample point by direct filling of the container. Surface water samples will typically be collected either by directly filling the container from the surface water body being sampled or by decanting the water from a collection device such as a stainless steel scoop or other device. If surface water samples are required, direct dipping of the sample container into the stream is desirable. Collecting samples in this manner is possible when sampling from accessible locations such as stream banks or by wading or from low platforms (Decker *et al.*, 2013).

3.3 Jar test experiment and optimization of pH and coagulant dosage

The optimum dosage of the natural coagulants and pH was evaluated by using jar test apparatus (JLT6, Leaching test Jar test). Jar test is the most widely used experimental methods for coagulation and flocculation process of water and waste water treatment. A conventional jar test apparatus was used for this study to conduct the experiment using natural coagulants.

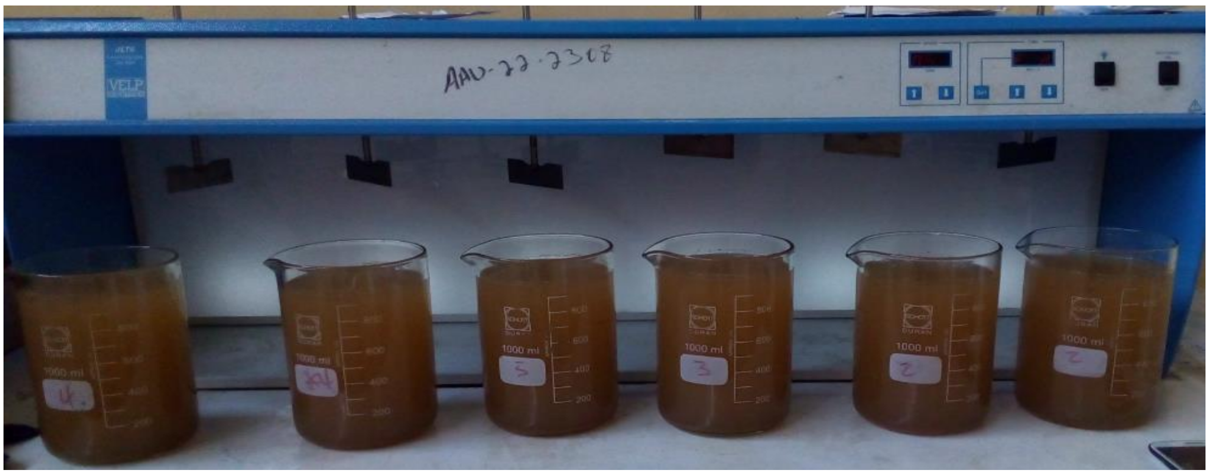


Figure 3.4 Jar test apparatus with surface water sample for coagulation flocculation treatment process.

The application of the powder as a coagulant to improve sample water quality was tested in laboratory using jar test method. The powder weighed based on already determined dosage trials range at respective pH trial range and added in to glass beakers that contain 1000ml water sample. Then solution in the beaker consisted of water sample and coagulant was mixed and rapidly stirred at 150rpm for two minutes prior to stirring process in maximum speed (90rpm), moderate speed (60rpm) and minimum or slow speed (30rpm) for 15,30 and 45minutes simultaneously to facilitate floc formation. The suspension was allowed to sedimentation for 45 minutes without any disturbance. The supernatant then taken for parameters and optimum pH determination purpose. Finally, after the parameters determined the efficiency was expressed in percentage change using the general equation (eq 3.1).

$$\% \text{ change} = \frac{\text{initial value} - \text{final value}}{\text{Initial value}} * 100\% \qquad (3.1)$$

It was carried out as a batch test consists of a series of six beakers together of 1-liter capacity with six spindle stirrer. Before operation of the test the sample was mix homogeneously. This study consists of a batch experiment of rapid mixing, slow mixing and sedimentation process. The apparatus normally consists of six rotating paddles or stirrers and beakers but for this study three 1000ml beakers were used by considering time and sample water since the final efficiency was taken as average percent of the three beakers for more accuracy.

The jar test apparatus has a maximum stirring capacity of 300 revolutions per minute (rpm). The jar test experiment for this study was done by setting the apparatus at 150rpm for uniform dispersion or mixing of dosed coagulant and sample for 2 minutes and 45 minutes was given for settlement or sedimentation of dispersed, coagulated and flocculated particles at the bottom of the beaker this was common for all experiments. But all experiments were tested at three trial of each factor. The floc speed of 30rpm, 60rpm and 90rpm at 15min, 30min 45min for coagulant dosage of 05g,1.0g and 1.5g at pH 2.5, 7.0 and 10.0.

The experiment was performed by using surface water sample having constant turbidity and color. For each three beakers filled by the same water sample and having the same adjusted pH, dosage of coagulant, stirring speed, stirring time and settling time for each batch of experiment. All experiments were performed according to the order of treatment combinations which set based on factors involving in this study, dosage, pH, stirring speed and time. The selected input variable trial interval was chosen randomly but somewhat consider or by taking care for trials already checked by previous researchers in order to prevent the redundancy of experimental tests at the same condition as well as to check the effectiveness of the selected coagulants at new condition and in addition to this the pH trial interval was chosen to check the effectiveness of selected natural coagulants at 2.5(extreme acidic condition), 7.0 (neutral condition) and 10.0 (extreme basic condition).

3.4 Chemicals and reagents used

3.4.1 Chemicals

- Concentrated Sulphuric acid (H_2SO4) for pH adjustment, to decrease it and sulfuric acid reagent preparation with silver sulfate.
- Sodium hydroxide(NaOH) for pH adjustment, to increase it.
- Silver sulphate (Ag_2SO4)

- Mercuric sulphate($HgSO4$)

3.4.2 Reagents

- Potassium dichromate reagent
- Ferrous ammonium sulphate (FAS) reagent
- Ferrion red indicator
- Sulfuric acid reagent (Ag_2SO4+ H_2SO_4)
- Distilled water to prepare reagent, to calibrate the instruments and rinsing purpose.

3.5 Determination of parameters

3.5.1 Determination of pH

The digital pH meter (model-pH3310) was used to measure the hydrogen ion concentration or pH of both raw surface water sample and coagulated water after coagulation flocculation and sedimentation. The probe/ electrode of the pH meter was rinsed with distilled water and dry then inserting the entire sensing edge and checking the full submerged probe. Finally, the pH values were recorded when the display on the meter was stable.

3.5.2 Determination of turbidity removal efficiency

Turbidity measurements were conducted using digital Nepheloturbidity meter, HANNA Instrument(HI-93703). By calibrating this apparatus with distilled water then the raw surface water sample and coagulated water was measured for turbidity. The values were determined when the display was stable in NTU.

The turbidity removal percentage was calculated as a function on the initial turbidity (T_i) and residual turbidity of the sample (T_f), according to Eq. (3.2) :(Rodiño-Arguello *et al.*, 2015).

Percentage Turbidity removal = $$\frac{T_i - T_f}{T_i} \times 100 \quad \text{……………………………………}(3.2)$$

3.5.3 Determination of color removal efficiency

The color of the untreated and treated samples was measured at a maximum wavelength of 420nm using UV- Spectrophotometer (model-6700). From this the higher absorbance reading indicates the more the presences of color in water.

The percentage color removal was calculated by the equation (3.3):

Percentage color removal = $\frac{Abs_i - Abs_t}{Abs_i} \times 100$ ……………………………………..(3.3)

Where,Abs_i and Abs_f are absorbance reading uncoagulated sample water initially and at any dosage interval samples for corresponding wavelength $\lambda_{max.}$

3.5.4 Determination of chemical oxygen demand (COD) removal efficiency

The COD concentration was measured by using COD reactor (HACH- type). The dichromate method is the American Public Health Association (APHA) standard method for determining COD with the use of potassium dichromate. The amount of dichromate was determined by direct titration using Ferrous Ammonium Sulfate (FAS) as the titrant and ferroin (1, 10 phenanthroline ferrous sulfate) as the indicator. During the course of the titration, the titrant (Fe^{2+}) reacts instantly with hexavalent chromium (Cr^{6+}) to form trivalent chromium (Cr^{3+}) and ferric ion (Fe^{3+}) which is shown below (Alam, 2015).

$3Fe^{2+} + Cr^{6+} \rightarrow 3Fe^{3+} + Cr^{3+}$ ………………………………………………………… (3.4)

The COD value was determined by using the dichromate closed reflux method strictly following the APHA. The organic matter present in the sample gets oxidized completely by $K_2Cr_2O_7$ in the presence of H_2SO_4 to produce CO_2 and H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with ferrous ammonium sulphate (FAS). The Dichromate consumed gives the O_2 required to oxidation of the organic matter. Procedures that was used for COD determination were:

To a 0.05 gram of mercuric sulphate, 2.5 ml sample, add 1.5 ml of $K_2Cr_2O_7$ reagent and 3.5 ml of H_2SO_4 reagent carefully, employ a hot blank (distilled water is taken instead of sample), reflux the mixture on a hot plate for two hours, cool the mixture to room temperature and titrate the excess dichromate with ferrous ammonium sulphate (0.1 M) using ferrion indicator. The end point is a sharp color change from blue – green to reddish brown, although the blue green color may reappear within minutes. Repeat the same procedure for the blank solution (Distilled water).

$COD\ (mg/L) = \frac{(V_{Blank} - V_{Sample}) * N * 8 * 1000}{V_{Sample\ taken}} (mg/L)$ ………………………………..................(3.5)

Where,

V_{Blank} - Volume of FAS used for blank solution

V_{Sample}- Volume of FAS used for sample solution

N – Normality of FAS

The percentage removal of COD in the effluent was calculated using the equation (3.6)

$$\text{Percentage COD removal} = \frac{COD_0 - COD_f}{COD_0} \times 100 \quad \text{...(3.6)}$$

Where, COD_0 and COD_f in (mg/l) are the Chemical Oxygen Demand at raw sample (before being coagulated) or before reaction and after coagulant dosage (after being coagulated) or after reaction respectively.

3.6 Study period

The study was conducted from May 2018 to October 2018. This duration includes all works starting from material and sample collection, experimental sample test, experimental result analysis and writing up of thesis

3.7 Study design

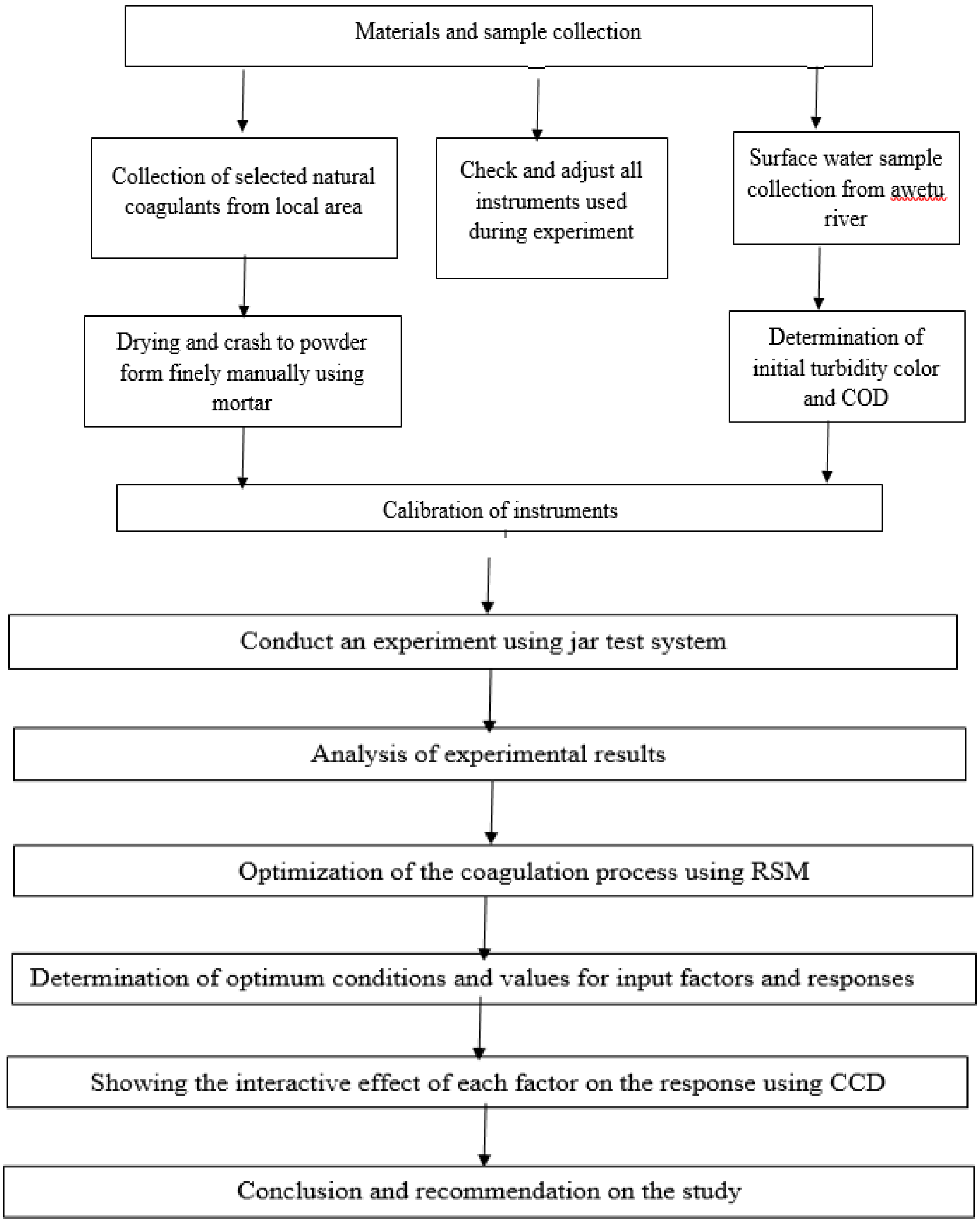


Figure 3.5: General study design

3.8. Study variables

3.8.1. Dependent variables

- Bio coagulant technology
- Percentage removal efficiency of natural coagulants on specified parameters
- Process optimization

3.8.2. Independent variables

- pH
- Coagulant dosage
- Stirring speed
- Stirring time

3.9. Analysis

3.9.1. Sample analysis

Table 3.1 Raw water characteristics

Characteristics	Unit	Value
pH	-	5.8
Temperature	°C	16.2
Conductivity	μs/cm	1795
Turbidity	NTU	107
COD	mg/L	128
Color	Abs	0.312

3.9.2. Experimental design and sample analysis

Response surface methodology is a statistical method frequently used in designing experimental, building models, for evaluating the effects of several factors and to find the optimum conditions for desirable responses as well as to reduce the number of experiments (Dawood and Li., 2013). Central composite design (CCD), a very efficient design tool for fitting the second-order models (Montgomery, 2001), is used as an RSM in the experimental design. The CCD was first introduced by Box Wilson in 1951, and is well suited for fitting quadratic surface, which usually works well for the process optimization (Obiora-Okafo and Onukwuli, 2015). In this study, the face-center experimental plan was implemented as a CCD. A CCD is made face- centered by choosing α = 1. Face-center is having the position of the star points at the face of the cube portion on the design. The choice of face-centered CCD was made considering that it is an option in the CCD design and due to the cumbersome nature of the design. Also face-centered option ensures that the axial runs will not be any more extreme than the factorial portion (Obiora-Okafo and Onukwuli, 2015). The independent variables selected for this study were pH (A), coagulant dosage (B), stirring speed (C), and stirring time (D). A total of 30 experiments were conducted for each response. Mathematically, Eq. (3.7) was used to determine the total number of runs performed. The total number of experiments, N with k factors is:

$$N = 2^k + 2k + n \quad (3.7)$$

where k is the number of factors and n is center points. According to the above equation only 30 experimental runs were required but in this study in order to see the detail experimental result based on the treatment combination that was arranged using the input parameters or independent variables this study consider 81 experiments by increasing the center point for CCD, parts of RSM. The additional experimental runs are chosen for the purpose of getting more information that can lead to the determination of optimum operating conditions on the control variables (Khuri1 and Mukhopadhyay, 2010).

3.9.3. Model and statistical analysis

Experiments were performed by triplicate each treatment combination at the same condition using three beakers and taking the average value of each beaker. For statistical and graphical analysis, the Design Expert trial version (11.0) software was used. A quadratic model was generated and an analysis of variance was applied in order to visualize the relationship between the experimental variables and responses through surface charts.

3.10. Materials and equipment used

- Turbidity meter
- pH meter
- conductivity meter
- UV/Visible spectrophotometer
- Jar tester (six stirrer)

- COD reactor/digester
- Kits
- Volumetric flasks (1L and 2L)
- Measuring cylinders(500ml)
- Beakers(1L)
- Analytical balance
- Spoons
- Sieve(600µm)
- Mortar
- Pipette/springs
- Burette
- Thermometer

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. Coagulation and flocculation activity of cactus and moringa stenopetala powder

Several chemical coagulants have been used in the treatment of polluted water such as synthetic polymer and inorganic and organic coagulants. But these chemical coagulants are costly and release harmful residues to the environment. Generally, as different previous studies investigate usage of chemicals as a coagulant have drawbacks in addition to its effectiveness, suspected to have health effects, cost and environmental pollution due to release of sludge that cannot easily degraded.

So in this study cactus and *moringa stenopetala* powder were used as a natural coagulant in order to overcome such type of drawbacks of chemical coagulants. The coagulation ability of both natural coagulants for surface water treatment was analyzed by using jar test. It was observed that cactus and moringa stenopetala powder forms large flocs with impurities in surface water sample to facilitate settling at the bottom of the beakers and resulted in clear supernatant formation.

In this thesis the potentiality of cactus opuntia(*ficus-indica*) and seed of shiferaw (*moringa stenopetala)* powder as a natural coagulant for surface water treatment in terms of color, COD and turbidity was investigated. The coagulation ability was evaluated by using standard jar test apparatus by varying operating parameters, pH (2.5, 7.0 and 10), coagulant dosage (0.5,1.0 and1.5g), stirring speed (30,60,90rpm) and stirring time (15, 30 and 45 min).

4.2. Effect of individual operating parameters on the responses

Operating parameters, pH, coagulant dosage, stirring speed and time has an effect on the coagulation and flocculation process. Their effect was seen mostly on the coagulant efficiency, on each response and as well as on each other since the increament or decrement of one parameter affect the other. Based on this, their effect may be positive or negative towards removal efficiency. Hence the color, COD and turbidity removal efficiency of the selected natural coagulants throughout the coagulation and flocculation process was depends up on the input factors.

4.2.1. Effect of coagulant dosage on the removal efficiency

According to Vishali and Karthikeyanb (2014) coagulant dosage is one of the most important parameters to be optimized. Insufficient dosage or over dosing would result in poorer performance in treatment. Optimum dosage will minimize the dosing cost and sludge formation. In this study to find out the optimum coagulant dosage, 0.5g, 1.0g and 1.5g of each coagulant was dosed simultaneously based on the treatment combination order. So generally for the case of cactus powder usage based on the experimental results as the dosage increase at the same condition the color, COD and turbidity removal was also increase to some extent but further increament decrease the efficiency. Based on the observed results from experimental analysis the cactus powders the maximum color, COD and turbidity removal efficiency was 92% at 1.0g, 68.1% at 0.5g and 89.1% at 0.5g respectively.

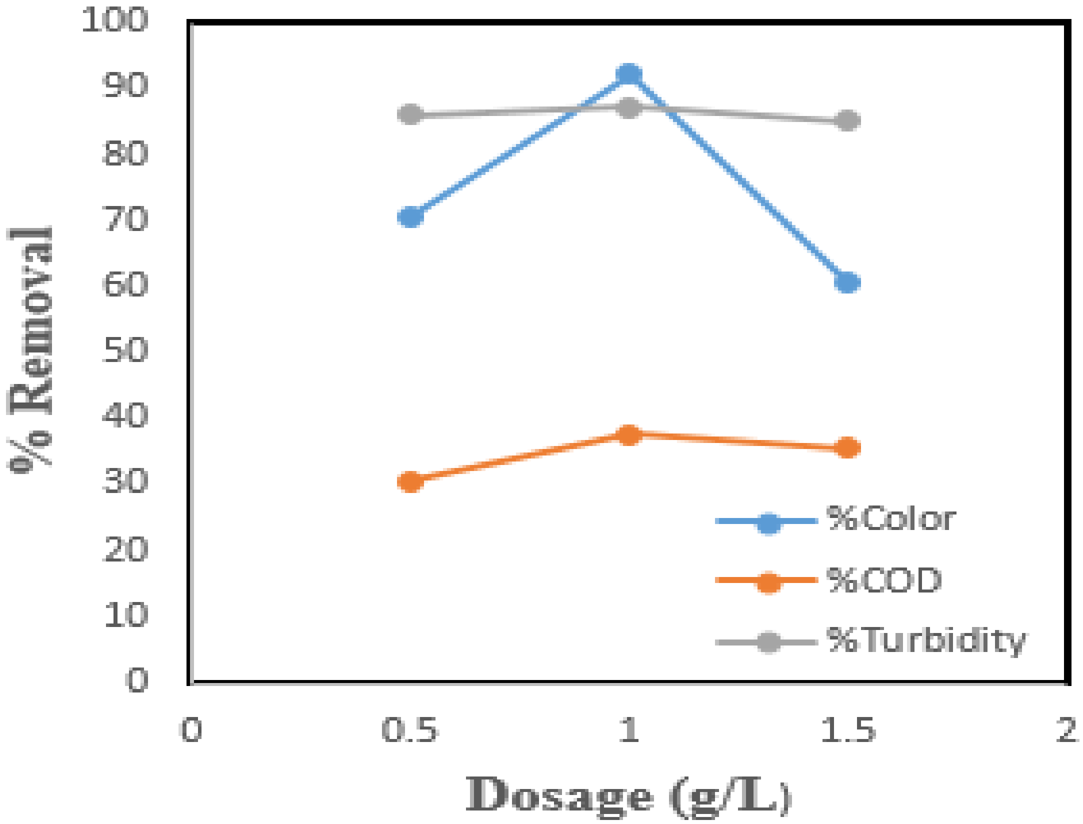


Figure 4.1 Effect of cactus powder dosage on the removal of color, COD and turbidity

Generally, as figure 4.1 shows that coagulant dosage has a significant effect on the removal efficiency of the targeted water quality parameters, color, COD and turbidity, coagulant dosage has a significant effect on its own removal efficiency. As each experimental run show when dosage increase the sample water was being turbid and colorful in case of cactus dosage this may be due to the fact that color of the cactus powder and due to the active site of the coagulant.

Therefore, dosage should be optimized in order to keep the range of best removal efficiency for coagulant dosage and reduce cost. According to (Zainol, Aziz, Yusoff, & Umar, 2011), the optimum dosage of coagulant is defined as a value above which there is no significant increase in removal efficiency with further addition of the coagulant.

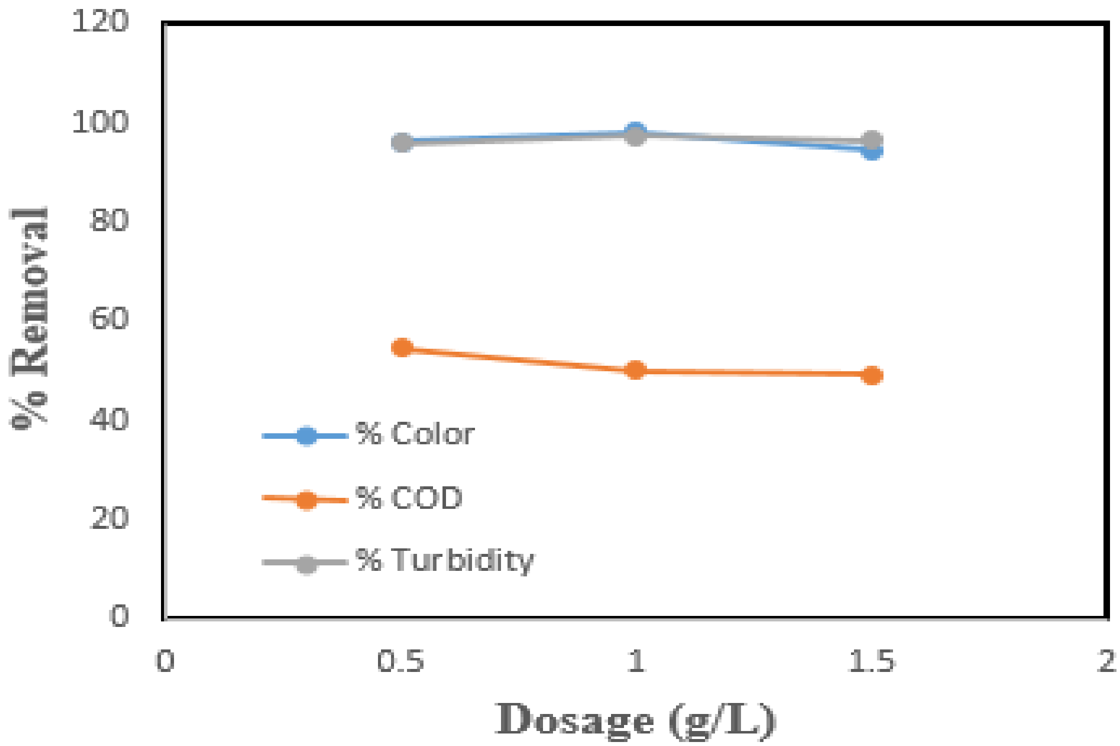


Figure 4.2 Effect of *moringa stenopetala* powder on removal of color, COD and turbidity

As per each experiment when moringa powder dosage increase, the clarity of water also increases but further dosage increament shows the decreasing of water quality. This may be due to when over dosage occurs the water having the color of the moringa powder, white cloudy color and being turbid in addition to it produce more sludge.

4.2.2. Effect of pH on the removal efficiency

The pH of sample water was 5.8 but for this experimental study it was adjusted in to three ranges, at 2.5, 7.0 and 10.0 in order to check the coagulants efficiency at extreme acidic, neutral and basic condition. So as the experimental result shows treating surface water using cactus powder as pH increase from 2.5 to 10 at the same condition the removal efficiency of color and COD was decrease but turbidity removal was increase from left to right up to the neutral state and almost constant at basic condition, best result was occurring at acidic condition.

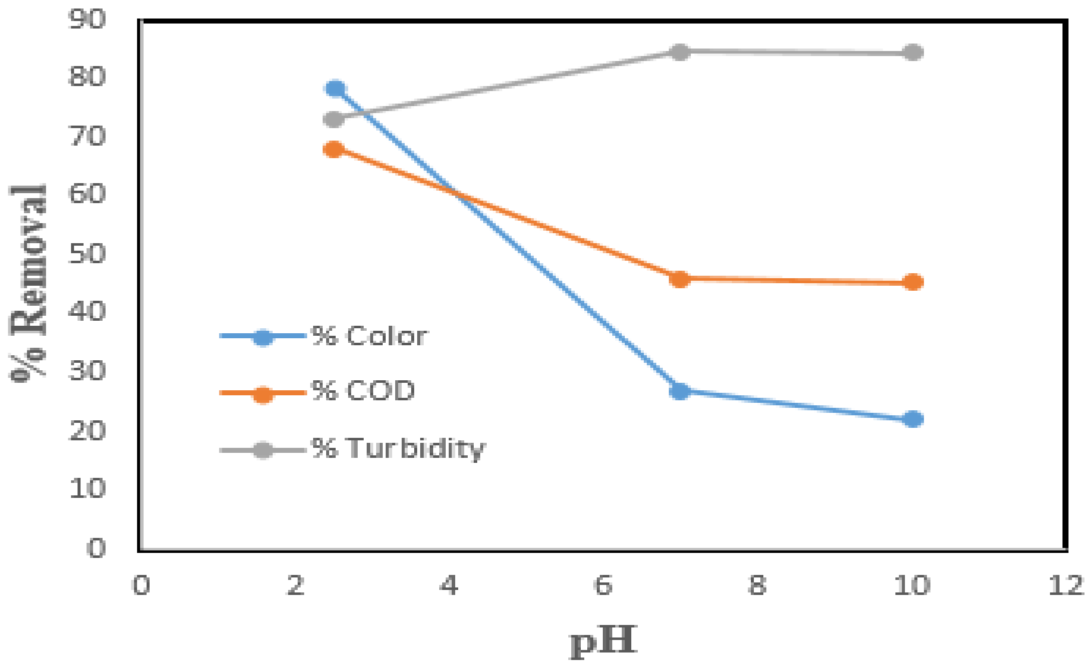


Figure 4.3 Effect of pH on color, COD and turbidity removal using cactus powder

As shown in figure 4.3 pH affects the removal efficiency of cactus powder on color, COD and turbidity. Hence, as the alkalinity of the sample increase the coagulant effectiveness is decrease. But in case of treating surface water sample using moringa stenopetala powder as the pH increase from 2.5 to 10 the removal efficiency was best, generally this well done at neutral and basic condition than acidic condition.

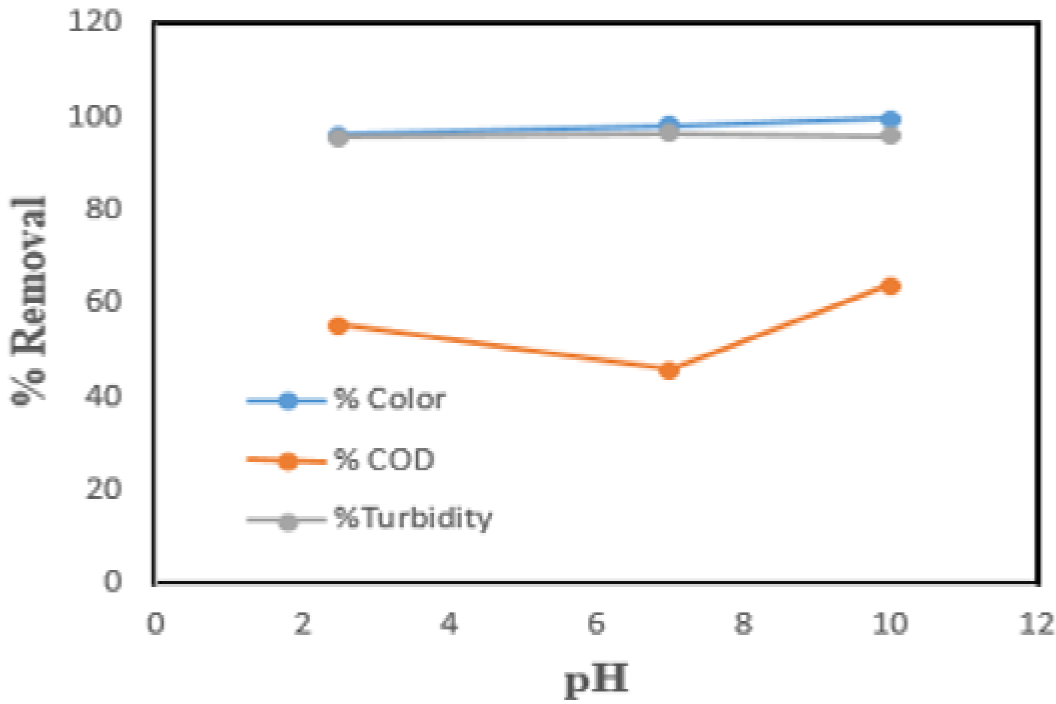


Figure 4.4 Effect of pH on color, COD and turbidity removal using moringa stenopetala powder

As shown in figure 4.4 usage of moringa stenopetala for coagulation water treatment process also affects the removal efficiency of the process. In this case as the alkalinity of the water sample increase the effectiveness of moringa also increase, moringa stenopetala is well done at basic condition than acidic condition.

4.2.3. Effect of stirring speed on the removal efficiency

As per the experimental detail of this study stirring speed play very important role in coagulation and flocculation water treatment process. In addition to its effect on the responses it also has an interesting physical property on the suspended flocs throughout each experimental trial at the given speed range. So since this study try to check the effect of stirring speed on coagulation process at 30, 60 and 90 rpm, at 30 rpm some suspended small size flocs was dispersed on the full surface of the sample water in beaker and take time for sedimentation at this slow stirring speed. But at 90rpm the stirrer was highly rotate and suspended small size flocs were collect at the center of the sample water surface and show the formation of agglomeration of those small size flocs quickly and easily settle.

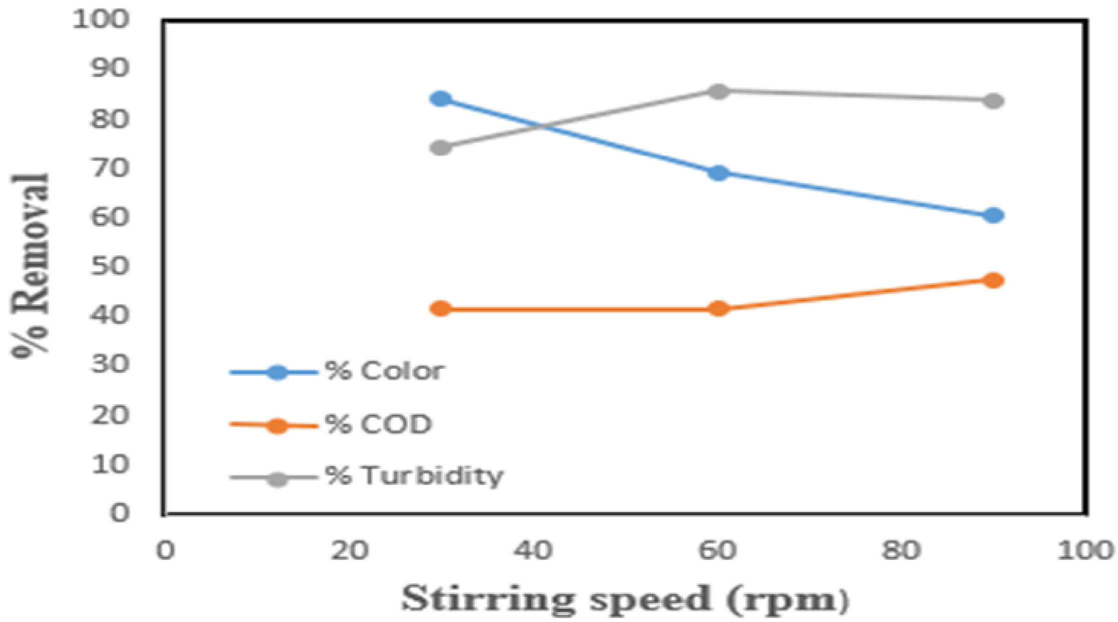


Figure 4.5 Effect of stirring speed on the removal of color, COD and turbidity using cactus powder

As shown by figure 4.5 and 4.6 as the stirring speed increases the removal efficiency also increase up to some extent but decrease generally from left to right as the speed increases except COD. This may be due to the breakdown of the flocs and the re-dispersion of colloidal particles at high speed in case of color and turbidity.

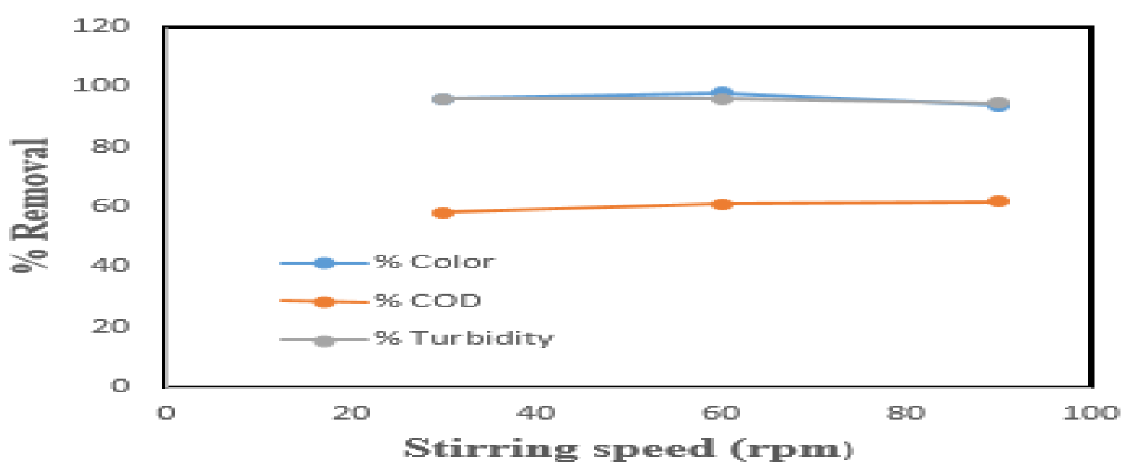


Figure 4.6 Effect of stirring speed on the removal of color, COD and turbidity using moringa stenopetala powder

Generally, as shown in figure 4.5 and 4.6 for both coagulants as the stirring speed increase the removal efficiency of the process on color and turbidity decrease. But COD removal efficiency increase this may be due to the rapid oxidation of organic pollutants at rapid speed by the oxidizer (potassium dichromate).

4.2.4. Effect of stirring time on the removal efficiency

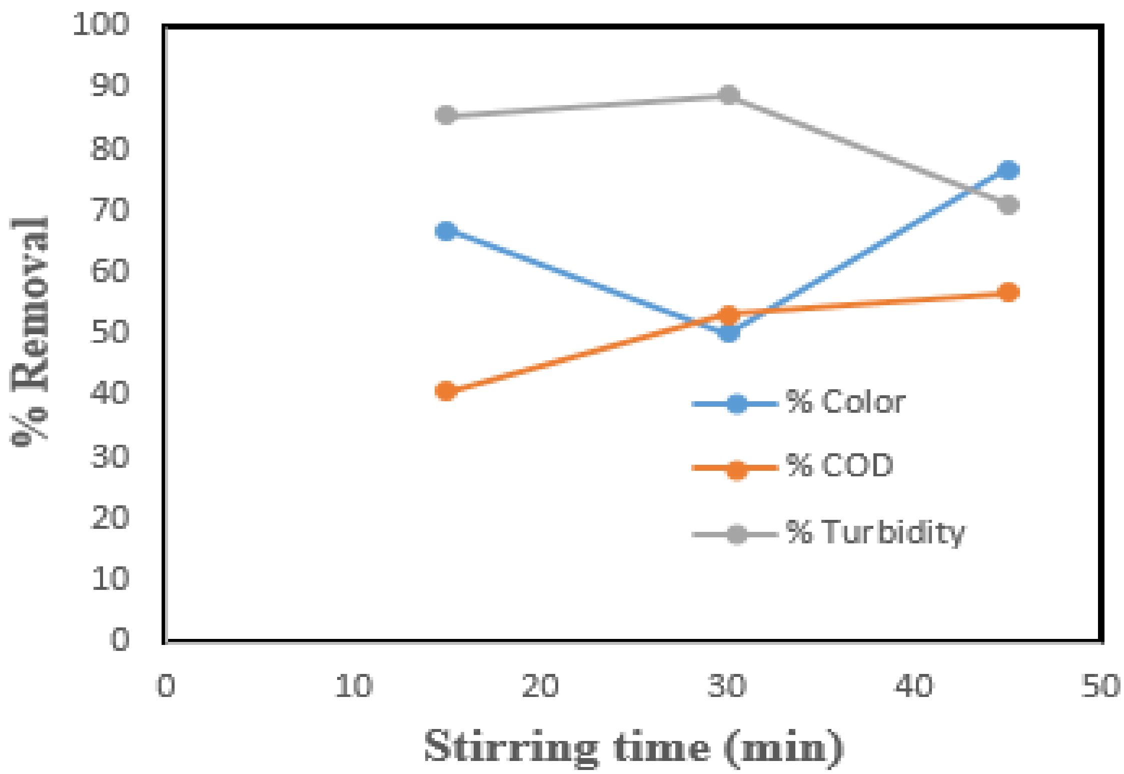


Figure 4.7 Effect of stirring time on the removal of color, COD and turbidity using cactus powder

As shown in figure 4.7 and 4.8 the color and COD removal efficiency of cactus powder was increase with in the selected time range. But its effectiveness was decrease for the turbidity removal. Normally, stirring time and speed highly inter dependent in addition to other factors. Due to this for the experiments at high speed and long time the turbidity of the sample was increase since colloidal particles breakdown again. Therefore, it requires more settling time for floc formation, agglomeration and sedimentation.

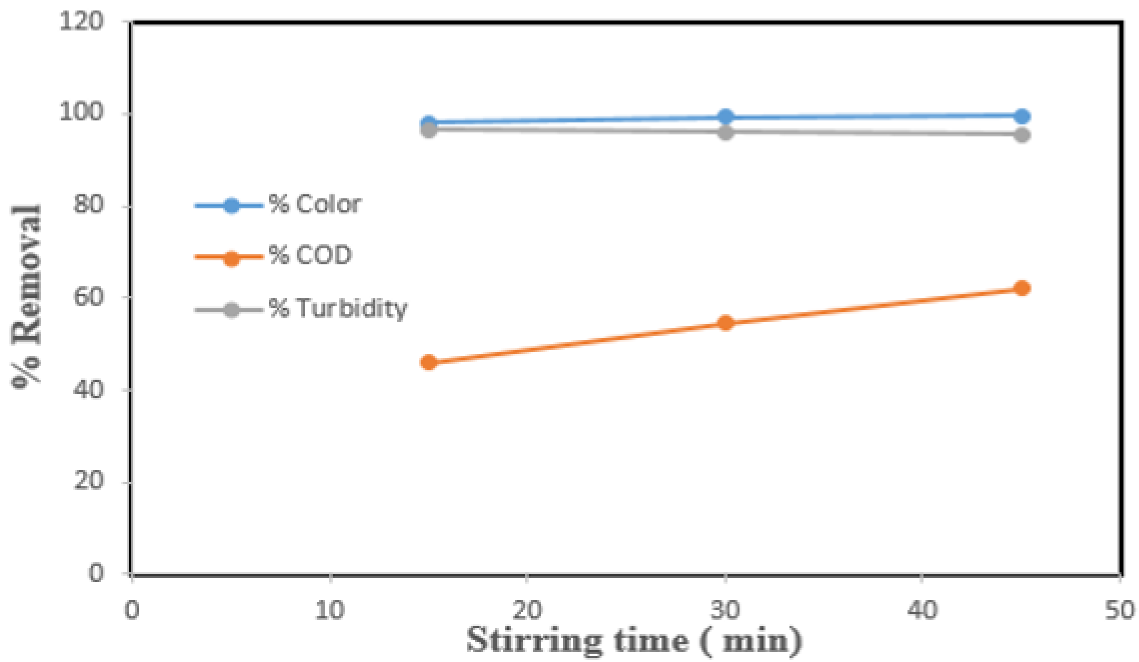


Figure 4.8 Effect of stirring time on the removal of color, COD and turbidity using moringa stenopetala powder

4.2.5. Effect of coagulant dosage on the sample water pH

As experimental results show that when cactus dosage was applying at acidic condition of the sample water, there was slightly incremental effect on the final pH of the coagulated water when the dose increase from 0.5 to 1.5 the pH of coagulated water also increase from 2.99 up to approximately 3.5 respectively. But when the dosage applying at neutral and basic condition at the same dosage intervals, the pH of final coagulated sample water was decreased or dropped from 7 to 5.2 and from 10 to 8.23. This may be due to the fact that the contribution of $H^{+}$to the alkalinity of the sample water from coagulants pH. In the case of moringa stenopetala powder dosage also the same trend.

4.2.6. Effect of initial COD concentration on the COD removal efficiency

Based on Asaithambi *et al.,* (2011), “From the practical point of view, the effect of initial concentration of COD on the percentage removal of COD was studied.” In this study also as per each experiment the initial COD concentration was vary between 23 and 300mg/L based on this concentration, the removal efficiency of color, COD and turbidity was decreased as initial concentration increase.

Table 4.1 Experimental and levels of the independent variables

S/N	Actual name	Coded name	Unite	Level		
				-1	0	+1
1	pH	A	-	2.5	7	10
2	Coagulant dosage	B	g/l	0.5	1	1.5
3	Stirring speed	C	rpm	30	60	90
4	Stirring time	D	minute	15	30	45

As shown in table 4.1, the levels are given based on the factorial design that is 2^k factorial design. According to (Khuri and Mukhopadhyay, 2010), in a 2^k factorial design, each control variable is measured at two levels, which can be coded to take the values, −1, 1, that correspond to the so-called low and high levels, respectively, of each variable. This design consists of all possible combinations of such levels of the k factors.

4.3. Statistical analysis for cactus powder coagulation flocculation treatment process

In this study the color, COD and turbidity removal efficiency of cactus and *moringa stenopetala* powder for surface water sample treatment was experimentally determined and statistically analyzed using central composite design (CCD), part of response surface methodology(RSM). Analysis of variances (ANOVA) was used for graphical analyses of the data to obtain the interaction between the process variables and the responses. The quality of the fit quadratic model was expressed by the coefficient of determination, R^2 and its statistical significance was checked by the *F*-test. Model terms were selected or rejected based on the *P* value (probability) with 95% confidence level. Three-dimensional (3D) surface plots were obtained based on the effects of the levels of four factors.

4.4. Sequential model sum of squares and model summary statistics for color removal using cactus powder.

Table 4.2 Sequential Model Sum of Squares

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Mean vs Total	1.428E+05	1	1.428E+05			
Linear vs Mean	27128.64	4	6782.16	47.67	< 0.0001	
2FI vs Linear	168.93	6	28.16	0.1852	0.9800	
Quadratic vs 2FI	**3488.63**	**4**	**872.16**	**8.04**	**< 0.0001**	**Suggested**
Cubic vs Quadratic	3221.40	16	201.34	2.56	0.0058	Aliased
Residual	3934.43	50	78.69			
Total	1.807E+05	81	2231.46			

As shown in table 4.2, the selected quadratic model was suggested for further investigation than other model types. In addition to this the suggested model is highly significant with 99% confidence level (p = 0.0001) and df is degree of freedom.

Table 4.3 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	11.93	0.7150	0.7000	0.6775	12235.60	
2FI	12.33	0.7195	0.6794	0.6282	14106.10	
Quadratic	**10.41**	**0.8114**	**0.7714**	**0.7161**	**10772.82**	**Suggested**
Cubic	8.87	0.8963	0.8341	0.6889	11804.27	Aliased

As sown in table 4.3 the selected model, quadratic model is suggested for further investigation. R^2 is the coefficient of determination that ensure the quality and performance of the quadratic model. The close relationship between adjusted and predicted R^2 also indicate the good performance of the model.

Table 4.4 ANOVA for Quadratic model

Response 1: Color removal

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	30786.21	14	2199.01	20.28	< 0.0001	Highly significant
A-pH	24668.60	1	24668.60	227.52	< 0.0001	Highly significant
B-dosage	16.34	1	16.34	0.1507	0.6991	
C-stirring speed	24.69	1	24.69	0.2277	0.6348	
D-stirring time	0.0013	1	0.0013	0.0000	0.9972	
AB	25.35	1	25.35	0.2338	0.6303	
AC	30.49	1	30.49	0.2812	0.5977	
AD	19.50	1	19.50	0.1798	0.6729	
BC	1.45	1	1.45	0.0134	0.9082	
BD	23.51	1	23.51	0.2169	0.6430	
CD	43.62	1	43.62	0.4023	0.5281	
A^2	3282.28	1	3282.28	30.27	< 0.0001	Highly significant
B^2	88.61	1	88.61	0.8172	0.3693	
C^2	44.99	1	44.99	0.4150	0.5217	
D^2	53.34	1	53.34	0.4920	0.4855	
Residual	7155.83	66	108.42			
Lack of Fit	7148.11	65	109.97	14.24	0.2081	
Pure Error	7.72	1	7.72			
Core Total	37942.04	80				

From this, table (4.4), the Model F-value of 20.28 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, A^2 are significant model terms, single factor and quadratic factor respectively. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy). The Lack of Fit F-value of 14.24 implies the Lack of Fit is not significant relative to the pure error. There is a 20.81% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

Table 4.5 Fit Statistics

Std. Dev.	10.41	**R^2**	0.8114
Mean	41.99	**Adjusted R^2**	0.7714
C.V. %	24.80	**Predicted R^2**	0.7161
		Adeq. Precision	11.7198

From table 4.5 the overall model performance is measured by the coefficient of determination, R^2. A higher R^2 value, close to 1, is desirable and ensures a satisfactory adjustment of the quadratic model to the experimental data. Therefore, since the R^2 value the quadratic model for this study for color removal was in good range 0.8114 indicates the selected quadratic has good performance.

According to the fit statistics, the Predicted R^2 of 0.7161 is in reasonable agreement with the Adjusted R^2 of 0.7714; i.e. the difference is less than 0.2. Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Therefore, ratio of 11.720 indicates an adequate signal. This model can be used to navigate the design space. Hence, in this study the adequate precision value for color removal model was greater than four. This indicates the quadratic model equation can be used within the range of factors in the design space.

4.4.1. Final Equation in Terms of Coded Factors

$$Color = 35.12 - 21.41A + 0.5526B + 0.6852C - 0.0050D + 0.8353AB - 0.9286AC + 0.7326AD - 0.2044BC - 0.8101BD - 1.12CD + 14.17A^2 - 2.22B^2 - 1.57C^2 + 1.72D^2 \ldots\ldots\ldots\ldots (4.1)$$

According to Fendri *et al.* (2013) the model equation adequately describes the response surfaces of color removal in the interval of investigation. Accordingly, for this study for color removal the equation in terms of coded factors can be used to make predictions about the response, color for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients. The models are found to be significant at 95% confidence level by the F-test as shown in table 4.4 above. According to (Obiora-Okafo and

Onukwuli, 2017), the positive sign in front of Eq. (4.1) indicates synergistic effect of the factors, whereas negative sign indicates antagonistic factor effect. Therefore, the overall quadratic models as expressed in Eq. (4.1) for the responses measured are significant and adequate.

4.5. Model adequacy checking

As shown in figure 4.9 below for a model to be reliable, the response should be predicted with a reasonable accuracy when compared with the experimental data. Figure 4.9 compares experimental color removal efficiencies (%) with the predicted values obtained from the model. The figure indicated good agreements between the experimental and predicted values. The observed points on these plots reveal that the actual values are distributed and concentrated relatively near to the straight line in most cases, indicating that the regression model is able to predict these removal efficiencies. A close relationship between predicted and experimental data indicates a good fit.

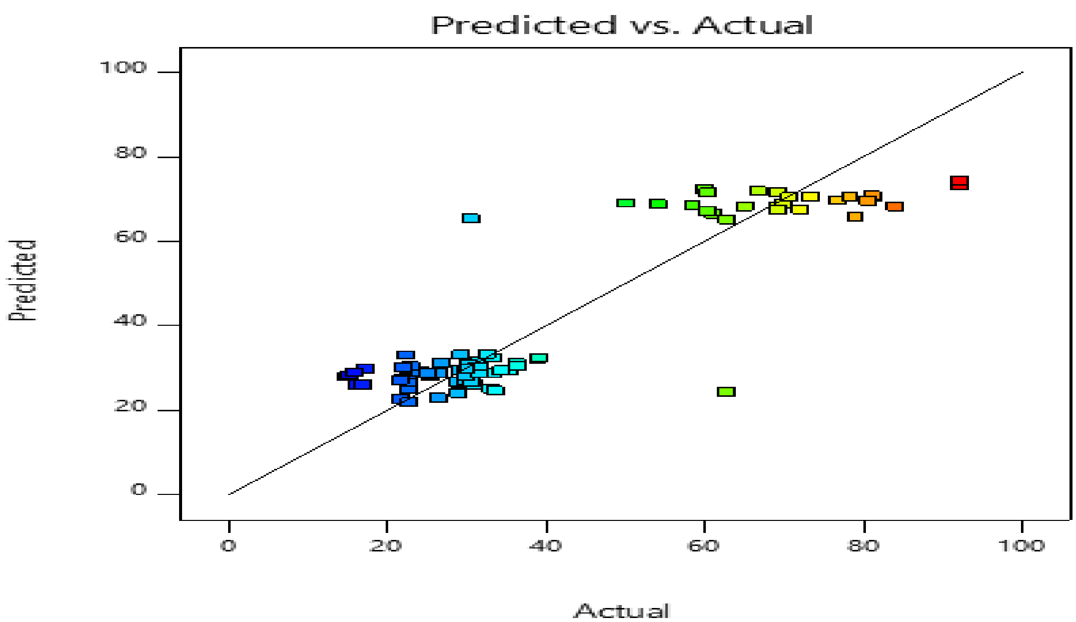


Figure 4.9 Predicted verses actual value for color removal using cactus powder

The performance of the model equation was analyzed based on the adequacy, significance, the effect of the interacting operating parameters, and optimization for maximum efficiency. The predicted values from the model were compared with the experimental values for color removal using cactus powder as a coagulant and are given in table 4.2 and are also figure 4.9 as actual verses to predicted. It was observed that the model predictions match with the experimental values and the data points close to the diagonal line.

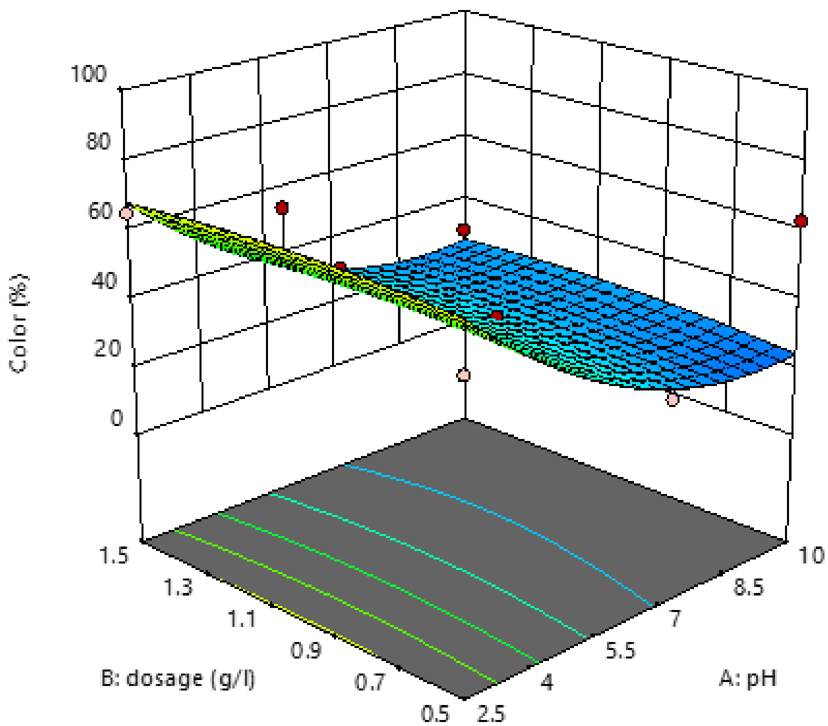


Figure 4.10 Response surface of the quadratic model for percentage color removal and the interaction between factors for cactus powder treatment process

As shown in figure 4.10 dosage and pH affects the color removal efficiency in percent. From this during cactus usage as the dose increase the removal efficiency decrease. And also the pH affects the color removal, as the pH increase the process effectiveness decrease.

4.5.1. Analysis of variance (ANOVA) for Response Surface Quadratic Model for COD removal

Table 4.6 Sequential Model Sum of Squares

Source	Sum of Squares	df	Mean Square	F-value	P-value	
Mean vs Total	1.530E+05	1	1.530E+05			
Linear vs Mean	**648.17**	**4**	**162.04**	**2.52**	**0.0480**	**Suggested**
2FI vs Linear	287.48	6	47.91	0.7292	0.6276	

Quadratic vs 2FI	193.73	4	48.43	0.7255	0.5776	
Cubic vs Quadratic	1065.89	16	66.62	0.9973	0.4746	Aliased
Residual	3339.84	50	66.80 `			
Total	1.585E+05	81	1956.95			

This table 4.6 shows the sequential model sum of squares that indicate for COD removal ANOVA analysis the linear model was suggested than the selected quadratic model for further investigation.

Table 4.7 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	**8.02**	**0.1171**	**0.0706**	**0.0059**	**5502.67**	**Suggested**
2FI	8.11	0.1690	0.0503	-0.0672	5907.05	
Quadratic	8.17	0.2040	0.0352	-0.1558	6397.60	
Cubic	8.17	0.3966	0.0346	-0.6581	9177.71	Aliased

From table 4.7 the model summary statistics of ANOVA result show that the linear model is best for further investigation than the selected model.In addition to this the coefficient of determination, R^2 value is low. Hence since the minimum R^2 indicates the model quality and performance so that due to this reason the selected quadratic model to predict experimental COD value not selected for further study.

Table 4.8 ANOVA for Linear model

Response 2: COD

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	648.17	4	162.04	2.52	0.0480	significant
A-pH	0.0131	1	0.0131	0.0002	0.9886	
B-dosage	21.23	1	21.23	0.3301	0.5673	

C-stirring speed	219.63	1	219.63	3.42	0.0685
D-stirring time	415.62	1	415.62	6.46	0.0130
Residual	4886.94	76	64.30		
Lack of Fit	4884.41	75	65.13	25.73	0.1558
Pure Error	2.53	1	2.53		
Core Total	5535.11	80			

The Model F-value of 2.52 implies the model is significant. There is only a 4.80% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case D is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model.

4.5.2. Final Equation in Terms of Coded Factors

COD = 43.48 – 0.0155A – 0.6271B +2.04C +2.77D………………………… (4.2)

This model equation indicates that the linear model equation for responses COD, the interactive effect of combined those are AB, AC, AD, BC, BD and CD as well as quadratic factors, A^2, B^2, C^2 and D^2 were not important, only single factors those are A, B, C and D were affect.

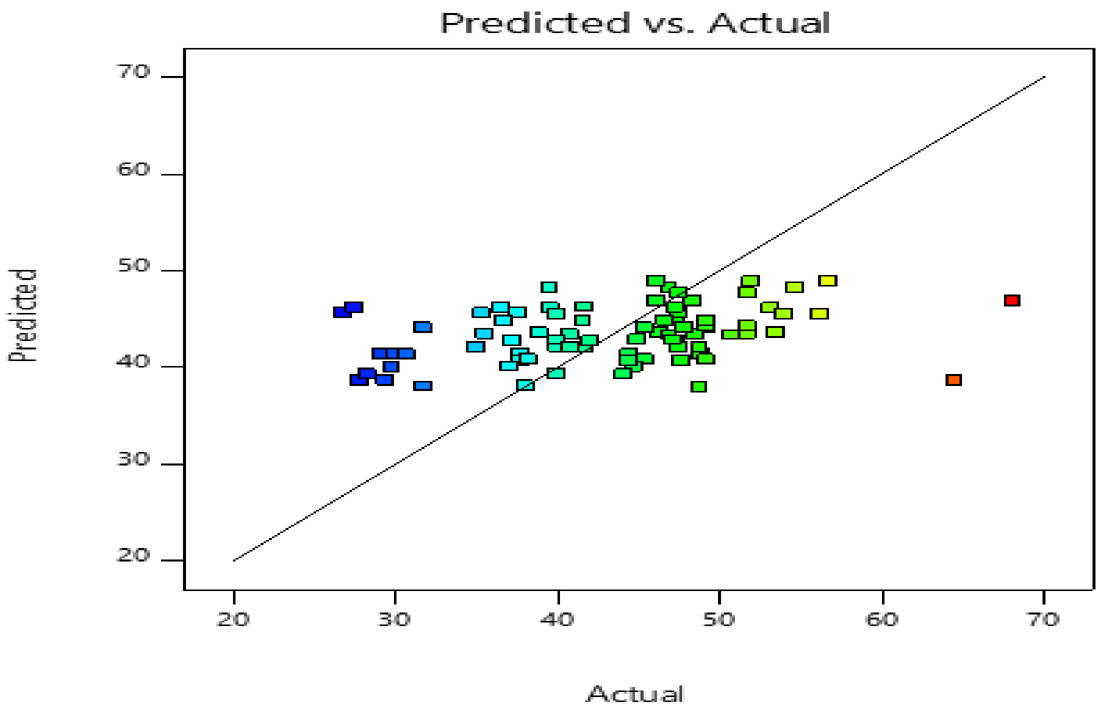


Figure 4.11 Predicted verses actual value for COD removal using cactus powder

As shown in figure 4.11 predicted verses actual value of COD removal using cactus powder. Hence, the points concentrated towards the diagonal line, about the mean indicate the is a close relation and agreement between the predicted and actual experimental value. But points those further away from the diagonal line indicate the presence of some disagreement between the predicted and actual value. General since most of the points close to the mean so there is a good agreement between the two value.

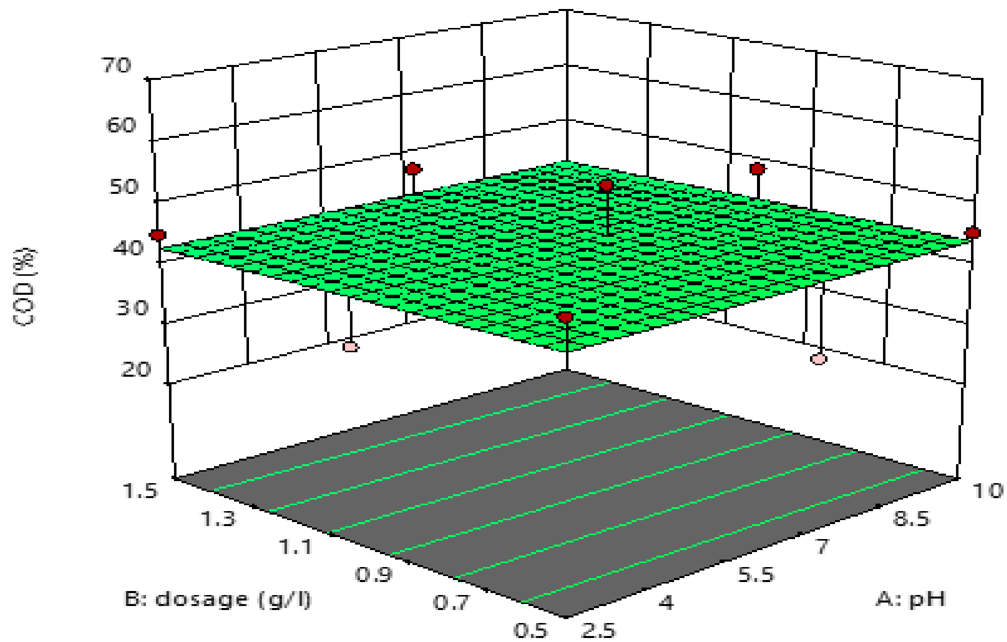


Figure 4.12 Response surface for linear model for percentage COD removal and the interactive effects between two variables using cactus powder

As shown in figure 4.12 coagulant dose and pH affects the COD removal efficiency of the coagulation and flocculation process, as dose of cactus powder and pH of the sample water increase the COD removal of the process was decrease. Therefore, it is well done at minimum dosage and acidic condition.

4.5.3. Analysis of variance (ANOVA) for Response Surface Quadratic Model for turbidity removal

Table 4.9.Sequential Model Sum of Squares

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Mean vs Total	5.149E+05	1	5.149E+05			
Linear vs Mean	1229.22	4	307.30	12.39	< 0.0001	
2FI vs Linear	972.47	6	162.08	12.43	< 0.0001	
Quadratic vs 2FI	**244.53**	**4**	**61.13**	**6.04**	**0.0003**	**Suggested**
Cubic vs Quadratic	196.98	16	12.31	1.31	0.2304	Aliased
Residual	471.08	50	9.42			

Total	5.180E+05	81	6394.69		

As shown in table 4.9 the selected quadratic model has been suggested for further study even if linear verses mean and 2FI verses linear models are indicating as highly significant models from the p- value, having 99% confidence level to predict the experimental data.

Table 4.10 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	4.98	0.3947	0.3628	0.3011	2176.69	
2FI	3.61	0.7070	0.6651	0.6074	1222.70	
Quadratic	3.18	0.7855	0.7400	0.6615	1054.17	Suggested
Cubic	3.07	0.8487	0.7580	0.5453	1415.93	Aliased

From table 4.10 the model summary statistics from ANOVA result show that the selected model, quadratic model has been suggested for further study. And also since the difference between the adjusted R^2 and the predicted R^2 is less than 0.2, there is a good agreement so quadratic model performance was good to predict the experimental data even if the value of R^2 is minimum.

Table 4.11 ANOVA for Quadratic model

Response 3: Turbidity removal

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-value**	**p-value**	
Model	2446.21	14	174.73	17.26	< 0.0001	Highly significant
A-pH	638.24	1	638.24	63.05	< 0.0001	Highly significant
B-dosage	382.16	1	382.16	37.76	< 0.0001	Highly significant
C-stirring speed	1.86	1	.86	0.1840	0.6693	
D-stirring time	39.37	1	39.37	3.89	0.0528	
AB	834.01	1	834.01	82.40	< 0.0001	Highly significant
AC	5.96	1	5.96	0.5891	0.4455	
AD	78.00	1	78.00	7.71	0.0072	

BC	37.45	1	37.45	3.70	0.0587	
BD	14.19	1	14.19	1.40	0.2406	
CD	5.01	1	5.01	0.4952	0.4841	
A^2	228.80	1	228.80	22.60	< 0.0001	Highly significant
B^2	0.0333	1	0.0333	0.0033	0.9545	
C^2	8.52	1	8.52	0.8415	0.3623	
D^2	5.22	1	5.22	0.5153	0.4754	
Residual	668.05	66	10.12			
Lack of Fit	667.95	65	10.28	101.49	0.0788	
Pure Error	0.1013	1	0.1013			
Core Total	3114.27	80				

P-values less than 0.0500 indicate model terms are significant. In this case A, B, AB, AD, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

4.5.4. Final model Equation in Terms of Coded Factors

Turbidity = 78.23-3.44A-2.67B-0.1882C-0.8577D-4.79AB-41.07AC+1.47AD-1.04BC+0.6294BD+0.3800CD+3.74A^2 - 0.0430B^2 - 0.6851C^2 - 0.5386D^2………………… (4.3)

Where, A= pH, B = coagulant dosage(g/L), C = stirring speed(rpm) and D = stirring time (minute).

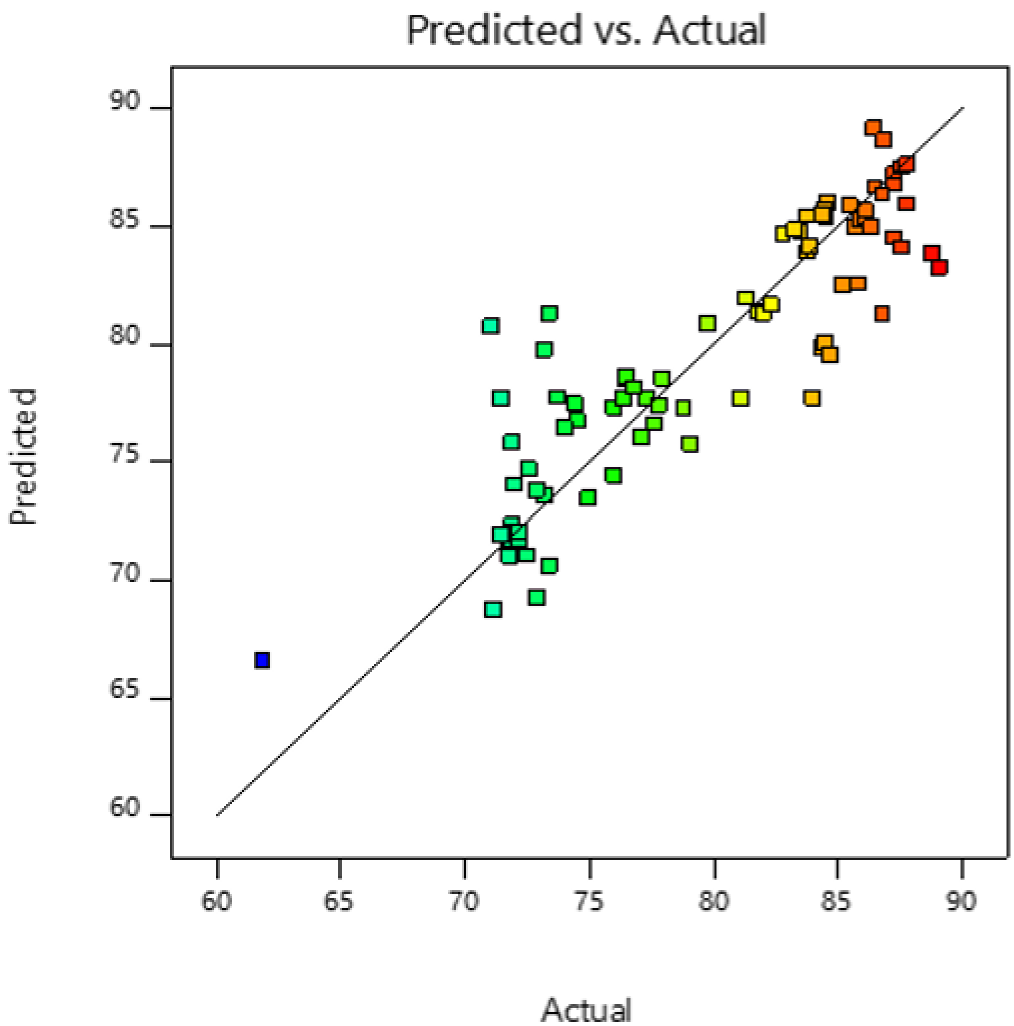
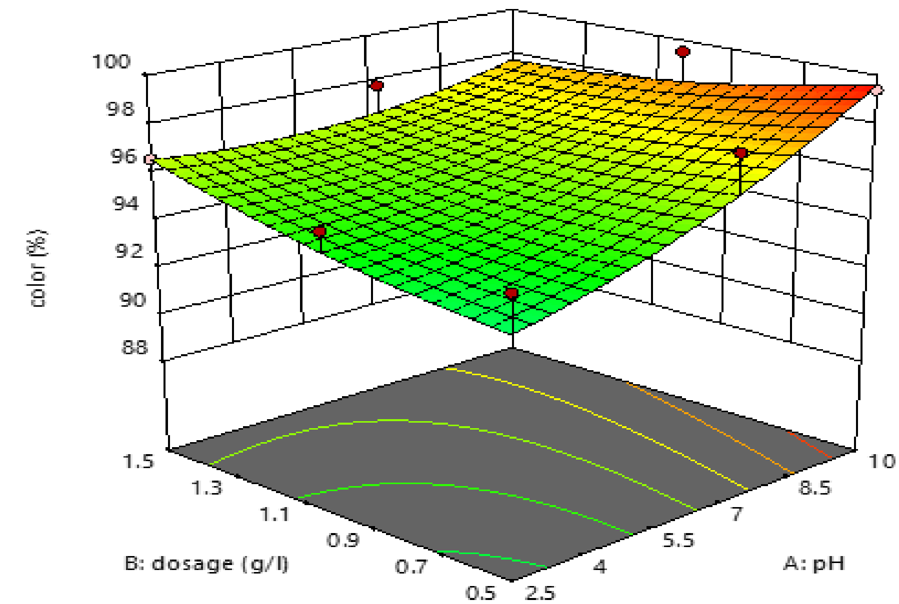
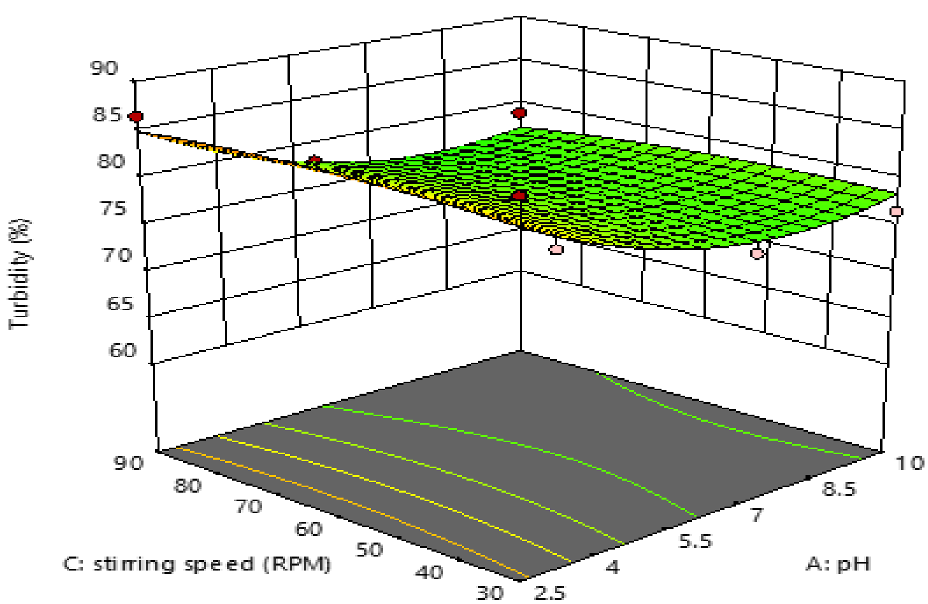


Figure 4.13 Predicted verses actual value of response turbidity for cactus powder treatment

As shown in figure 4.13 predicted verses actual value of turbidity removal using cactus powder. Hence, the points concentrated towards the diagonal line, about the mean indicate the is a close relation and agreement between the predicted and actual experimental value. But points those further away from the diagonal line indicate the presence of some disagreement between the predicted and actual value. General since most of the points close to the mean so there is a good agreement between the two value.



(a)



(b)

Figure 4.14 Response surface for quadratic model for percentage color and turbidity removal and the interactive effects of four factors on turbidity removal using cactus powder

As shown in figure 4.14a the interactive effect of both pH and dosage on color removal efficiency of coagulation and flocculation process. Hence as the cactus powder dosage and pH of the sample water increase the percentage color removal of the process also increase to some extent but further dosage and increment of pH leads to reduction of the efficiency. And also figure 4.14b the interactive effect of stirring speed and pH on the turbidity removal efficiency of coagulation process using cactus powder. Therefore, in this case as the stirring speed increase the turbidity removal effectiveness decrease, sample water being more turbid due to the break down again and as pH increase its effect is marginal.

4.6. Statistical analysis for moringa stenopetala powder coagulation flocculation treatment process

The coagulation and flocculation process using *moringa stenopetala* powder also affects the color, COD and turbidity removal efficiency as the operating parameters vary. In this case the general trend of the process was the same with cactus except when moringa well done at basic state.

4.6.1. Analysis of variance (ANOVA) for Response Surface Quadratic Model for color removal

Table 4.12 Sequential Model Sum of Squares

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	7.573E+05	1	7.573E+05			
Linear vs Mean	171.32	4	42.83	10.34	< 0.0001	
2FI vs Linear	**61.35**	**6**	**10.22**	**2.83**	**0.0161**	**Suggested**
Quadratic vs 2FI	15.81	4	3.95	1.10	0.3646	
Cubic vs Quadratic	80.56	16	5.03	1.60	0.1025	Aliased
Residual	156.94	50	3.14			
Total	7.578E+05	81	9355.34			

From this table 2FI vs linear model was suggested for further investigation over the selected quadratic model and also linear verses mean model type is significant with 99% confidence level (p = 0.0001).

Table 4.13 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS
Linear	2.03	0.3525	0.3184	0.2627	358.32

2FI	**1.90**	**0.4788**	**0.4043**	**0.2996**	**340.36**	**Suggested**
Quadratic	1.90	0.5113	0.4076	0.2621	358.58	
Cubic	1.77	0.6771	0.4833	0.1749	401.00	Aliased

From table 4.13 the model summary statistics from ANOVA result show that 2FI model type has been suggested for further study. And also since the difference between the adjusted R^2 and the predicted R^2 is less than 0.2, there is a good agreement, the model performance was good to predict the experimental data even if the value of R^2 is minimum.

Table 4.14 ANOVA for Quadratic model

Response 1: color

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-value**	**p-value**	
Model	248.48	14	17.75	4.93	< 0.0001	significant
A-pH	170.20	1	170.20	47.30	< 0.0001	
B-dosage	3.27	1	3.27	0.9073	0.3443	
C-stirring speed	7.32	1	7.32	2.04	0.1584	
D-stirring time	0.5418	1	0.5418	0.1506	0.6992	
AB	52.27	1	52.27	14.53	0.0003	
AC	2.45	1	2.45	0.6797	0.4127	
AD	1.06	1	1.06	0.2945	0.5892	
BC	2.61	1	2.61	0.7246	0.3977	
BD	1.20	1	1.20	0.3338	0.5654	
CD	0.7940	1	0.7940	0.2207	0.6401	
A^2	8.15	1	8.15	2.26	0.1371	
B^2	3.34	1	3.34	0.9288	0.3387	
C^2	2.73	1	2.73	0.7593	0.3867	
D^2	1.83	1	1.83	0.5081	0.4785	
Residual	237.50	66	3.60			
Lack of Fit	234.19	65	3.60	1.09	0.6581	
Pure Error	3.30	1	3.30			
Core Total	485.98	80				

The Model F-value of 4.93 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 1.09 implies the Lack of Fit is not significant relative to the pure error. There is a 65.81% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

4.6.2. Final Equation in Terms of Coded Factors

$$Color = 95.77 + 1.87A + 0.2470B - 0.3732C - 0.1006D - 1.20AB + 0.2630AC + 0.1708AD - 0.2741BC + 0.1831BD + 0.1512CD + 0.7061A^2 + 0.4311B^2 + 0.3881C^2 - 0.3189D^2 \quad (4.4)$$

Where, A=pH, B= dosage, C= stirring speed and D= stirring time

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

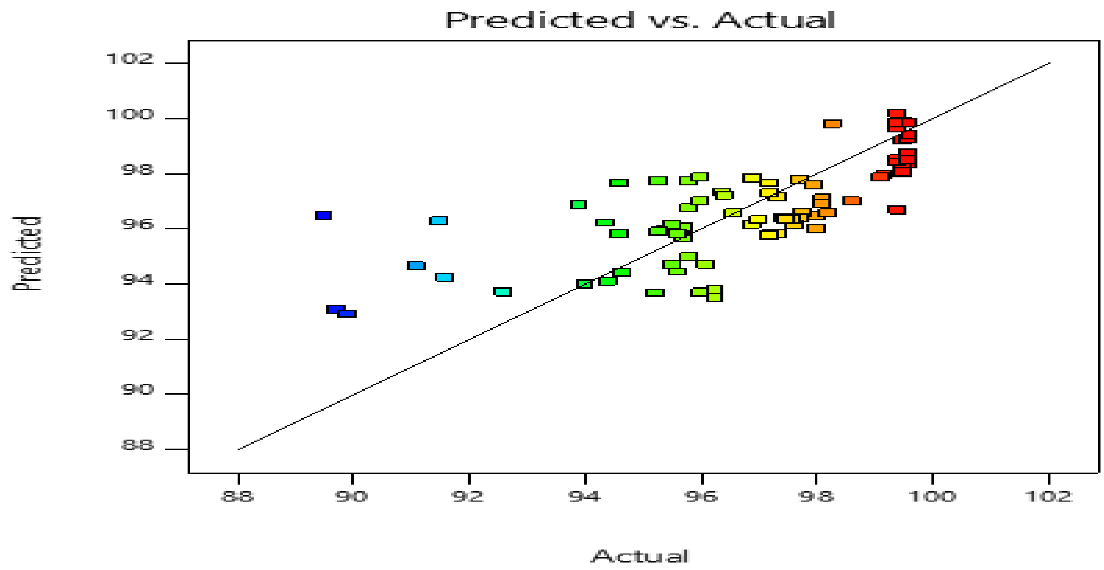


Figure 4.15 Predicted verses actual values of response color for moringa powder treatment

As shown in figure 4.15 predicted verses actual value of color removal using moringa powder. Hence, the points concentrated towards the diagonal line, about the mean indicate the is a close relation and agreement between the predicted and actual experimental value. But points those further away from the diagonal line indicate the presence of some disagreement between the predicted and actual value. General since most of the points close to the mean so there is a good agreement between the two value.

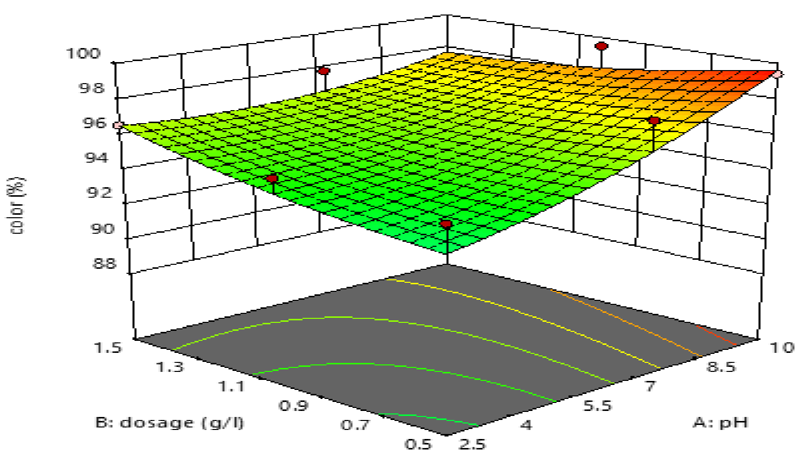


Figure 4.16 Response surface for quadratic model on percentage color removal and the interactive effects of four factors for moringa powder treatment

4.6.3. Analysis of variance(ANOVA) for Response Surface Quadratic Model for COD removal by moringa powder

Table 4.15 Sequential Model Sum of Squares

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	2.210E+05	1	2.210E+05			
Linear vs Mean	400.52	4	100.13	4.73	0.0018	
2FI vs Linear	**294.67**	**6**	**49.11**	**2.62**	**0.0239**	**Suggested**
Quadratic vs 2FI	37.89	4	9.47	0.4903	0.7428	
Cubic vs Quadratic	166.61	16	10.41	0.4698	0.9505	Aliased
Residual	1108.29	50	22.17			
Total	2.230E+05	81	2753.21			

From this table 2FI vs linear model was suggested for further investigation over the selected quadratic model and also linear verses mean model type is significant with 99% confidence level ($p < 0.05$). in addition to this linear verses mean model type also significant since $p < 0.05$.

Table 4.16 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	4.60	0.1995	0.1573	0.0923	1822.65	
2FI	**4.33**	**0.3462**	**0.2528**	**0.1426**	**1721.59**	**Suggested**
Quadratic	4.40	0.3651	0.2304	0.0630	1881.54	
Cubic	4.71	0.4481	0.1169	-0.4543	2920.24	Aliased

Table 4.17 ANOVA for Quadratic model

Response 2: COD removal

Source

	Sum of Squares	**df**	**Mean Square**	**F-value**	**p-value**	
Model	733.08	14	52.36	2.71	0.0033	significant
A-pH	70.39	1	70.39	3.64	0.0606	
B-dosage	283.93	1	283.93	14.70	0.0003	
C-stirring speed	0.0945	1	0.0945	0.0049	0.9444	
D-stirring time	23.23	1	23.23	1.20	0.2768	
AB	27.41	1	27.41	1.42	0.2378	
AC	21.50	1	21.50	1.11	0.2953	
AD	62.78	1	62.78	3.25	0.0760	
BC	85.36	1	85.36	4.42	0.0394	
BD	85.21	1	85.21	4.41	0.0395	
CD	9.61	1	9.61	0.4977	0.4830	
A^2	1.69	1	1.69	0.0876	0.7682	
B^2	21.20	1	21.20	1.10	0.2986	
C^2	15.86	1	15.86	0.8211	0.3681	
D^2	0.0306	1	0.0306	0.0016	0.9684	
Residual	1274.90	66	19.32			
Lack of Fit	1258.65	65	19.36	1.19	0.6369	
Pure Error	16.25	1	16.25			
Core Total	2007.98	80				

The Model F-value of 2.71 implies the model is significant. There is only a 0.33% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case B, BC, BD are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 1.19 implies the Lack of Fit is not significant relative to the pure error.

There is a 63.69% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

4.6.4. Final Equation in Terms of Coded Factors

COD = 50.76 – 1.14A -2.30B + 0.0424C +0. 6589D – 0.8686AB + 0.7797AC + 1.31AD + 1.57 BC – 1.54BD – 0.5262CD + 0.3218 A^2 + 1.09B^2 + 0.9350C^2 - 0.0413D^2…………………. (4.5)

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficient.

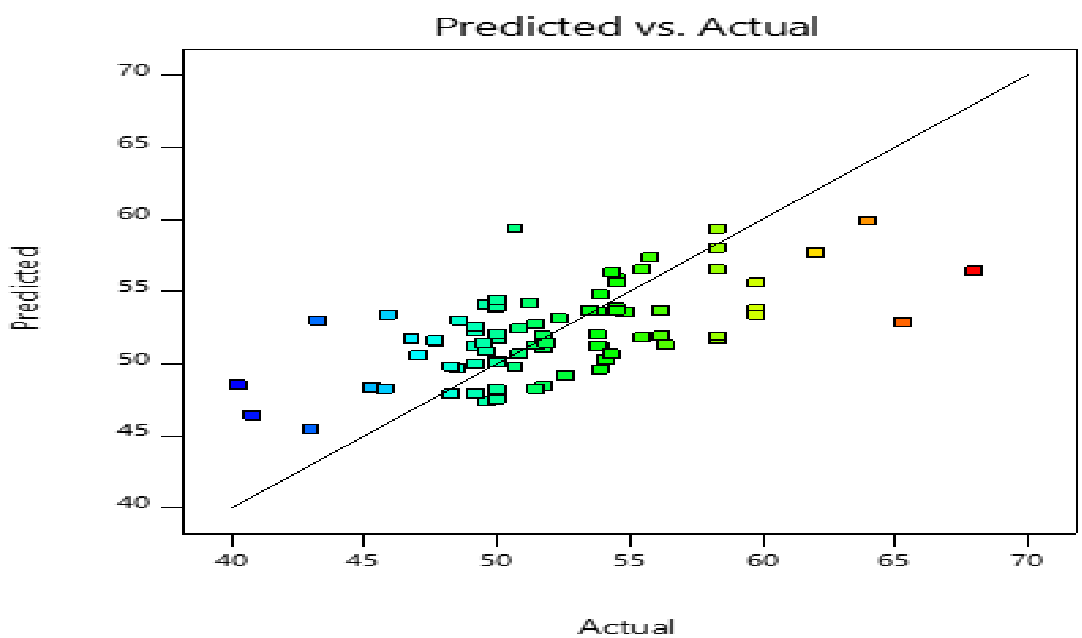


Figure 4.17 Predicted verses actual value of response COD for moringa powder treatment

As shown in figure 4.17 predicted verses actual value of COD removal using moringa powder. Hence, the points concentrated towards the diagonal line, about the mean indicate the is a close relation and agreement between the predicted and actual experimental value. But points those further away from the diagonal line indicate the presence of some disagreement between the predicted and actual value. General since most of the points close to the mean so there is a good agreement between the two value.

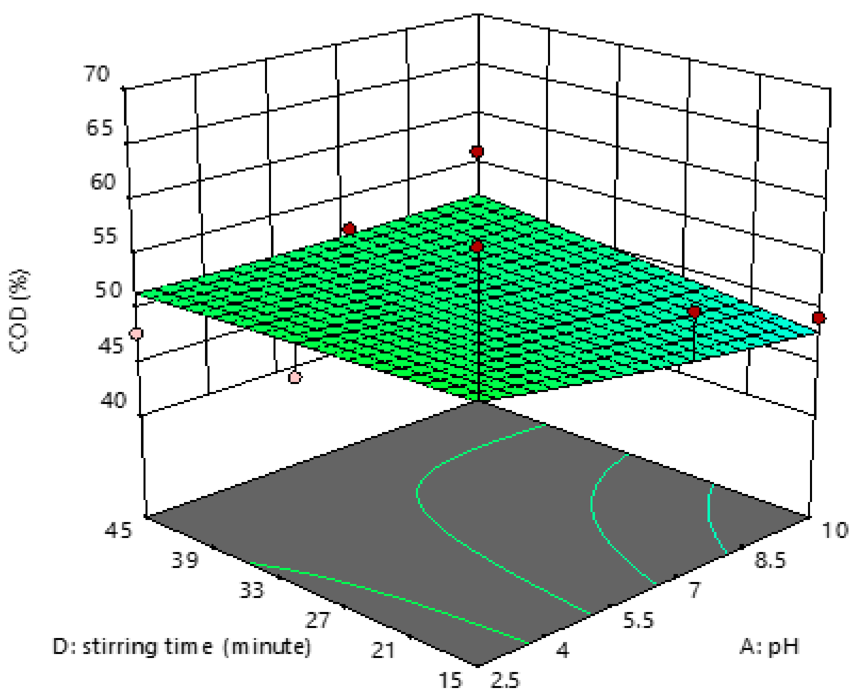


Figure 4.18 Response surface of quadratic model for percentage COD removal and the interactive effects of four factors for treatment using moringa powder

As shown in figure 4.18 coagulant stirring time and pH affects the COD removal efficiency of the coagulation and flocculation process, as stirring time and pH of the sample water increase the COD removal of the process was decrease. Therefore, it is well done at minimum dosage and acidic condition.

4.6.5. Analysis of variance(ANOVA) for Response Surface Quadratic Model for turbidity removal by moringa powder

Table 4.18 Sequential Model Sum of Squares

Source	Sum of Squares	df	Mean Square	F-value	p-value
Mean vs Total	7.446E+05	1	7.446E+05		
Linear vs Mean	24.82	4	6.20	15.43	< 0.0001

2FI vs Linear	3.56	6	0.5926	1.54	0.1791	
Quadratic vs 2FI	**7.10**	**4**	**1.77**	**5.89**	**0.0004**	**Suggested**
Cubic vs Quadratic	10.16	16	0.6347	3.26	0.0007	Aliased
Residual	9.74	50	0.1948			
Total	7.446E+05	81	9192.66			

Table 4.19 Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	0.6340	0.4482	0.4192	0.3699	34.89	
2FI	0.6210	0.5124	0.4428	0.3290	37.15	
Quadratic	**0.5491**	**0.6406**	**0.5644**	**0.4243**	**31.88**	**Suggested**
Cubic	0.4414	0.8241	0.7185	0.4450	30.73	Aliased

Table 4.20 ANOVA for Quadratic model

Response 3: turbidity

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	35.47	14	2.53	8.40	< 0.0001	Highly significant
A-pH	22.16	1	22.16	73.51	< 0.0001	
B-dosage	0.4416	1	0.4416	1.46	0.2305	
C-stirring speed	1.37	1	1.37	4.54	0.0368	
D-stirring time	0.1864	1	0.1864	0.6182	0.4345	
AB	1.39	1	1.39	4.61	0.0356	
AC	0.0983	1	0.0983	0.3260	0.5700	
AD	0.0972	1	0.0972	0.3226	0.5720	
BC	0.1375	1	0.1375	0.4559	0.5019	
BD	1.88	1	1.88	6.24	0.0150	
CD	0.0023	1	0.0023	0.0077	0.9302	
A^2	0.1908	1	0.1908	0.6329	0.4291	
B^2	5.77	1	5.77	19.14	< 0.0001	
C^2	0.1467	1	0.1467	0.4867	0.4879	
D^2	0.9360	1	0.9360	3.10	0.0827	
Residual	19.90	66	0.3015			

Lack of Fit	19.77	65	0.3042	2.43	0.4762
Pure Error	0.1250	1	0.1250		
Core Total	55.37	80			

The Model F-value of 8.40 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

P-values less than 0.0500 indicate model terms are significant. In this case A, C, AB, BD, B^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 2.43 implies the Lack of Fit is not significant relative to the pure error. There is a 47.62% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

4.6.6 Final Equation in Terms of Coded Factors

Turbidity = 96.38 + 0.6417A + 0.0908B – 0.1614C – 0.0590D + 0.1955AB – 0.0527AC + 0.0517AD +0.0629BC + 0.2291BD – 0.0082CD – 0.1080A^2 - 0.5665B^2 + 0.0899C^2 - 0.2282D^2………………………………………………………………………….... (4.6)

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

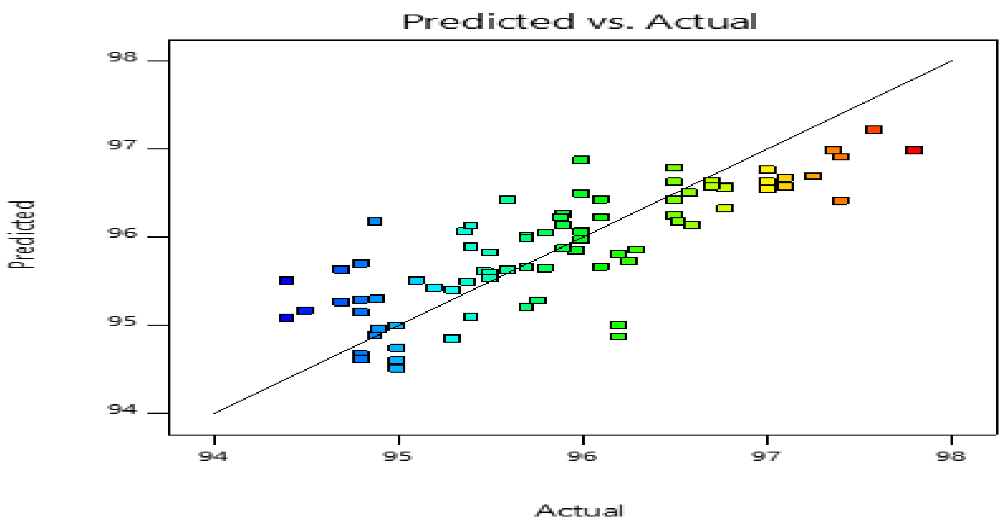


Figure 4.19 Predicted verses actual value of response turbidity for moringa powder treatment

As shown in figure 4.19 predicted verses actual value of turbidity removal using moringa powder. Hence, the points concentrated towards the diagonal line, about the mean indicate the is a close relation and agreement between the predicted and actual experimental value. But points those further away from the diagonal line indicate the presence of some disagreement between the predicted and actual value. General since most of the points close to the mean so there is a good agreement between the two value.

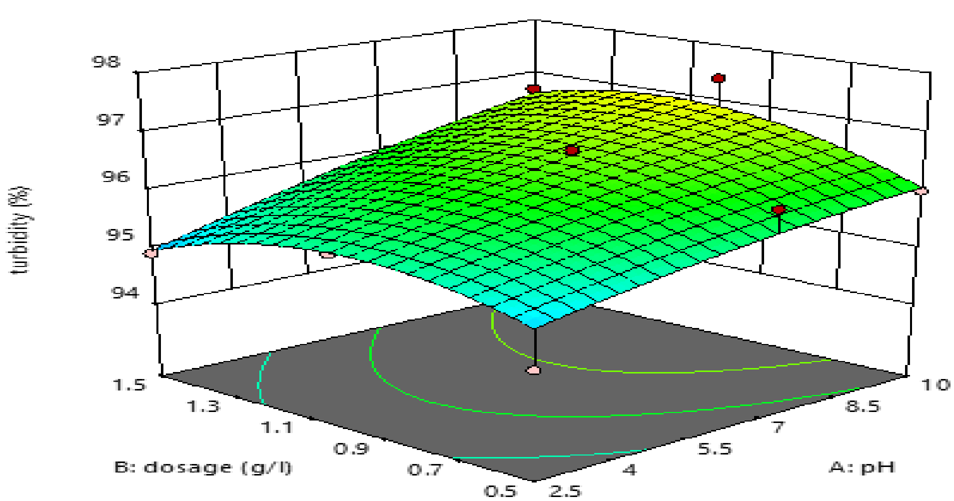


Figure 4.20 Response surface of the quadratic model for percentage turbidity removal and the interaction between the four factors using moringa powder

As shown in figure 4.20 the interactive effect of pH and coagulant dosage also affects the turbidity removal efficiency of coagulation and flocculation process using moringa powder. So in this case as the dose and pH increase the percentage removal of turbidity also increase to but the further dosage of the moringa powder leads to the water turbid again.

4.7. Response surface methodology(RSM) and optimization

According to (Khuri and Mukhopadhyay, 2010), one of the main objectives of RSM is the determination of the optimum settings of the control variables that result in a maximum (or a minimum) response over a certain region of interest, R. This requires having a 'good' fitting model that provides an adequate representation of the mean response because such a model is to be utilized the value of the optimum. Optimization techniques used in RSM depend on the nature of the fitted model. Optimization study of the experimental results were performed by keeping responses within desired ranges by using responses surface methodology (Asghar, et al., 2014). And also in this study the responses, color, COD and turbidity removal was targeted to the maximum and other variables were kept in a range.

So in this investigation with the color, COD, and turbidity removal as the response for both coagulant, the response surfaces (3D) of the quadratic model with one variable kept at central level and the other two varying within the experimental ranges are respectively shown in Figures above. The obvious trough in the response surfaces indicates that the optimal conditions were exactly located inside the design boundary. The results showed that four factors were considered in this study contribute an important role on the removal efficiency of color, COD and turbidity. The optimum conditions or values obtained from the numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 2.5, 1.167g, 83.191rpm and 42.093minutes respectively when cactus powder was used as a natural coagulant. Under this optimum conditions, about 70.218%, 47.102 % and 83.799% for color, COD and turbidity removal efficiency was obtained respectively.

And also in the same manner when moringa stenopetala used as a natural coagulant, the optimum conditions or values obtained from numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 10, 0.602g, 30.000rpm and 36.563 minute respectively. Then under this optimum condition, about 99.402%, 56.134%, and 96.557%, for color, COD and turbidity removal efficiency was obtained respectively.

CHAPTER FIVE

CONCLUSIONS AND RECCOMENDATIONS

5.1. CONCULUSIONS

Coagulation flocculation is the physicochemical process that is best for surface water treatment using natural coagulants. Cactus and moringa stenopetala was proven to be able to be used for surface water treatment. This study demonstrates the application of indigenous natural coagulants, specifically cactus and moringa stenopetala powder for pollutants removal from surface water in terms of selected physical and chemical parameters of surface water like color, COD and turbidity. In addition to this the study demonstrated the application of response surface methodology (RSM) in order to evaluate the optimal conditions and determining the optimum value from the optimization process with respect to color, COD and turbidity removal. The central composite design, parts of RSM was used to evaluate the interactive effects of input factors or operating parameters those are pH, coagulant dosage, stirring speed and stirring time on the coagulation flocculation effectiveness and then determine the optimal condition or value.

The results showed that four factors were considered in this study contribute an important role on the removal efficiency of color, COD and turbidity. The optimum conditions or values obtained from the numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 2.5, 1.167g, 83.191rpm and 42.093minutes respectively when cactus powder was used as a natural coagulant. Under this optimum conditions, about 70.218%, 47.102 % and 83.799% for color, COD and turbidity removal efficiency was obtained respectively.

And also in the same manner when moringa stenopetala used as a natural coagulant, the optimum conditions or values obtained from numerical optimization system for pH, coagulant dosage, stirring speed and stirring time were 10, 0.602g, 30.000rpm and 36.563 minute respectively. Then under this optimum condition, about 99.402%, 56.134%, and 96.557%, for color, COD and turbidity removal efficiency was obtained respectively. The verification of the results was done by incorporating the experimentally analyzed results in to the optimization process using CCD. Therefore, these experimental findings were in close agreement with model prediction. And also it can be concluded that moringa stenopetala has high potential than cactus in removing color, turbidity and COD.

5.2. RECCOMENDATIONS

Based on the outcomes or results showed throughout the experimental processes as well as from optimized values and also condition of design parameters on respective responses for this study, the following recommendations were recommended:

I. Filtration water treatment system should be work in combination with coagulation flocculation treatment process. And also there should be comparation between filtered and nonfiltered treated water that preliminary treated by coagulation process. Then this filtration system should take place after sedimentation in order to increase the effectiveness of the coagulation flocculation process by trapping some non-settable suspended smaller particles that present due to the designed factors including coagulant powder dosage, high coagulation speed and time.

II. The next suggestion goes to model selection from design expert software for optimization purpose. So as the result show for this study the quadratic model was selected to predict or estimate the removal efficiency. But even if it was selected randomly and it is best fitted to predict or estimate the removal efficiency for coagulation and flocculation process, for some responses the software recommends or suggest another model type for further investigation. Therefore, I recommend for future investigator or researcher to check the data using more than one model type in order to examine the prediction or estimation capability of responses under different model to determine the best model type, the model that can best capability to predict the responses.

III. As experimental and optimized results show in case of coagulation flocculation treatment system using cactus powder the removal efficiency was better at low pH, acidic condition. But coagulating at low pH requires more attention to potential corrosion problems. Therefore, there should be post treatment pH adjustment or alkalinity adjustment in order to insure that the treated water is not corrosive.

IV. Since the treatment process conducted for this study was coagulation and flocculation(CF), there was the sludge producing process due to the floc and sediment formation per each experiment. Therefore, there should be further study on the sludge produced from the coagulation flocculation process to take part in best sludge management system in order to prevent secondary pollution of the environment either by selecting suitable disposal site or by analyzing it for land application.

V. Finally I suggest that plantation based researches should be developed in terms of natural coagulants based on the existing one. As the result of this study show cactus and moringa stenopetala powder have high potential to reduce pollutants color, COD and turbidity from water specially moringa stenopetala (seed of shiferaw), actually they are available in some part of Ethiopia but there should be exist at all area.

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APPENDIXES

Appendix A: Experimental design matric and response based on the experimental run and predicted value on color, COD and turbidity removal (%) for cactus powder based on central composite design (CCD). The last three columns at the right side are the predicted values for responses (color, COD and turbidity) respectively.

Un Coded/coded values of factors					responses					
Run	A	B	C	D	Color	COD	Turbidity			
	-	g/L	rpm	minute	%	%	%			
1	2.5	0.5	30	15	79.1	40	87.6	65.90	39.32	84.10
2	2.5	0.5	60	15	70.8	30.7	86.1	70.41	41.35	85.67
3	2.5	0.5	90	15	66.87	40.8	85.5	71.78	43.39	85.86
4	2.5	0.5	30	30	30.6	48.78	73.38	65.37	42.09	81.31
5	2.5	0.5	60	30	54.15	49.2	89.1	68.76	44.13	83.25
6	2.5	0.5	90	30	50.2	53.17	88.8	69.01	46.16	83.83
7	2.5	0.5	30	45	84.1	41.6	74.4	68.29	44.86	77.44
8	2.5	0.5	60	45	78.4	68.1	73.2	70.56	46.90	79.76
9	2.5	0.5	90	45	76.9	56.7	71.1	69.68	48.94	80.72
10	7	0.5	30	15	16.3	44.1	79.75	25.84	39.30	80.86
11	7	0.5	60	15	35.37	29.17	81.3	29.24	41.33	81.94
12	7	0.5	90	15	30.13	46.9	82.3	29.49	43.37	81.64
13	7	0.5	30	30	29.2	35	84.4	26.19	42.07	79.83
14	7	0.5	60	30	25.3	31.7	82	28.47	44.11	81.28

15	7	0.5	90	30	22.77	36.55	81.8	27.60	46.15	81.36
16	7	0.5	30	45	31.3	36.7	84	29.98	44.85	77.71
17	7	0.5	60	45	26.9	46.1	84.7	31.14	46.88	79.55
18	7	0.5	90	45	24.1	46.15	84.5	29.15	48.92	80.01
19	10	0.5	30	15	23	28.3	82.8	21.81	39.28	84.69
20	10	0.5	60	15	33.76	44.44	83.8	24.46	41.32	85.43
21	10	0.5	90	15	29.15	50.78	83.5	23.97	43.36	84.81
22	10	0.5	30	30	26.57	47.5	83.3	22.74	42.06	84.83
23	10	0.5	60	30	62.9	45.4	87.8	24.28	44.10	85.95
24	10	0.5	90	30	21.7	39.57	84.47	22.66	46.13	85.71
25	10	0.5	30	45	21.7	46.7	83.8	27.12	44.83	83.89
26	10	0.5	60	45	22	48.3	84.55	27.54	46.87	85.39
27	10	0.5	90	45	22.97	52	84.4	24.80	48.91	85.52
28	2.5	1	30	15	69.95	29.4	86.5	68.85	38.69	86.67
29	2.5	1	60	15	92.2	37.7	87.3	73.16	40.73	87.20
30	2.5	1	90	15	92.27	37.2	86.8	74.32	42.76	86.36
31	2.5	1	30	30	72.2	37.77	87.3	67.51	41.46	84.51
32	2.5	1	60	30	81.5	35.55	86.12	70.70	43.50	85.42
33	2.5	1	90	30	81.27	56.2	86.37	70.74	45.54	84.95
34	2.5	1	30	45	80.72	51.7	86.8	69.62	44.24	81.27
35	2.5	1	60	45	69.3	41.7	85.8	71.69	46.27	82.56
36	2.5	1	90	45	73.4	46.9	85.2	70.60	48.31	82.47
37	7	1	30	15	17.4	64.5	76.4	29.79	38.67	77.68
38	7	1	60	15	22.6	47.7	73.7	32.99	40.71	77.72
39	7	1	90	15	29.4	42.1	74	33.03	42.74	76.38
40	7	1	30	30	29.16	48.8	76	29.33	41.44	77.28
41	7	1	60	30	31.6	51.7	71.47	31.41	43.48	77.69

42	7	1	90	30	36.4	40	74.5	30.33	45.52	76.74
43	7	1	30	45	33.5	49.2	71.9	32.32	44.22	75.79
44	7	1	60	45	32.68	27.5	77.6	33.27	46.26	76.59
45	7	1	90	45	36.4	39.55	77.1	31.08	48.29	76.01
46	10	1	30	15	22.97	27.77	81.1	26.43	38.66	77.68
47	10	1	60	15	15.9	44.45	77.8	28.88	40.69	77.38
48	10	1	90	15	15.26	47.4	79.1	28.18	42.73	75.72
49	10	1	30	30	28.82	30	76.5	26.55	41.43	78.44
50	10	1	60	30	14.9	48.55	77.97	27.89	43.47	78.53
51	10	1	90	30	17.1	54	78.8	26.07	45.51	77.25
52	10	1	30	45	22.1	47.9	76.8	30.12	44.21	78.13
53	10	1	60	45	23.1	47.3	76.5	30.34	46.24	78.60
54	10	1	90	45	30.5	54.65	77.3	27.40	48.28	77.69
55	2.5	1.5	30	15	69.45	38.07	86.45	67.36	38.06	89.16
56	2.5	1.5	60	15	60.6	37	86.9	71.47	40.10	88.65
57	2.5	1.5	90	15	60	39.97	87.27	72.42	42.13	86.77
58	2.5	1.5	30	30	62.9	45.4	87.8	65.21	40.84	87.62
59	2.5	1.5	60	30	65.1	45	87.58	68.20	42.87	87.49
60	2.5	1.5	90	30	69.3	49.25	84.6	68.03	44.91	85.99
61	2.5	1.5	30	45	61.2	46.3	85.7	66.51	43.61	85.01
62	2.5	1.5	60	45	58.57	26.8	85.9	68.37	45.65	85.26
63	2.5	1.5	90	45	60.56	47.5	83.88	67.09	47.68	84.14
64	7	1.5	30	15	34.5	31.8	76	29.31	38.04	74.42
65	7	1.5	60	15	39.2	29.8	75	32.30	40.08	73.42
66	7	1.5	90	15	39.1	40.88	72.5	32.14	42.12	71.04
67	7	1.5	30	30	30	49.2	72.57	28.04	40.82	74.64
68	7	1.5	60	30	30.2	47.1	71.97	29.91	42.85	74.02

69	7	1.5	90	30	33.5	49.2	71.9	28.63	44.89	72.03
70	7	1.5	30	45	31.8	53.48	72.88	30.21	43.59	73.79
71	7	1.5	60	45	30.3	47.5	73.2	30.96	45.63	73.55
72	7	1.5	90	45	31.6	51.7	71.47	28.56	47.67	71.93
73	10	1.5	30	15	30.6	48.78	73.38	26.61	38.03	70.58
74	10	1.5	60	15	25.38	44.7	72.9	28.86	40.07	69.25
75	10	1.5	90	15	25.7	41.65	61.88	27.96	42.10	66.55
76	10	1.5	30	30	31.2	38.2	72.2	25.93	40.80	71.98
77	10	1.5	60	30	29.9	40	71.8	27.05	42.84	71.02
78	10	1.5	90	30	33.2	47.4	71.15	25.03	44.88	68.70
79	10	1.5	60	45	26.57	35.35	71.75	28.69	45.62	71.72
80	10	1.5	60	45	30.5	37.6	72.2	28.69	45.62	71.72
81	10	1.5	30	45	31.3	38.88	71.9	28.69	43.58	72.29

Appendix B: Experimental design matric and response based on the experimental run and predicted values on the removal of color, COD and turbidity (%) for moringa powder based on the central composite design and the last three columns at the right side are the predicted value for responses (color, COD and turbidity) respectively.

	Values of uncoded factors				responses					
Run	A	B	C	D	Color	COD	turbidity			
	-	g/L	rpm	minute	%	%	%			
1	2.5	0.5	30	15	96.1	55.5	95.5	94.72	56.53	95.53
2	2.5	0.5	60	15	96.25	54.5	95.76	93.82	53.82	95.28
3	2.5	0.5	90	15	96	48.6	95.7	93.69	52.97	95.21
4	2.5	0.5	30	30	94.65	58.3	95.2	94.43	57.99	95.43
5	2.5	0.5	60	30	95.2	53.9	94.5	93.68	54.75	95.17
6	2.5	0.5	90	30	92.6	59.8	94.4	93.71	53.38	95.09
7	2.5	0.5	30	45	96.25	58.3	96.2	93.51	59.36	94.87
8	2.5	0.5	60	45	89.9	54.5	95	92.91	55.59	94.60
9	2.5	0.5	90	45	89.7	53.5	95	93.08	53.70	94.51
10	7	0.5	30	15	98.1	45.9	96.52	97.09	53.38	96.17
11	7	0.5	60	15	89.5	47.71	96.3	96.51	51.60	95.86
12	7	0.5	90	15	99.4	58.3	96.26	96.70	51.69	95.72
13	7	0.5	30	30	98.6	68	96.6	97.01	56.41	96.13
14	7	0.5	60	30	98.2	50	96.2	96.58	54.11	95.81
15	7	0.5	90	30	98.1	54.5	96.1	96.92	53.67	95.66
16	7	0.5	30	45	91.5	50.7	94.7	96.29	59.36	95.63

17	7	0.5	60	45	98	58.3	94.89	96.01	56.53	95.30
18	7	0.5	90	45	98	59.8	94.8	96.50	55.57	95.15
19	10	0.5	30	15	98.27	55.5	95.6	99.80	51.79	96.43
20	10	0.5	60	15	99.6	50.88	95.37	99.43	50.64	96.07
21	10	0.5	90	15	99.6	49.5	95.4	99.83	51.36	95.89
22	10	0.5	30	30	99.4	54.5	96.1	99.86	55.88	96.43
23	10	0.5	60	30	99.4	51.26	96	99.64	54.20	96.06
24	10	0.5	90	30	99.4	50	95.9	100.19	54.39	95.87
25	10	0.5	30	45	99.57	64	96	99.28	59.88	95.97
26	10	0.5	60	45	99.5	62	95.5	99.20	57.67	95.59
27	10	0.5	90	45	99.47	55.8	95.3	99.91	57.33	95.40
28	2.5	1	30	15	95.6	50	94.8	95.82	53.99	95.70
29	2.5	1	60	15	91.1	65.3	95.1	94.65	52.84	95.51
30	2.5	1	90	15	91.6	54.86	94.4	94.25	53.56	95.50
31	2.5	1	30	30	95.7	50	95.5	95.72	53.90	95.83
32	2.5	1	60	30	95.5	49.2	95.6	94.70	52.23	95.63
33	2.5	1	90	30	95.6	50.88	95.47	94.45	52.42	95.61
34	2.5	1	30	45	95.8	59.8	95.38	94.98	53.73	95.50
35	2.5	1	60	45	94.4	47.7	94.8	94.11	51.53	95.29
36	2.5	1	90	45	94	49.2	94.7	94.01	51.20	95.26
37	7	1	30	15	95.8	48.3	96.7	96.76	49.79	96.58
38	7	1	60	15	95.28	53.9	96.78	95.90	49.58	96.32
39	7	1	90	15	94.6	51.5	96.5	95.82	51.24	96.25
40	7	1	30	30	93.9	56.36	97	96.86	51.28	96.76
41	7	1	60	30	95.5	47.1	96.58	96.15	50.54	96.50
42	7	1	90	30	94.37	50	96.5	96.22	51.68	96.42
43	7	1	30	45	97	51.5	96	96.32	52.69	96.50

44	7	1	60	45	97.17	51.9	96.1	95.77	51.43	96.23
45	7	1	90	45	95.4	50	95.9	95.98	52.03	96.14
46	10	1	30	15	99.57	50	97.36	98.51	47.51	96.99
47	10	1	60	15	99.1	49.2	97.25	97.86	47.92	96.69
48	10	1	90	15	99.17	50	97.1	97.99	50.21	96.58
49	10	1	30	30	99.57	50	97.58	98.75	50.05	97.22
50	10	1	60	30	99.5	49.2	97.4	98.25	49.94	96.91
51	10	1	90	30	99.4	46.8	96.5	98.53	51.70	96.79
52	10	1	30	45	99.6	49.2	97.8	98.35	52.51	96.99
53	10	1	60	45	99.5	56.2	97.1	98.00	51.87	96.68
54	10	1	90	45	99.4	52.37	97	98.43	53.10	96.54
55	2.5	1.5	30	15	97.7	53.87	95	97.79	53.61	94.74
56	2.5	1.5	60	15	97.55	49.6	94.8	96.34	54.03	94.61
57	2.5	1.5	90	15	95.7	54.37	94.8	95.67	56.33	94.66
58	2.5	1.5	30	30	96	53.8	95.4	97.87	51.98	95.09
59	2.5	1.5	60	30	96.57	51.76	94.9	96.57	51.88	94.96
60	2.5	1.5	90	30	95.7	56.2	96.2	96.05	53.64	95.00
61	2.5	1.5	30	45	96.38	54.14	95	97.31	50.27	94.99
62	2.5	1.5	60	45	96.89	48.55	95.3	96.17	49.64	94.85
63	2.5	1.5	90	45	97.34	49.6	94.88	95.79	50.88	94.88
64	7	1.5	30	15	97.2	51.8	95.97	97.29	48.37	95.85
65	7	1.5	60	15	97.6	50.7	95.7	96.15	49.73	95.66
66	7	1.5	90	15	97.2	43.3	95.8	95.80	52.96	95.65
67	7	1.5	30	30	97.97	45.3	95.9	97.57	48.32	96.26
68	7	1.5	60	30	97.75	52.6	96	96.59	49.15	96.07
69	7	1.5	90	30	97.4	58.3	95.8	96.38	51.85	96.05
70	7	1.5	30	45	96.4	50	95.88	97.22	48.19	96.23

71	7	1.5	60	45	97.7	40.27	95.7	96.39	48.49	96.02
72	7	1.5	90	45	97.45	54.3	95.7	96.33	50.67	95.99
73	10	1.5	30	15	99.5	43	97.4	98.08	45.40	96.41
74	10	1.5	60	15	97.34	49.6	94.88	97.16	47.38	96.18
75	10	1.5	90	15	96	53.8	95.4	97.01	51.23	96.13
76	10	1.5	30	30	99.57	40.8	96	98.50	46.40	96.87
77	10	1.5	60	30	95.8	48.3	96.7	97.73	47.85	96.63
78	10	1.5	90	30	95.28	53.9	96.78	97.73	51.18	96.57
79	10	1.5	60	45	94.6	51.5	96.5	97.66	48.24	96.63
80	10	1.5	60	45	97.17	45.8	97	97.66	48.24	96.63
81	10	1.5	90	45	96.9	51.8	96.77	97.82	51.04	96.56

Appendix C: Experimental results for cactus powder usage of coagulation and flocculation process for surface water treatment

Experiment: 1(D1, PH1, S1, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment Interval		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal	Turbidity removal	pH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD (mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	30	15	45	420	0.067	78.53	0.2	64	33.33	13.7	87.2	2.8
2	0.5	2.5	30	15	45	420	0.065	79.17	0.18	57.6	40	12.9	87.9	2.87
3	0.5	2.5	30	15	45	420	0.0637	79.58	0.16	51.2	46.7	13.2	87.66	2.83
							Average,%	79.1	-	-	40.0	-	87.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.3	96.0	-	107	-	-

Experiment:2(D1, PH1, S2, T1) system: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD (mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	60	15	45	420	0.051	83.65	0.16	51.2	36	16.6	84.5	2.99
2	0.5	2.5	60	15	45	420	0.099	68.3	0.16	51.2	36	13.9	87.0	2.91
3	0.5	2.5	60	15	45	420	0.123	60.57	0,2	64	20	14.2	86.7	2.97
							Average, %	70.8	-	-	30.7	-	86.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.25	80.0	-	107	-	-

Experiment: 3 (D1, PH1, S3, T1) system: Jar test Coagulant type: Cactus powder Date: 16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	pH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal ,%	FAS (ml)	COD (mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	90	15	45	420	0.063	79.8	0.18	57.6	41.9	17.4	83.74	2.99
2	0.5	2.5	90	15	45	420	0.097	68.9	0.16	51.2	48.38	14.9	86.0	2.91
3	0.5	2.5	90	15	45	420	0.15	51.9	0.21	67.2	32.25	14.2	86.73	2.97
							Average,%	66.87	-	-	40.8	-	85.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.31	99.2	-	107	-	-

Experiment: 4 (D1, PH1, S1, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorb-ance	Color removal %	FAS (ml)	COD (mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	30	30	45	420	0.216	30.76	0.19	60.8	53.66	27.8	74	2.77
2	0.5	2.5	30	30	45	420	0.213	31.7	0.23	73.6	43.9	29.8	72.15	2.89
3	0.5	2.5	30	30	45	420	0.220	29.5	0.21	67.2	48.78	27.9	73.9	2.87
							Average,%	30.6	-	-	48.78	-	73.38	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 5 (D1, PH1, S2, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD (mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	60	30	45	420	0.13	58.3	0.19	60.8	52.5	12.8	88.0	2.99
2	0.5	2.5	60	30	45	420	0.129	58.65	0.21	67.2	47.5	10.4	90.3	2.84
3	0.5	2.5	60	30	45	420	0.17	45.5	0.21	67.2	47.5	11.8	88.97	2.843
							Average, %	54.15	-	-	49.2	-	89.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 6 (D1, PH1, S3, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	90	30	45	420	0.14	55.13	0.18	57.6	61.7	13.1	87.76	2.99
2	0.5	2.5	90	30	45	420	0.157	49.7	0.25	80.0	46.8	10.9	89.8	2.84
3	0.5	2.5	90	30	45	420	0.17	45.5	0.23	73.6	51.0	11.8	88.97	2.843
							Average,%	50.2	-	-	53.17	-	88.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment:7(D1, PH1, S1, T3) system: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	30	45	45	420	0.062	80.13	0.36	115.2	35.7	27.3	74.5	2.74
2	0.5	2.5	30	45	45	420	0.07	77.56	0.32	102.4	42.8	27.0	74.8	2.81
3	0.5	2.5	30	45	45	420	0.017	94.55	0.30	96.0	46.4	27.8	74.0	2.79
							Average,%	84.1	-	-	41.6	-	74.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.56	179.2	-	107	-	-

Experiment:8(D1, PH1, S2, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	60	45	45	420	0.072	76.9	0.22	70.4	68.57	31	76	2.81
2	0.5	2.5	60	45	45	420	0.064	79.5	0.24	76.8	65.7	30	71.9	2.98
3	0.5	2.5	60	45	45	420	0.066	78.8	0.21	67.2	70	30.3	71.7	2.99
							Average,%	78.4	-	-	68.1	-	73.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.7	224	-	107	-	-

Experiment: 9(D1, PH1, S3, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	90	45	45	420	0.078	75	0.23	73.6	54	31.8	70.28	3.2
2	0.5	2.5	90	45	45	420	0.069	77.88	0.21	67.2	58	30.6	71.4	2.99
3	0.5	2.5	90	45	45	420	0.069	77.88	0.21	67.2	58	30.3	71.7	2.99
							Average,%	76.9	-	-	56.7	-	71.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment:10(D1, PH2, S1, T1) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	30	15	45	420	0.287	8.0	0.19	60.8	38.7	22.3	79.16	5.3
2	0.5	7	30	15	45	420	0.28	10.256	0.17	54.4	45.2	21.3	80.1	5.39
3	0.5	7	30	15	45	420	0.216	30.77	0.16	51.2	48.4	21.4	80	5.5
							Average,%	16.3	-	-	44.1	-	79.75	-
Control	0	5.8	-	-	-	420	0.312	-	0.31	99.2	-	107	-	-

Experiment:11(D1, PH2, S2, T1) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	60	15	45	420	0.2	35.9	0.3	96	25	19.8	81.5	5.4
2	0.5	7	60	15	45	420	0.215	31.1	0.28	89.6	30	21.3	80.1	5.38
3	0.5	7	60	15	45	420	0.19	39.1	0.27	86.4	32.5	19.4	81.87	5.4
							Average,%	35.37	-	-	29.17	-	81.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 12(D1, PH2, S3, T1) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	90	15	45	420	0.214	31.4	0.27	86.4	44.9	20.9	80.46	5.77
2	0.5	7	90	15	45	420	0.21	32.7	0.24	76.8	51.0	21.3	80.1	58.81
3	0.5	7	90	15	45	420	0.23	26.3	0.27	86.4	44.9	20.7	86.3	5.21
							Average,%	30.13	-	-	46.9	-	82.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment:13(D1, PH2, S1, T2) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	30	30	45	420	0.211	32.4	0.26	83.2	35	16.9	84.2	5.3
2	0.5	7	30	30	45	420	0.202	35.3	0.3	96	25	16.4	84.7	5.08
3	0.5	7	30	30	45	420	0.25	19.9	0.22	70.4	45	16.8	84.3	5.2
							Average,%	29.2	-	-	35.0	-	84.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 14(D1, PH2, S2, T2) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	60	30	45	420	0.24	23.1	0.28	89.6	33.33	19.2	82.0	5.5
2	0.5	7	60	30	45	420	0.208	33.33	0.27	86.4	35.7	19.4	81.87	5.45
3	0.5	7	60	30	45	420	0.251	19.55	0.31	99.2	26.2	18.9	82.3	5.41
							Average,%	25.3	-	-	31.7	-	82.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 15(D1, PH2, S3, T2) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	90	30	45	420	0.242	22.4	0.27	86.4	40	19.5	81.77	5.55
2	0.5	7	90	30	45	420	0.223	28.5	0.29	92.8	35.55	19.9	81.4	5.48
3	0.5	7	90	30	45	420	0.211	32.4	0.31	99.2	31.1	18.9	82.3	5.42
							Average,%	27.77	-	-	36.55	-	81.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment:16(D1, PH2, S1, T3) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	30	45	45	420	0.23	26.3	0.26	83.2	35	17.3	83.8	5.59
2	0.5	7	30	45	45	420	0.199	36.2	0.24	76.8	40	16.9	84.2	5.71
3	0.5	7	30	45	45	420	0.214	31.4	0.26	83.2	35	17.1	84	5.63
							Average,%	31.3	-	-	36.7	-	84.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:17(D1, PH2, S2, T3) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(27/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	60	45	45	420	0.22	29.5	0.21	67.2	46.1	16.5	84.57	5.6
2	0.5	7	60	45	45	420	0.236	24.4	0.22	70.4	43.6	16.1	84.9	5.6
3	0.5	7	60	45	45	420	0.228	26.9	0.2	64	48.7	16.3	84.77	5.58
							Average,%	26.9	-	-	46.1	-	84.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment: 18(D1, PH2, S3, T3) System: Jar test Coagulant type: Cactus powder Date:17/12/2010(23/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	7	90	45	45	420	0.242	22.4	0.22	70.4	43.59	16.8	84.3	5.63
2	0.5	7	90	45	45	420	0.236	24.4	0.2	64	48.7	16.3	84.76	5.621
3	0.5	7	90	45	45	420	0.232	25.6	0.21	67.2	46.15	16.6	84.5	5.5
							Average,%	24.1	-	-	46.15	-	84.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment:19(D1, PH3, S1, T1) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	30	15	45	420	0.21	32.7	0.32	102.4	20	18.3	82.89	8.4
2	0.5	10	30	15	45	420	0.27	13.46	0.28	89.6	30	18.2	83.0	8.49
3	0.5	10	30	15	45	420	0.24	23.07	0.26	83.2	35	18.7	82.5	8.37
							Average,%	23.0	-	-	28.3	-	82.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:20(D1, PH3, S2, T1) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	60	15	45	420	0.2	35.89	0.22	70.4	47.6	17.2	83.9	8.4
2	0.5	10	60	15	45	420	0.19	39.1	0.24	76.8	42.86	17.6	83.55	8.6
3	0.5	10	60	15	45	420	0.23	26.3	0.24	76.8	42.86	17.1	84.0	8.37
							Average,%	33.76	-	-	44.44	-	83.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 21 (D1, PH3, S3, T1) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	90	15	45	420	0.231	25.96	0.22	70.4	47.6	17.3	83.8	8.458

2	0.5	10	90	15	45	420	0.22	29.5	0.2	64	52.38	17.6	83.55	8.6
3	0.5	10	90	15	45	420	0.212	32.0	0.2	64	52.38	17.9	83.27	8.39
							Average,%	29.15	-	-	50.78	-	83.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 22 (D1, PH3, S1, T2) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	30	30	45	420	0.24	23.0	0.19	60.8	52.5	18.2	83.0	8.44
2	0.5	10	30	30	45	420	0.219	29.8	0.21	67.2	47.5	17.8	83.36	8.47
3	0.5	10	30	30	45	420	0.228	26.9	0.23	73.6	42.5	17.5	83.6	8.37
							Average,%	26.57	-	-	47.5	-	83.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 23 (D1, PH3, S2, T2) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	60	30	45	420	0.12	61.5	0.23	73.6	47.7	13.5	87.3	2.73
2	0.5	10	60	30	45	420	0.107	65.7	0.28	89.6	36.36	12.7	88.1	3.09
3	0.5	10	60	30	45	420	0.12	61.5	0.21	67.2	52.27	12.6	88.2	3.22
							Average,%	62.9	-	-	45.4	-	87.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 24 (D1, PH3, S2, T2) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	90	30	45	420	0.241	22.75	0.27	86.4	35.7	16.9	84.2	8.3
2	0.5	10	90	30	45	420	0.247	20.8	0.26	83.2	38	16.2	84.8	8.54
3	0.5	10	90	30	45	420	0.245	21.5	0.23	73.6	45	16.7	84.4	8.512
							Average,%	21.7	-	-	39.57	-	84.47	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment:25 (D1, PH3, S1, T3) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	30	45	45	420	0.241	22.75	0.2	64	50	18.98	82.26	8.3
2	0.5	10	30	45	45	420	0.247	20.8	0.22	70.4	45	16.2	84.86	8.47
3	0.5	10	30	45	45	420	0.245	21.5	0.22	70.4	45	16.9	84.2	8.4
							Average,%	21.7	-	-	46.7	-	83.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:26 (D1, PH3, S2, T3) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	60	45	45	420	0.25	19.87	0.19	60.8	52.5	16.7	84.4	8.5
2	0.5	10	60	45	45	420	0.23	26.28	0.21	67.2	47.5	16.2	84.86	8.4
3	0.5	10	60	45	45	420	0.25	19.87	0.22	70.4	45	16.7	84.4	8.5
							Average,%	22.0	-	-	48.3	-	84.55	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 27 (D1, PH3, S3, T3) System: Jar test Coagulant type: Cactus powder Date:18/12/2010(24/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	10	90	45	45	420	0.241	22.75	0.18	57.6	56.1	17.0	84	8.521
2	0.5	10	90	45	45	420	0.239	23.4	0.20	64	51.22	16.3	84.77	8.46
3	0.5	10	90	45	45	420	0.241	22.75	0.21	67.2	48.78	16.7	84.4	8.48
							Average,%	22.97	-	-	52.0	-	84.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment:28 (D2, PH1, S1, T1) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	30	15	45	420	0.081	74	0.45	144	23.73	14.1	86.8	3.08
2	1.0	2.5	30	15	45	420	0.11	64.7	0.4	128	32.2	13.8	87.1	3.12
3	1.0	2.5	30	15	45	420	0.09	71.15	0.4	128	32.2	15.5	85.5	3.087
							Average,%	69.95	-	-	29.4	-	86.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.59	188.8	-	107	-	-

Experiment:29 (D2, PH1, S2, T1) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	60	15	45	420	0.023	92.6	0.3	96	67	13.9	87	3.62
2	1.0	2.5	60	15	45	420	0.022	92.95	0.6	192	34	13.5	87.35	3.42
3	1.0	2.5	60	15	45	420	0.028	91.0	0.8	256	12	13.2	87.66	3.19
							Average,%	92.2	-	-	37.7	-	87.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.91	291.2	-	107	-	-

Experiment: 30 (D2, PH1, S3, T1) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	90	15	45	420	0.0238	92.4	0.32	102.4	37.25	13.9	87.0	3.698
2	1.0	2.5	90	15	45	420	0.0221	92.9	0.34	108.8	33.33	14.4	86.5	3.4
3	1.0	2.5	90	15	45	420	0.0264	91.5	0.30	96	41.1	13.9	87.0	3.6
							Average,%	92.27	-	-	37.2	-	86.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.51	163.2	-	107	-	-

Experiment:31 (D2, PH1, S1, T2) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	30	30	45	420	0.071	77.2	0.21	67.2	30	13.9	87	3.08
2	1.0	2.5	30	30	45	420	0.12	61.5	0.18	57.6	40	13.7	87.2	3.12
3	1.0	2.5	30	30	45	420	0.069	77.88	0.17	54.4	43.3	13.2	87.66	3.17
							Average,%	72.2	-	-	37.77	-	87.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.3	96.0	-	107	-	-

Experiment:32 (D2, PH1, S2, T2) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	60	30	45	420	0.061	80.45	0.3	96	50	13.6	87.28	3.4
2	1.0	2.5	60	30	45	420	0.058	81.4	0.4	128	33.33	17.3	83.8	3.33
3	1.0	2.5	60	30	45	420	0.054	82.69	0.46	147.2	23.33	13.6	87.28	3.37
							Average,%	81.5	-	-	35.55	-	86.12	-
Control	0	5.8	-	-	-	420	0.312	-	0.6	192	-	107	-	-

Experiment: 33 (D2, PH1, S3, T2) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	90	30	45	420	0.0618	80.2	0.28	74.7	56.77	13.8	87.1	3.49
2	1.0	2.5	90	30	45	420	0.0587	81.2	0.26	69.3	59.9	15.3	85.7	3.35
3	1.0	2.5	90	30	45	420	0.055	82.4	0.31	82.7	52.1	14.6	86.3	3.37
							Average,%	81.27	-	-	56.2	-	86.37	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment: 34(D2, PH1, S1, T3) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	30	45	45	420	0.07	77.56	0.36	115.2	55	14.1	86.8	3.3
2	1.0	2.5	30	45	45	420	0.062	80	0.4	128	50	13.8	87.1	3.23
3	1.0	2.5	30	45	45	420	0.048	84.6	0.4	128	50	14.4	86.5	3.42
							Average,%	80.72	-	-	51.7	-	86.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.8	256	-	107	-	-

Experiment: 35 (D2, PH1, S2, T3) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	60	45	45	420	0.087	72.1	0.2	64	50	15.6	85.42	3.5
2	1.0	2.5	60	45	45	420	0.09	71.15	0.3	96	25	15.2	85.79	3.19
3	1.0	2.5	36	45	45	420	0.11	64.7	0.2	64	50	14.8	86.17	3.27
							Average,%	69.3	-	-	41.7	-	85.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment: 36 (D2, PH1, S3, T3) System: Jar test Coagulant type: Cactus powder Date:19/12/2010(25/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	2.5	90	45	45	420	0.077	75.3	0.21	67.2	52.27	16.5	84.6	3.59
2	1.0	2.5	90	45	45	420	0.083	73.4	0.27	86.4	38.6	15.2	85.8	3.39
3	1.0	2.5	90	45	45	420	0.089	71.47	0.22	70.4	50	15.8	85.2	3.247
							Average,%	73.4	-	-	46.9	-	85.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:37 (D2, PH2, S1, T1) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	30	15	45	420	0.27	13.6	0.38	121.6	17.4	26.1	75.6	6.21
2	1.0	7	30	15	45	420	0.288	7.7	0.04	12.8	91.3	24.3	77.28	6.43
3	1.0	7	30	15	45	420	0.215	31	0.07	22.4	84.78	24.9	76.73	6.35
							Average,%	17.4	-	-	64.5	-	76.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment:38 (D2, PH2, S2, T1) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	60	15	45	420	0.22	29.48	0.4	128	45.9	28.1	73.7	6.51
2	1.0	7	60	15	45	420	0.235	24.68	0.36	115.2	51.35	28.3	73.55	6.38
3	1.0	7	60	15	45	420	0.27	13.6	0.4	128	45.9	27.9	73.9	6.29
							Average,%	22.6	-	-	47.7	-	73.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.74	236.8	-	107	-	-

Experiment: 39 (D2, PH2, S3, T1) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	90	15	45	420	0.21	32.7	0.30	96	43.4	26.8	75.0	6.49
2	1.0	7	90	15	45	420	0.235	24.68	0.33	105.6	37.7	29.4	72.5	6.38
3	1.0	7	90	15	45	420	0.216	30.76	0.29	92.8	45.28	27.9	74.3	6.28
							Average,%	29.4	-	-	42.1	-	74.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.53	169.6	-	107	-	-

Experiment:40 (D2, PH2, S1, T2) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	30	30	45	420	0.219	29.8	0.32	102.4	42.85	25.7	75.98	6.55
2	1.0	7	30	30	45	420	0.214	31.4	0.44	140.8	21.43	25.1	76.5	6.36
3	1.0	7	30	30	45	420	0.23	26.28	0.4	32	82.14	26.2	75.5	6.7
							Average,%	29.16	-	-	48.8	-	76.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.56	179.2	-	107	-	-

Experiment: 41 (D2, PH2, S2, T2) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	60	30	45	420	0.217	30.44	0.17	54.4	57.5	31.8	70.28	6.17
2	1.5	7	60	30	45	420	0.213	31.7	0.21	67.2	47.5	29.8	72.15	6.19
3	1.5	7	60	30	45	420	0.21	32.7	0.20	64	50	29.9	72	6.23
							Average,%	31.6	-	-	51.7	-	71.47	-
Control	0	5.8	-	-	-	420	0.312	-	0.40	128	-	107	-	-

Experiment: 42 (D2, PH2, S3, T2) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	90	30	45	420	0.188	39.7	0.26	83.2	48	27.8	74.0	5.94
2	1.0	7	90	30	45	420	0.197	36.85	0.33	105.6	34	27.2	74.57	6.35
3	1.0	7	90	30	45	420	0.21	32.7	0.31	99.2	38	26.8	75	6.67
							Average,%	36.4	-	-	40.0	-	74.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment: 43 (D2, PH2, S1, T3) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	30	30	45	420	0.213	31.7	0.24	76.8	42.88	30.6	71.4	6.108
2	1.0	7	30	30	45	420	0.194	37.8	0.20	64	52.38	29.9	72	6.12
3	1.0	7	30	30	45	420	0.215	31.08	0.20	64	52.38	29.5	72.43	6.14
							Average,%	33.5	-	-	49.2	-	71.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 44(D2, PH2, S2, T3) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	60	45	45	420	0.18	42.3	0.35	112	23.9	23.8	77.75	6.1
2	1.0	7	60	45	45	420	0.23	26.28	0.34	108.8	26.08	24	77.57	6.34
3	1.0	7	60	45	45	420	0.22	29.48	0.31	99.2	32.6	24.1	77.5	6.23
							Average,%	32.68	-	-	27.5	-	77.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment: 45 (D2, PH2, S3, T3) System: Jar test Coagulant type: Cactus powder Date:20/12/2010(26/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	7	90	45	45	420	0.19	39.1	0.3	96	34.7	24.8	76.8	6.19
2	1.0	7	90	45	45	420	0.22	29.5	0.28	74.7	49.25	24.1	77.47	6.34
3	1.0	7	90	45	45	420	0.185	40.7	0.3	96	34.7	24.6	77.0	6.25
							Average,%	36.4	-	-	39.55	-	77.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment:46 (D2, PH3, S1, T1) System: Jar test Coagulant type: Cactus powder Date:21/12/2010(27/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	30	15	45	420	0.241	22.75	0.28	89.6	33.33	22.1	84.9	8.51
2	1.0	10	30	15	45	420	0.25	19.87	0.32	102.4	23.8	21.8	79.6	8.37
3	1.0	10	30	15	45	420	0.23	26.28	0.31	99.2	26.2	22.7	78.78	8.44
							Average,%	22.97	-	-	27.77	-	81.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment:47 (D2, PH3, S2, T1) System: Jar test Coagulant type: Cactus powder Date:21/12/2010(27/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	60	15	45	420	0.27	13.46	0.29	92.8	35.6	23.4	78.13	8.44
2	1.0	10	60	15	45	420	0.268	14.1	0.22	70.4	51.1	23.8	77.76	8.51
3	1.0	10	60	15	45	420	0.249	20.2	0.24	76.8	46.7	24.1	77.5	8.29
							Average,%	15.9	-	-	44.45	-	77.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 48 (D2, PH3, S3, T1) System: Jar test Coagulant type: Cactus powder Date:21/12/2010(27/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	90	15	45	420	0.266	14.7	0.25	80	44.44	23.9	77.7	8.57
2	1.0	10	90	15	45	420	0.268	14.1	0.22	70.4	51.1	24.2	77.38	8.519
3	1.0	10	90	15	45	420	0.259	16.98	0.24	76.8	46.7	24.1	82.9	8.39
							Average,%	15.26	-	-	47.4	-	79.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment:49 (D2, PH3, S1, T2) System: Jar test Coagulant type: Cactus powder Date:21/12/2010(27/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	30	30	45	420	0.231	25.96	0.26	83.2	35	24.5	77.1	8.56
2	1.0	10	30	30	45	420	0.22	29.5	0.3	96	25	26	75.7	8.43
3	1.0	10	30	30	45	420	0.215	31.0	0.28	89.6	30	24.9	76.7	852
							Average,%	28.82	-	-	30	-	76.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:50 (D2, PH3, S2, T2) System: Jar test Coagulant type: Cactus powder Date:22/12/2010(28/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	60	30	45	420	0.26	16.7	0.26	83.2	45.95	24.8	76.8	8.71
2	1.0	10	60	30	45	420	0.279	10.57	0.28	89.6	41.5	21.8	79.6	8.49
3	1.0	10	60	30	45	420	0.257	17.6	0.20	64	58.2	24.1	77.5	8.44
							Average,%	14.9	-	-	48.55	-	77.97	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment:51 (D2, PH3, S3, T2) System: Jar test Coagulant type: Cactus powder Date:22/12/2010(28/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	90	30	45	420	0.255	18.27	0.23	73.6	54	22.8	78.69	8.7
2	1.0	10	90	30	45	420	0.264	15.4	0.25	80	50	21.9	79.5	8.48
3	1.0	10	90	30	45	420	0.257	17.6	0.21	67.2	58	23.3	78.2	8.44
							Average,%	17.1	-	-	54.0	-	78.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment:52 (D2, PH3, S1, T3)   System: Jar test   Coagulant type: Cactus powder   Date:22/12/2010(28/8/2018)   Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal,%	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	30	45	45	420	0.249	20.19	0.18	57.6	56.1	25.1	76.5	8.66
2	1.0	10	30	45	45	420	0.251	19.55	0.23	73.6	43.9	24.4	77.2	8.49
3	1.0	10	30	45	45	420	0.229	26.6	0.23	73.6	43.9	24.8	76.8	8.7
							Average,%	22.1	-	-	47.9	-	76.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 53(D2, PH3, S2, T3)   System: Jar test   Coagulant type: Cactus powder   Date:22/12/2010(28/8/2018)   Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	60	45	45	420	0.22	29.5	0.21	67.2	44.7	24.8	76.8	8.2
2	1.0	10	60	45	45	420	0.23	26.3	0.18	57.6	52.6	26	75.7	8.33
3	1.0	10	60	45	45	420	0.27	13.46	0.21	67.2	44.7	24.7	76.9	8.45
							Average,%	23.1	-	-	47.3	-	76.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.38	121.6	-	107	-	-

Experiment: 54 (D2, PH3, S3, T3) System: Jar test Coagulant type: Cactus powder Date22/12/2010(28/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.0	10	90	45	45	420	0.217	30.4	0.19	60.8	64	23.8	77.75	8.27
2	1.0	10	90	45	45	420	0.214	31.4	0.18	57.6	53.8	24.7	76.9	8.21
3	1.0	10	90	45	45	420	0.219	29.8	0.21	67.2	46.15	24.2	77.38	8.44
							Average,%	30.5	-	-	54.65	-	77.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment: 55 (D3, PH1, S1, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	30	15	45	420	0.093	70.2	0.29	92.8	40.8	13.8	87.1	3.7
2	1.5	2.5	30	15	45	420	0.098	68.6	0.31	99.2	36.7	14.7	86.26	3.55
3	1.5	2.5	30	15	45	420	0.095	69.55	0.31	99.2	36.7	14.9	86.0	3.37
							Average,%	69.45	-	-	38.07	-	86.45	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment: 56 (D3, PH1, S2, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	60	15	45	420	0.099	68.27	0.28	89.6	37.77	14.2	86.7	3.48
2	1.5	2.5	60	15	45	420	0.15	52	0.31	99.2	31.1	13.7	87.2	3.33
3	1.5	2.5	60	15	45	420	0.12	61.54	0.26	83.2	42.2	14.1	86.8	3.19
							Average,%	60.6	-	-	37.0	-	86.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 57 (D3, PH1, S3, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	90	15	45	420	0.087	72	0.25	80	44.4	14.9	86.0	2.99
2	1.5	2.5	90	15	45	420	0.11	64.7	0.3	96	33.3	11.7	89.0	3.31
3	1.5	2.5	90	15	45	420	0.179	42.6	0.26	83.2	42.2	14.1	86.8	3.39
							Average,%	60.0	-	-	39.97	-	87.27	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 58 (D3, PH1, S1, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	30	30	45	420	0.12	61.5	0.23	73.6	47.7	13.5	87.3	2.77
2	1.5	2.5	30	30	45	420	0.107	65.7	0.28	89.6	36.36	12.7	88.1	3.09
3	1.5	2.5	30	30	45	420	0.12	61.5	0.21	67.2	52.27	12.6	88.2	3.29
							Average,%	62.9	-	-	45.4	-	87.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 59 (D3, PH1, S2, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	60	30	45	420	0.133	57.37	0.22	70.4	45.0	13.5	87.38	3.195
2	1.5	2.5	60	30	45	420	0.088	71.8	0.24	76.8	40.0	12.9	87.9	3.39
3	1.5	2.5	60	30	45	420	0.105	66.3	0.20	64.0	50.0	13.4	87.47	3.12
							Average,%	65.1	-	-	45.0	-	87.58	-
Control	0	5.8	-	-	-	420	0.312	-	0.40	128	-	107	-	-

Experiment: 60 (D3, PH1, S3, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	90	30	45	420	0.079	74.67	0.24	76.8	47.8	15.9	85.1	3.15
2	1.5	2.5	90	30	45	420	0.098	68.58	0.22	70.4	52.15	17.9	83.27	3.38
3	1.5	2.5	90	30	45	420	0.11	64.7	0.24	76.8	47.8	15.4	85.6	3.42
							Average,%	69.3	-	-	49.25	-	84.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment: 61 (D3, PH1, S1, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	30	45	45	420	0.11	64.7	0.26	83.2	43.47	15.9	85.1	3.18
2	1.5	2.5	30	45	45	420	0.13	58.3	0.24	76.8	47.8	14.9	86.0	3.28
3	1.5	2.5	30	45	45	420	0.126	60.57	0.24	76.8	47.8	15.4	85.6	3.45
							Average,%	61.2	-	-	46.3	-	85.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment: 62 (D3, PH1, S2, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	60	45	45	420	0.117	62.5	0.24	76.8	45.45	15.7	85.3	3.08
2	1.5	2.5	60	45	45	420	0.15	60.0	0.34	108.8	22.7	15.1	85.88	3.27
3	1.5	2.5	60	45	45	420	0.146	53.2	0.28	89.6	12.35	14.4	86.5	3.25
							Average,%	58.57	-	-	26.8	-	85.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 63 (D3, PH1, S3, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	2.5	90	45	45	420	0.13	58.3	0.19	60.8	52.5	18.7	82.5	3.18
2	1.5	2.5	90	45	45	420	0.126	60.57	0.22	70.4	45	15.6	85.4	3.11
3	1.5	2.5	90	45	45	420	0.116	62.8	0.22	70.4	45	17.4	83.74	3.258
							Average,%	60.56	-	-	47.5	-	83.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.40	128	-	107	-	-

Experiment: 64(D3, PH2, S1, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	30	15	45	420	0.213	31.7	0.34	108.8	26.0	26.9	74.8	6.085
2	1.5	7	30	15	45	420	0.189	39.4	0.31	99.2	32.6	23.7	77.8	6.12
3	1.5	7	30	15	45	420	0.211	32.37	0.29	92.8	36.9	26.1	75.6	5.99
							Average,%	34.5	-	-	31.8	-	76.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment: 65 (D3, PH2, S2, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	60	15	45	420	0.175	43.9	0.26	83.2	31.57	26.1	75.6	6.81
2	1.5	7	60	15	45	420	0.184	41	0.27	86.4	28.9	27.7	74.1	6.22
3	1.5	7	60	15	45	420	0.21	32.7	0.24	76.8	28.9	26.3	75.4	6.45
							Average,%	39.2	-	-	29.8	-	75.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.38	121.6	-	107	-	-

Experiment: 66 (D3, PH2, S2, T1) System: Jar test Coagulant type: Cactus powder Date: 16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	90	15	45	420	0.199	36.2	0.27	86.4	38.6	31.2	70.8	6.1
2	1.5	7	90	15	45	420	0.186	40.38	0.27	86.4	38.6	28.7	73.18	6.23
3	1.5	7	90	15	45	420	0.185	40.7	0.24	76.8	45.45	28.3	73.55	5.45
							Average,%	39.1	-	-	40.88	-	72.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 67 (D3, PH2, S1, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	30	30	45	420	0.22	29.5	0.22	70.4	50	30.2	71.77	6.18
2	1.5	7	30	30	45	420	0.198	36.5	0.25	80	43.18	28.3	73.55	6.21
3	1.5	7	30	30	45	420	0.237	24	0.20	64	54.5	29.5	72.4	6.55
							Average,%	30.0	-	-	49.2	-	72.57	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 68 (D3, PH2, S2, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	60	30	45	420	0.221	29.17	0.22	70.4	46.3	30.8	71.2	6.14
2	1.5	7	60	30	45	420	0.197	36.86	0.23	73.6	43.9	29.2	72.7	6.11
3	1.5	7	60	30	45	420	0.235	24.68	0.20	64	51.23	29.9	72.0	6.51
							Average,%	30.2	-	-	47.1	-	71.97	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 69 (D3, PH2, S3, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	90	30	45	420	0.213	31.7	0.24	76.8	42.88	30.6	71.4	6.108
2	1.5	7	90	30	45	420	0.194	37.8	0.20	64	52.38	29.9	72	6.12
3	1.5	7	90	30	45	420	0.215	31.08	0.20	64	52.38	29.5	72.43	6.14
							Average,%	33.5	-	-	49.2	-	71.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 70 (D3, PH2, S1, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	30	45	45	420	0.215	31.08	0.19	60.8	55.8	28.4	73.45	6.24
2	1.5	7	30	45	45	420	0.212	32	0.21	67.2	51.16	29.1	72.8	6.18
3	1.5	7	30	45	45	420	0.211	32.37	0.20	64	53.48	29.5	72.4	6.23
							Average,%	31.8	-	-	53.48	-	72.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.43	137.6	-	107	-	-

Experiment: 71 (D3, PH2, S2, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	60	45	45	420	0.217	30.44	0.17	54.4	57.5	28.8	73.08	6.24
2	1.5	7	60	45	45	420	0.215	31.1	0.21	67.2	47.4	27.7	74.1	6.18
3	1.5	7	60	45	45	420	0.22	29.5	0.25	80.0	37.5	29.5	72.4	6.23
							Average,%	30.3	-	-	47.5	-	73.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.40	128	-	107	-	-

Experiment: 72 (D3, PH2, S3, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	7	90	45	45	420	0.217	30.44	0.17	54.4	57.5	31.8	70.28	6.17
2	1.5	7	90	45	45	420	0.213	31.7	0.21	67.2	47.5	29.8	72.15	6.19
3	1.5	7	90	45	45	420	0.21	32.7	0.20	64	50	29.9	72	6.23
							Average,%	31.6	-	-	51.7	-	71.47	-
Control	0	5.8	-	-	-	420	0.312	-	0.40	128	-	107	-	-

Experiment: 73 (D3, PH3, S1, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	30	15	45	420	0.216	30.76	0.19	60.8	53.66	27.8	74	8.26
2	1.5	10	30	15	45	420	0.213	31.7	0.23	73.6	43.9	29.8	72.15	8.49
3	1.5	10	30	15	45	420	0.220	29.5	0.21	67.2	48.78	27.9	73.9	8.23
							Average,%	30.6	-	-	48.78	-	73.38	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 74 (D3, PH3, S2, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	30	15	45	420	0.221	29.7	0.24	76.8	41.46	28.3	73.55	8.66
2	1.5	10	30	15	45	420	0.243	22.1	0.23	73.6	43.9	29.8	72.15	8.89
3	1.5	10	30	15	45	420	0.236	24.35	0.21	67.2	48.78	28.9	73.0	8.28
							Average,%	25.38	-	-	44.7	-	72.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 75 (D3, PH3, S3, T1) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	90	15	45	420	0.231	25.96	0.31	99.2	35.4	28.5	43.36	8.54
2	1.5	10	90	15	45	420	0.231	25.96	0.27	86.4	43.75	30.8	71.2	8.77
3	1.5	10	90	15	45	420	0.233	25.32	0.26	83.2	45.8	30.9	71.1	8.81
							Average,%	25.7	-	-	41.65	-	61.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 76 (D3, PH3, S1, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	30	30	45	420	0.214	31.4	0.33	105.6	31.25	28.9	73	8.13
2	1.5	10	30	30	45	420	0.216	30.76	0.29	92.8	39.58	30.0	71.9	8.94
3	1.5	10	30	30	45	420	0.22	29.5	0.27	86.4	43.75	30.2	71.77	8.88
							Average,%	31.2	-	-	38.2	-	72.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 77 (D3, PH3, S2, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	60	30	45	420	0.197	36.86	0.31	99.2	31.1	29.9	72	8.23
2	1.5	10	60	30	45	420	0.236	24.36	0.26	83.2	42.2	30.2	71.77	8.64
3	1.5	10	60	30	45	420	0.223	28.5	0.24	76.8	46.7	30.2	71.77	8.89
							Average,%	29.9	-	-	40.0	-	71.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 78 (D3, PH3, S2, T2) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	90	30	45	420	0.196	37.18	0.21	67.2	53.3	31.9	70.2	8.25
2	1.5	10	90	30	45	420	0.216	30.77	0.26	83.2	42.2	30.2	71.77	8.617
3	1.5	10	90	30	45	420	0.213	31.7	0.24	76.8	46.7	30.5	71.5	8.79
							Average,%	33.2	-	-	47.4	-	71.15	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 79 (D3, PH3, S1, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	30	45	45	420	0.246	21.15	0.31	99.2	36.7	31.7	70.37	8.35
2	1.5	10	30	45	45	420	0.216	30.77	0.36	115.2	26.5	28.2	73.6	8.67
3	1.5	10	30	45	45	420	0.223	27.8	0.28	89.6	42.86	30.7	71.3	8.48
							Average,%	26.57	-	-	35.35	-	71.75	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment: 80 (D3, PH3, S2, T3) System: Jar test Coagulant type: Cactus powder Date: 16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	60	45	45	420	0.214	31.4	0.30	96	36.17	30.7	71.3	8.36
2	1.5	10	60	45	45	420	0.213	31.7	0.32	102.4	31.9	28.1	73.7	8.58
3	1.5	10	60	45	45	420	0.223	28.5	0.26	83.2	44.7	30.3	71.7	8.38
							Average,%	30.5	-	-	37.6	-	72.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 81 (D3, PH3, S3, T3) System: Jar test Coagulant type: Cactus powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	1.5	10	90	45	45	420	0.211	32.37	0.31	99.2	35.4	30.9	71.1	8.66
2	1.5	10	90	45	45	420	0.212	32.0	0.30	96	37.5	28.7	73.2	8.58
3	1.5	10	90	45	45	420	0.220	29.5	0.27	86.4	43.75	30.5	71.5	8.78
							Average,%	31.3	-	-	38.88	-	71.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Appendix D: Experimental results for moringa powder usage of coagulation and flocculation process for surface water treatment

Experiment: 1(D1, pH1, S1, T1) System: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment Interval		PH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	30	15	45	420	0.01	96.7	0.24	76.8	50	5.2	95.14	2.8
2	0.5	2.5	30	15	45	420	0.012	96.15	0.2	64	58.3	4.8	95.5	2.88
3	0.5	2.5	30	15	45	420	0.014	95.5	0.2	64	58.3	4.2	96.0	2.86
							Average,%	96.1	-	-	55.5	-	95.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 2 (D1, pH1, S2, T1) system: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	60	15	45	420	0.013	95.8	0.2	64	55.55	4.3	95.98	2.8
2	0.5	2.5	60	15	45	420	0.012	96.15	0.18	57.6	60	4.6	95.7	2.87
3	0.5	2.5	60	15	45	420	0.01	96.8	0.15	48	66.7	4.7	95.6	2.9
							Average,%	96.25	-	-	54.5	-	95.76	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 3 (D1, pH1, S3, T1) system: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	90	15	45	420	0.014	95.5	0.12	38.4	50	4.4	95.88	2.86
2	0.5	2.5	90	15	45	420	0.012	96.1	0.13	41.6	45.8	4.5	95.8	2.88
3	0.5	2.5	90	15	45	420	0.011	96.47	0.12	38.4	50	4.9	95.4	2.97
							Average,%	96.0	-	-	48.6	-	95.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.24	76.8	-	107	-	-

Experiment:4 (D1, pH1, S1, T2) System: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal,%	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU		-
1	0.5	2.5	30	30	45	420	0.021	93.26	0.1	32	68.75	5.3	95.0	2.79
2	0.5	2.5	30	30	45	420	0.018	94.23	0.15	48	53.1	5.1	95.2	2.84
3	0.5	2.5	30	30		420	0.011	96.47	0.15	48	53.1	4.8	95.5	2.89
							Average,%	94.65	-	-	58.3	-	95.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.32	102.4	-	107	-	-

Experiment: 5 (D1, pH1, S2, T2) System: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	60	30	45	420	0.013	95.8	0.15	48	55.88	6.1	94.3	2.87
2	0.5	2.5	60	30	45	420	0.0147	95.3	0.17	54.4	50.0	5.7	94.67	2.8
3	0.5	2.5	60	30	45	420	0.017	94.55	0.15	48	55.88	5.9	94.5	2.79
							Average,%	95.2	-	-	53.9	-	94.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.34	108.8	-	107	-	-

Experiment: 6 (D1, pH1, S3, T2) System: Jar test Coagulant type: Moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	90	30	45	420	0.023	92.63	0.16	51.2	58.97	6.2	94.2	2.87
2	0.5	2.5	90	30	45	420	0.0247	92.1	0.14	44.8	64.1	5.9	94.5	2.89
3	0.5	2.5	90	30	45	420	0.0214	93.1	0.17	54.4	56.4	5.9	94.5	2.79
							Average,%	92.6	-	-	59.8	-	94.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment: 7(D1, pH1, S1, T3) system: Jar test Coagulant type: moringa powder Date: 16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal,%	NTU	%	-
1	0.5	2.5	30	45	45	420	0.012	96.15	0.1	32	68.75	4.3	95.98	2.84
2	0.5	2.5	30	45	45	420	0.011	96.47	0.15	48	53.1	3.8	96.45	2.84
3	0.5	2.5	30	45	45	420	0.012	96.15	0.15	48	53.1	4.1	96.17	2.87
							Average,%	96.25	-	-	58.3	-	96.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.32	102.4	-	107	-	-

Experiment: 8 (D1, pH1, S2, T3) System: Jar test Coagulant type: moringa powder Date:16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	60	45	45	420	0.031	90.0	0.2	64	55.55	4.9	95.4	3.1
2	0.5	2.5	60	45	45	420	0.028	91.0	0.18	57.6	60	5.3	95.0	2.98
3	0.5	2.5	60	45	45	420	0.035	88.78	0.15	48	66.7	5.5	94.8	2.94
							Average,%	89.9	-	-	54.5	-	95.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 9(D1, pH1, S3, T3) System: Jar test Coagulant type: moringa powder Date: 16/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	2.5	90	45	45	420	0.034	89.1	0.16	51.2	57.6	4.9	95.4	3.3
2	0.5	2.5	90	45	45	420	0.028	91.0	0.18	57.6	47.0	5.4	94.95	2.99
3	0.5	2.5	90	45	45	420	0.034	89.1	0.15	48	55.88	5.7	94.67	2.97
							Average,%	89.7	-	-	53.5	-	95.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.34	108.8	-	107	-	-

Experiment: 10(D1, pH2, S1, T1) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	30	15	45	420	0.005	98.4	0.21	67.2	43.3	4.1	96.16	4.5
2	0.5	7	30	15	45	420	0.007	97.75	0.2	64	45.9	3.8	96.4	4.57
3	0.5	7	30	15	45	420	0.0058	98.14	0.19	60.8	48.6	3.2	97.0	4.59
							Average,%	98.1	-	-	45.9	-	96.52	-
Control	0	5.8	-	-	-	420	0.312	-	0.37	118.4	-	107	-	-

Experiment: 11(D1, pH2, S2, T1) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	60	15	45	420	0.035	88.78	0.2	64.0	54.5	4.1	96.17	4.55
2	0.5	7	60	15	45	420	0.029	90.7	0.28	89.6	36.36	3.9	96.4	4.5
3	0.5	7	60	15	45	420	0.034	89.1	0.21	67.2	52.27	3.7	96.5	4.54
							Average,%	89.5	-	-	47.71	-	96.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 12 (D1, pH2, S3, T1) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	90	15	45	420	0.037	88.1	0.1	32	68.75	4.3	95.98	4.57
2	0.5	7	90	15	45	420	0.029	90.7	0.15	48	53.1	3.9	96.4	4.53
3	0.5	7	90	15	45	420	0.035	88.78	0.15	48	53.1	3.9	96.4	4.57
							Average,%	89.2	-	-	58.3	-	96.26	-
Control	0	5.8	-	-	-	420	0.312	-	0.32	102.4	-	107	-	-

Experiment:13(D1, pH2, S1, T2) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	30	30	45	420	0.0041	98.68	0.16	51.2	66.7	4.0	96.26	3.98
2	0.5	7	30	30	45	420	0.0045	98.55	0.16	51.2	66.7	3.1	97.1	4.12
3	0.5	7	30	30	45	420	0.0043	98.6	0.14	44.8	70.8	3.8	96.45	4.4
							Average,%	98.6	-	-	68.0	-	96.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment:14(D1, pH2, S2, T2) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	60	30	45	420	0.0052	98.3	0.27	86.4	50	4.1	96.17	4.47
2	0.5	7	60	30	45	420	0.0055	98.4	0.25	80	53.7	3.7	96.5	4.88
3	0.5	7	60	30	45	420	0.0061	98.0	0.29	92.8	46.3	4.3	95.98	4.53
							Average,%	98.2	-	-	50.0	-	96.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment: 15(D1, pH2, S3, T2) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	90	30	45	420	0.0056	98.2	0.2	64	55.55	4.3	95.98	4.67
2	0.5	7	90	30	45	420	0.0055	98.24	0.18	57.6	60	3.7	96.5	4.88
3	0.5	7	90	30	45	420	0.0062	98	0.15	48	66.7	4.5	95.8	4.78
							Average,%	98.1	-	-	54.5	-	96.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 16(D1, pH2, S1, T3) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	30	45	45	420	0.0061	98.0	0.3	96	40	5.1	95.2	4.57
2	0.5	7	30	45	45	420	0.0058	98.14	0.2	64.0	60	5.5	94.86	4.48
3	0.5	7	30	45	45	420	0.067	78.5	0.24	76.8	52	6.3	94.1	4.53
							Average,%	91.5	-	-	50.7	-	94.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment: 17(D1, pH2, S2, T3) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	60	45	45	420	0.006	98.0	0.1	32	68.75	5.2	95.14	5
2	0.5	7	60	45	45	420	0.0068	97.8	0.15	48	53.1	5.7	94.67	4.88
3	0.5	7	60	45	45	420	0.0053	98.3	0.15	48	53.1	5.2	95.14	4.79
							Average,%	98.0	-	-	58.3	-	94.89	-
Control	0	5.8	-	-	-	420	0.312	-	0.32	102.4	-	107	-	-

Experiment: 18 (D1, pH2, S2, T3) System: Jar test Coagulant type: moringa powder Date:17/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	7	90	45	45	420	0.0061	98	0.16	51.2	58.97	5.4	94.95	5.7
2	0.5	7	90	45	45	420	0.0067	97.85	0.14	44.8	64.1	5.7	94.67	4.88
3	0.5	7	90	45	45	420	0.0055	98.2	0.17	54.4	56.4	5.5	94.86	4.69
							Average,%	98.0	-	-	59.8	-	94.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment:19(D1, pH3, S1, T1) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	30	15	45	420	0.001	99.68	0.24	76.8	50	4.7	95.6	9.57
2	0.5	10	30	15	45	420	0.0012	99.6	0.20	64.0	58.3	4.3	95.98	9.6
3	0.5	10	30	15	45	420	0.0014	95.55	0.20.	64.0	58.3	5.1	95.2	9.66
							Average,%	98.27	-	-	55.5	-	95.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment:20(D1, pH3, S2, T1) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	60	15	45	420	0.0018	99.4	0.16	51.2	57.9	4.8	95.5	9.2
2	0.5	10	60	15	45	420	0.0013	99.6	0.2	64.0	47.37	4.9	95.4	9.43
3	0.5	10	60	15	45	420	0.0012	99.6	0.2	64.0	47.37	5.1	95.2	9.38
							Average,%	99.5	-	-	50.88	-	95.37	-
Control	0	5.8	-	-	-	420	0.312	-	0.38	121.6	-	107	-	-

Experiment: 21(D1, pH3, S3, T1) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	90	15	45	420	0.0013	99.59	0.18	57.6	53.8	4.9	95.4	9.3
2	0.5	10	90	15	45	420	0.0011	99.65	0.21	67.2	46.1	4.7	95.6	9.43
3	0.5	10	90	15	45	420	0.0014	99.55	0.20	64	48.7	5.0	95.3	9.28
							Average,%	99.59	-	-	49.5	-	95.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment: 22 (D1, pH3, S1, T2) System: Jar test Coagulant type: Moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	30	30	45	420	0.0015	99.52	0.2	64.0	55.55	4.5	95.8	9.13
2	0.5	10	30	30	45	420	0.0021	99.3	0.18	57.6	60.0	4.1	96.17	9.45
3	0.5	10	30	30	45	420	0.0014	99.55	0.15	48.0	66.7	3.7	96.5	9.28
							Average,%	99.4	-	-	54.5	-	96.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment:23 (D1, pH3, S2, T2) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	60	30	45	420	0.0021	99.3	0.24	76.8	53.8	4.5	95.8	8.97
2	0.5	10	60	30	45	420	0.0015	99.5	0.23	73.6	55.76	3.8	96.45	9.41
3	0.5	10	60	30	45	420	0.0018	99.4	0.29	92.8	44.23	4.3	95.98	9.23
							Average,%	99.4	-	-	51.26	-	96.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.52	166.4	-	107	-	-

Experiment: 24 (D1, pH3, S3, T2) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	90	30	45	420	0.0023	99.26	0.27	86.4	50	4.6	95.7	8.99
2	0.5	10	90	30	45	420	0.0017	99.45	0.25	80	53.7	3.8	96.45	9.48
3	0.5	10	90	30	45	420	0.0014	99.55	0.29	92.8	46.3	4.7	95.6	9.43
							Average,%	99.4	-	-	50.0	-	95.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:25 (D1, pH3, S1, T3) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	30	45	45	420	0.0013	99.6	0.32	102.4	27.27	3.8	96.45	9.08
2	0.5	10	30	45	45	420	0.0011	99.6	0.26	83.3	40.8	4.3	95.98	9.38
3	0.5	10	30	45	45	420	0.0015	99.52	0.2	64.0	54.5	4.7	95.6	8.88
							Average,%	99.57	-	-	64.0	-	96.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:26 (D1, pH3, S2, T3) System: Jar test Coagulant type: moringa powder Date:18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	60	45	45	420	0.0014	99.55	0.23	73.6	47.7	5.1	95.2	8.59
2	0.5	10	60	45	45	420	0.0015	99.52	0.22	70.4	50.0	4.8	95.5	8.88
3	0.5	10	60	45	45	420	0.0013	99.6	0.25	80.0	43.2	4.6	95.7	9.2
							Average,%	99.5	-	-	62.0	-	95.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 27 (D1, pH3, S3, T3) System: Jar test Coagulant type: moringa powder Date: 18/12/2010(22/8/2018) Day: Friday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	0.5	10	90	45	45	420	0.0016	99.5	0.24	76.8	45.45	5.4	94.9	8.49
2	0.5	10	90	45	45	420	0.0015	99.52	0.23	73.6	47.7	4.9	95.4	8.87
3	0.5	10	90	45	45	420	0.0018	99.4	0.26	83.2	40.9	4.6	95.7	9.28
							Average,%	99.47	-	-	55.8	-	95.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:28 (D2, pH1, S1, T1) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	30	15	45	420	0.016	94.87	0.27	86.4	50	5.7	94.67	2.7
2	1.0	2.5	30	15	45	420	0.014	95.5	0.25	80	53.7	5.1	95.23	2.66
3	1.0	2.5	30	15	45	420	0.011	96.47	0.29	92.8	46.3	5.6	94.76	2.67
							Average,%	95.6	-	-	50.0	-	94.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:29 (D2, pH1, S2, T1) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	60	15	45	420	0.016	94.87	0.29	42.0	74.26	5.8	94.6	2.81
2	1.0	2.5	60	15	45	420	0.018	94.23	0.2	64.0	60.78	4.7	95.6	2.74
3	1.0	2.5	60	15	45	420	0.049	84.3	0.2	64.0	60.78	5.2	95.14	2.77
							Average,%	91.1	-	-	65.3	-	95.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.51	163.2	-	107	-	-

Experiment: 30 (D2, pH1, S3, T1) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	90	15	45	420	0.021	93.27	0.25	80	50.98	6.0	94.4	2.88
2	1.0	2.5	90	15	45	420	0.019	93.9	0.22	70.4	56.8	5.8	94.58	2.75
3	1.0	2.5	90	15	45	420	0.038	87.8	0.22	70.4	56.8	6.2	94.2	2.77
							Average,%	91.6	-	-	54.86	-	94.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.51	163.2	-	107	-	-

Experiment:31 (D2, pH1, S1, T2) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	30	30	45	420	0.013	95.8	0.27	86.4	50	5.1	95.23	2.87
2	1.0	2.5	30	30	45	420	0.012	96.15	0.25	80	53.7	4.7	95.6	2.99
3	1.0	2.5	30	30	45	420	0.015	95.2	0.29	92.8	46.3	4.1	96.17	2.63
							Average,%	95.7	-	-	50.0	-	95.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:32 (D2, pH1, S2, T2 System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	60	30	45	420	0.012	96.15	0.19	60.8	56.8	5.0	95.3	2.68
2	1.0	2.5	60	30	45	420	0.015	95.2	0.25	80	43.2	4.7	95.6	2.58
3	1.0	2.5	60	30	45	420	0.014	95.5	0.23	73.6	47.7	4.2	96.0	2.74
							Average,%	95.5	-	-	49.2	-	95.6	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 33(D2, pH1, S3, T2) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	90	30	45	420	0.013	95.8	0.31	99.2	36.35	5.2	95.1	2.62
2	1.0	2.5	90	30	45	420	0.013	95.8	0.25	80	48.98	4.8	95.5	2.58
3	1.0	2.5	90	30	45	420	0.015	95.2	0.28	89.6	42.85	4.5	95.8	2.73
							Average,%	95.6	-	-	50.88	-	95.47	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment:34 (D2, pH1, S1, T3) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	30	45	45	420	0.011	96.47	0.16	51.2	58.97	4.9	95.4	2.71
2	1.0	2.5	30	45	45	420	0.013	95.8	0.14	44.8	64.1	4.7	95.6	2.66
3	1.0	2.5	30	45	45	420	0.015	95.2	0.17	54.4	56.4	5.2	95.14	2.74
							Average,%	95.8	-	-	59.8	-	95.38	-
Control	0	5.8	-	-	-	420	0.312	-	0.39	124.8	-	107	-	-

Experiment:35 (D2, pH1, S2, T3) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	60	45	45	420	0.014	95.5	0.19	60.8	54.76	4.9	95.4	2.71
2	1.0	2.5	60	45	45	420	0.02	93.6	0.27	86.4	35.7	6.0	94.4	2.69
3	1.0	2.5	60	45	45	420	0.018	94.23	0.2	64.0	52.38	5.7	94.67	2.75
							Average,%	94.4	-	-	47.7	-	94.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 36 (D2, pH1, S3, T3) System: Jar test Coagulant type: moringa powder Date:19/12/2010(22/8/2018) Day: Saturday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	2.5	90	45	45	420	0.014	95.5	0.19	60.8	56.8	5.0	95.3	2.74
2	1.0	2.5	90	45	45	420	0.027	91.3	0.25	80	43.2	6.1	94.3	2.69
3	1.0	2.5	90	45	45	420	0.015	95.2	0.23	73.6	47.7	5.9	94.5	2.78
							Average,%	94.0	-	-	49.2	-	94.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:37 (D2, pH2, S1, T1) System: Jar test Coagulant type: moringa powder Date: 20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	30	15	45	420	0.013	95.8	0.26	83.2	35	3.7	96.5	9.5
2	1.0	7	30	15	45	420	0.015	95.2	0.19	60.8	52.5	3.3	96.9	9.425
3	1.0	7	30	15	45	420	0.011	96.47	0.17	54.4	57.5	3.4	96.8	9.47
							Average,%	95.8	-	-	48.3	-	96.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:38 (D2, pH2, S2, T1) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	60	15	45	420	0.012	96.15	0.23	73.6	45.23	3.9	96.35	8.87
2	1.0	7	60	15	45	420	0.019	93.9	0.21	67.2	50.0	3.4	96.8	9.25
3	1.0	7	60	15	45	420	0.013	95.8	0.14	44.8	66.7	3.0	97.2	8.94
							Average,%	95.28	-	-	53.9	-	96.78	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 39 (D2, pH2, S2, T1) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	90	15	45	420	0.015	95.2	0.24	76.8	45.45	3.9	96.35	8.87
2	1.0	7	90	15	45	420	0.019	93.9	0.22	70.4	50	3.5	96.7	9.45
3	1.0	7	90	15	45	420	0.016	94.87	0.18	57.6	59.1	3.8	96.45	8.96
							Average,%	94.6	-	-	51.5	-	96.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 40 (D2, pH2, S1, T2) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	30	30	45	420	0.019	93.9	0.23	73.6	45.23	3.4	96.8	9.51
2	1.0	7	30	30	45	420	0.021	93.27	0.14	44.8	66.7	3.1	97.1	9.22
3	1.0	7	30	30	45	420	0.017	94.55	0.18	57.6	57.14	3.0	97.2	9.74
							Average,%	93.9	-	-	56.36	-	97.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 41 (D2, pH2, S2, T2) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	60	30	45	420	0.013	95.8	0.32	102.4	36	3.4	96.8	8.89
2	1.0	7	60	30	45	420	0.017	94.55	0.24	76.8	52	3.8	96.45	9.12
3	1.0	7	60	30	45	420	0.012	96.15	0.28	74.7	53.3	3.7	96.5	9.21
							Average,%	95.5	-	-	47.1	-	96.58	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment: 42(D2, pH2, S3, T2) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	90	30	45	420	0.017	94.55	0.28	89.6	44	3.5	96.7	8.89
2	1.0	7	90	30	45	420	0.021	93.27	0.23	73.6	54	3.8	96.45	9.15
3	1.0	7	90	30	45	420	0.0147	95.3	0.24	76.8	52	3.8	96.45	9.22
							Average,%	94.37	-	-	50.0	-	96.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment:43 (D2, pH2, S1, T3) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	30	45	45	420	0.005	98.4	0.24	76.8	45.45	4.6	95.57	9.13
2	1.0	7	30	45	45	420	0.012	96.15	0.16	51.2	63.6	3.7	96.5	9.25
3	1.0	7	30	45	45	420	0.011	96.47	0.24	76.8	45.45	4.2	96.0	8.98
							Average,%	97.0	-	-	51.5	-	96.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:44 (D2, pH2, S2, T3) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	60	45	45	420	0.013	95.8	0.18	57.6	58.14	3.7	96.5	9.18
2	1.0	7	60	45	45	420	0.012	96.15	0.22	70.4	48.8	4.1	96.17	9.23
3	1.0	7	60	45	45	420	0.0012	99.6	0.22	70.4	48.8	4.5	95.8	9.4
							Average,%	97.17	-	-	51.9	-	96.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.43	137.6	-	107	-	-

Experiment:45 (D2, pH2, S3, T3) System: Jar test Coagulant type: moringa powder Date:20/12/2010(22/8/2018) Day: Sunday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	7	90	45	45	420	0.014	95.5	0.27	86.4	50	3.8	96.45	9.38
2	1.0	7	90	45	45	420	0.013	95.8	0.25	80	53.7	4.5	95.8	9.23
3	1.0	7	90	45	45	420	0.0016	94.87	0.29	92.8	46.3	4.6	95.7	9.33
							Average,%	95.4	-	-	50.0	-	95.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:46 (D2, pH3, S1, T1) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	30	15	45	420	0.0013	99.58	0.27	86.4	50	2.5	97.7	10.32
2	1.0	10	30	15	45	420	0.0011	99.6	0.25	80	53.7	2.8	97.38	10.4
3	1.0	10	30	15	45	420	0.0051	99.52	0.29	92.8	46.3	3.2	97.0	10.39
							Average,%	99.57	-	-	50.0	-	97.36	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:47 (D2, pH3, S2, T1) System: Jar test Coagulant type: moringa powder Date:2112/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	60	15	45	420	0.0014	99.55	0.19	60.8	56.8	2.6	97.57	10.32
2	1.0	10	60	15	45	420	0.0022	99.3	0.25	80	43.2	2.8	97.38	10.55
3	1.0	10	60	15	45	420	0.0045	98.55	0.23	73.6	47.7	3.4	96.8	10.34
							Average,%	99.1	-	-	49.2	-	97.25	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:48 (D2, pH3, S3, T1) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	90	15	45	420	0.0019	99.4	0.27	86.4	50	2.9	97.29	10.49
2	1.0	10	90	15	45	420	0.0021	99.3	0.25	80	53.7	2.7	97.47	10.51
3	1.0	10	90	15	45	420	0.0035	98.8	0.29	92.8	46.3	3.5	96.7	10.44
							Average,%	99.17	-	-	50.0	-	97.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:49 (D2, pH3, S1, T2) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	30	30	45	420	0.0015	99.51	0.27	86.4	50	2.6	97.57	10.54
2	1.0	10	30	30	45	420	0.0012	99.6	0.25	80	53.7	2.3	97.8	10.49
3	1.0	10	30	30	45	420	0.0012	99.6	0.29	92.8	46.3	2.8	97.38	10.37
							Average,%	99.57	-	-	50.0	-	97.58	-
Control	0	5.8	-	-	-	420	0.312	-	0.54	172.8	-	107	-	-

Experiment:50 (D2, pH3, S2, T2) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	60	30	45	420	0.0013	99.6	0.19	60.8	56.8	2.7	97.47	10.44
2	1.0	10	60	30	45	420	0.0012	99.6	0.25	80	43.2	3.1	97.1	10.53
3	1.0	10	60	30	45	420	0.002	99.36	0.23	73.6	47.7	2.5	97.7	10.48
							Average,%	99.5	-	-	49.2	-	97.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 51 (D2, pH3, S3, T2) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	90	30	45	420	0.0016	99.5	0.24	76.8	48.9	3.8	96.4	10.55
2	1.0	10	90	30	45	420	0.0018	99.4	0.25	80	46.8	3.5	96.7	10.58
3	1.0	10	90	30	45	420	0.0020	99.36	0.26	83.2	44.7	3.6	96.6	10.39
							Average,%	99.4	-	-	46.8	-	96.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment:52 (D2, pH3, S1, T3 System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	30	45	45	420	0.001	99.67	0.19	60.8	56.8	2.1	98.0	10.5
2	1.0	10	30	45	45	420	0.0011	99.6	0.25	80	43.2	2.2	97.9	10.3
3	1.0	10	30	45	45	420	0.0015	99.52	0.23	73.6	47.7	2.6	97.57	10.47
							Average,%	99.6	-	-	49.2	-	97.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:53 (D2, pH3, S2, T3) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	60	45	45	420	0.0014	99.55	0.21	67.2	56.25	3.4	96.8	10.39
2	1.0	10	60	45	45	420	0.0016	99.48	0.18	57.6	62.5	3.0	97.2	10.28
3	1.0	10	60	45	45	420	0.0011	99.6	0.24	76.8	50.0	2.8	97.4	10.39
							Average,%	99.5	-	-	56.25	-	97.1	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 54(D2, pH3, S3, T3) System: Jar test Coagulant type: moringa powder Date:21/12/2010(22/8/2018) Day: Monday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.0	10	90	45	45	420	0.0021	99.3	0.27	86.4	44.9	3.6	96.6	10.34
2	1.0	10	90	45	45	420	0.0019	99.4	0.19	60.8	61.2	3.2	97.0	10.48
3	1.0	10	90	45	45	420	0.0016	99.5	0.24	76.8	51	2.9	97.3	10.39
							Average,%	99.4	-	-	52.37	-	97.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment: 55 (D3, pH1, S1, T1) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	30	15	45	420	0.018	94.2	0.23	73.6	51	5.3	95	2.88
2	1.5	2.5	30	15	45	420	0.0021	99.3	0.2	64	57.4	5.6	94.7	3.34
3	1.5	2.5	30	15	45	420	0.0016	99.5	0.22	70.4	53.2	4.9	95.4	3.27
							Average,%	97.7	-	-	53.87	-	95	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 56 (D3, pH1, S2, T1) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	60	15	45	420	0.019	93.9	0.21	67.2	57.1	5.7	94.67	2.878
2	1.5	2.5	60	15	45	420	0.0022	99.3	0.3	96	38.77	5.1	95.2	2.59
3	1.5	2.5	60	15	45	420	0.0017	99.45	0.23	73.6	53.0	5.8	94.58	3.47
							Average,%	97.55	-	-	49.6	-	94.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment: 57(D3, pH1, S3, T1) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	90	15	45	420	0.021	93.27	0.21	67.2	57.1	5.8	94.58	2.75
2	1.5	2.5	90	15	45	420	0.0018	94.2	0.25	80	48.9	5.4	94.95	2.56
3	1.5	2.5	90	15	45	420	0.0015	99.52	0.21	67.2	57.1	5.5	94.86	3.77
							Average,%	95.7	-	-	54.37	-	94.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.49	156.8	-	107	-	-

Experiment: 58 (D3, pH1, S1, T2) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	30	30	45	420	0.035	88.78	0.22	70.4	53.2	5.1	95.2	2.85
2	1.5	2.5	30	30	45	420	0.0011	99.65	0.23	73.6	51	5.0	95.3	2.96
3	1.5	2.5	30	30	45	420	0.0013	99.58	0.20	64	57.4	4.5	95.8	2.88
							Average,%	96.0	-	-	53.8	-	95.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 59 (D3, pH1, S2, T2) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	60	30	45	420	0.029	90.7	0.22	70.4	53.2	5.8	94.58	2.85
2	1.5	2.5	60	30	45	420	0.0017	99.4	0.26	83.2	44.68	6.1	94.3	2.96
3	1.5	2.5	60	30	45	420	0.0013	99.6	0.20	64	57.4	4.4	95.88	2.88
							Average,%	96.57	-	-	51.76	-	94.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 60 (D3, pH1, S3, T2) System: Jar test Coagulant type: moringa powder Date: 22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	90	30	45	420	0.037	88.1	0.27	86.4	43.75	5.7	94.67	3.1
2	1.5	2.5	90	30	45	420	0.0013	99.6	0.31	99.2	35.4	4.4	95.88	2.99
3	1.5	2.5	90	30	45	420	0.0015	99.52	0.23	73.6	52.0	4.5	95.8	2.87
							Average,%	95.7	-	-	43.7	-	96.2	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 61 (D3, pH1, S1, T3) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	30	45	45	420	0.031	90.0	0.21	67.2	56.25	5.6	94.7	2.95
2	1.5	2.5	30	45	45	420	0.0014	99.55	0.23	73.6	52.0	5.1	95.2	2.96
3	1.5	2.5	30	45	45	420	0.00117	99.6	0.22	70.4	54.17	4.7	95	2.88
							Average,%	96.38	-	-	54.14	-	95.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 62(D3, pH1, S2, T3) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	60	45	45	420	0.025	91.98	0.26	83.2	43.48	5.5	94.86	3.29
2	1.5	2.5	60	45	45	420	0.0021	99.3	0.23	73.6	50	4.7	95.6	2.78
3	1.5	2.5	60	45	45	420	0.0018	99.4	0.22	70.4	52.17	4.8	95.5	2.88
							Average,%	96.89	-	-	48.55	-	95.3	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment: 63(D3, pH1, S3, T3) System: Jar test Coagulant type: moringa powder Date:22/12/2010(22/8/2018) Day: Tuesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	2.5	90	45	45	420	0.021	93.27	0.23	73.6	51	4.9	95.4	3.19
2	1.5	2.5	90	45	45	420	0.0022	99.3	0.23	73.6	51	5.4	94.95	2.98
3	1.5	2.5	90	45	45	420	0.0017	99.45	0.25	80	46.8	6.1	94.3	2.98
							Average,%	97.34	-	-	49.6	-	94.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 64(D3, pH2, S1, T1) System: Jar test Coagulant type: moringa powder Date:23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	30	15	45	420	0.022	92.9	0.21	67.2	53.3	4.4	95.88	9.41
2	1.5	7	30	15	45	420	0.0023	99.26	0.23	73.6	48.9	4.4	95.88	9.35
3	1.5	7	30	15	45	420	0.0018	99.4	0.21	67.2	53.3	4.1	96.17	8.98
							Average,%	97.2	-	-	51.8	-	95.97	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-

Experiment: 65(D3, pH2, S2, T1)   System: Jar test   Coagulant type: moringa powder   Date:23/12/2010(22/8/2018)   Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	60	15	45	420	0.019	93.9	0.24	76.8	45.45	4.6	95.7	9.47
2	1.5	7	60	15	45	420	0.0011	99.6	0.20	64	54.5	4.7	95.6	9.78
3	1.5	7	60	15	45	420	0.0018	99.4	0.21	67.2	52.27	4.3	95.98	9.44
							Average,%	97.6	-	-	50.7	-	95.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 66 (D3, pH2, S3, T1)   System: Jar test   Coagulant type: moringa powder   Date:23/12/2010(22/8/2018)   Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	90	15	45	420	0.022	92.9	0.28	89.6	44	4.7	95.6	9.23
2	1.5	7	90	15	45	420	0.0023	99.26	0.26	83.2	48	4.6	95.7	9.18
3	1.5	7	90	15	45	420	0.0018	99.4	0.31	99.2	38	4.1	96.17	9.24
							Average,%	97.2	-	-	43.3	-	95.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.5	160	-	107	-	-

Experiment: 67 (D3, pH2, S1, T2) System: Jar test Coagulant type: moringa powder Date: 23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	30	30	45	420	0.015	95.2	0.23	73.6	51	4.3	95.98	9.12
2	1.5	7	30	30	45	420	0.0021	99.3	0.24	76.8	48.9	4.2	96	9.17
3	1.5	7	30	30	45	420	0.0019	99.4	0.30	96	36.17	4.5	95.8	9.24
							Average,%	97.97	-	-	45.3	-	95.9	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 68 (D3, pH2, S2, T2) System: Jar test Coagulant type: moringa powder Date:23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	60	30	45	420	0.017	94.55	0.25	80	47.9	4.4	95.88	8.88
2	1.5	7	60	30	45	420	0.0022	99.3	0.22	70.4	54	4.7	95.6	9.10
3	1.5	7	60	30	45	420	0.0019	99.4	0.21	67.2	56	3.9	96.35	9.16
							Average,%	97.75	-	-	52.6	-	96.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 69 (D3, pH2, S3, T2) System: Jar test Coagulant type: moringa powder Date:23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	90	30	45	420	0.019	93.9	0.20	64	58.3	4.6	95.7	9.88
2	1.5	7	90	30	45	420	0.0023	99.2	0.19	60.8	60.4	4.0	96.2	9.13
3	1.5	7	90	30	45	420	0.0026	99.17	0.21	67.2	56.2	4.9	95.4	9.11
							Average,%	97.4	-	-	58.3	-	95.8	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 70 (D3, pH2, S1, T3) System: Jar test Coagulant type: moringa powder Date:23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	30	45	45	420	0.016	94.87	0.21	67.2	52.27	4.1	96.17	9.38
2	1.5	7	30	45	45	420	0.0011	99.6	0.24	76.8	45.45	4.4	95.88	8.93
3	1.5	7	30	45	45	420	0.0016	94.87	0.21	67.2	52.27	4.7	95.6	9.71
							Average,%	96.4	-	-	50.0	-	95.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 71 (D3, pH2, S2, T3) System: Jar test Coagulant type: moringa powder Date:23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	60	45	45	420	0.018	94.2	0.32	102.4	33.3	4.3	95.98	9.48
2	1.5	7	60	45	45	420	0.0017	99.45	0.28	89.6	41.7	4.7	95.6	8.91
3	1.5	7	60	45	45	420	0.0014	99.55	0.26	83.2	45.8	4.7	95.6	9.70
							Average,%	97.7	-	-	40.27	-	95.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.48	153.6	-	107	-	-

Experiment: 72 (D3, pH2, S3, T3) System: Jar test Coagulant type: moringa powder Date: 23/12/2010(22/8/2018) Day: Wednesday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	7	90	45	45	420	0.019	93.9	0.20	64	56.5	4.5	95.79	9.42
2	1.5	7	90	45	45	420	0.0021	99.3	0.22	70.4	52.17	4.9	95.4	8.93
3	1.5	7	90	45	45	420	0.0024	99.2	0.21	67.2	54.3	4.5	95.8	9.89
							Average,%	97.45	-	-	54.3	-	95.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.46	147.2	-	107	-	-

Experiment:73 (D3, pH3, S1, T1) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	30	15	45	420	0.0013	99.6	0.24	76.8	41.46	2.7	97.47	10.44
2	1.5	10	30	15	45	420	0.0012	99.6	0.2	64.0	51.2	3.1	97.1	10.53
3	1.5	10	30	15	45	420	0.002	99.36	0.26	83.2	36.6	2.5	97.7	10.48
							Average,%	99.5	-	-	43.0	-	97.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 74(D3, pH3, S2, T1) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	60	15	45	420	0.021	93.27	0.23	73.6	51	4.9	95.4	3.19
2	1.5	10	60	15	45	420	0.0022	99.3	0.23	73.6	51	5.4	94.95	2.98
3	1.5	10	60	15	45	420	0.0017	99.45	0.25	80	46.8	6.1	94.3	2.98
							Average,%	97.34	-	-	49.6	-	94.88	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment: 75 (D3, pH3, S3, T1) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	90	30	45	420	0.035	88.78	0.22	70.4	53.2	5.1	95.2	2.85
2	1.5	10	90	30	45	420	0.0011	99.65	0.23	73.6	51	5.0	95.3	2.96
3	1.5	10	90	30	45	420	0.0013	99.58	0.20	64	57.4	4.5	95.8	2.88
							Average,%	96.0	-	-	53.8	-	95.4	-
Control	0	5.8	-	-	-	420	0.312	-	0.47	150.4	-	107	-	-

Experiment:76 (D3, pH3, S1, T2) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	30	30	45	420	0.0013	99.6	0.32	102.4	27.27	3.8	96.45	9.08
2	1.5	10	30	30	45	420	0.0011	99.6	0.26	83.3	40.8	4.3	95.98	9.38
3	1.5	10	30	30	45	420	0.0015	99.52	0.2	64.0	54.5	4.7	95.6	8.88
							Average,%	99.57	-	-	40.8	-	96.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment:77 (D3, pH3, S2, T2) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	60	30	45	420	0.013	95.8	0.26	83.2	35	3.7	96.5	9.5
2	1.5	10	60	30	45	420	0.015	95.2	0.19	60.8	52.5	3.3	96.9	9.425
3	1.5	10	60	30	45	420	0.011	96.47	0.17	54.4	57.5	3.4	96.8	9.47
							Average,%	95.8	-	-	48.3	-	96.7	-
Control	0	5.8	-	-	-	420	0.312	-	0.4	128	-	107	-	-

Experiment:78 (D3, pH3, S3, T2) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	90	30	45	420	0.012	96.15	0.23	73.6	45.23	3.9	96.35	8.87
2	1.5	10	90	30	45	420	0.019	93.9	0.21	67.2	50.0	3.4	96.8	9.25
3	1.5	10	90	30	45	420	0.013	95.8	0.14	44.8	66.7	3.0	97.2	8.94
							Average,%	95.28	-	-	53.9	-	96.78	-
Control	0	5.8	-	-	-	420	0.312	-	0.42	134.4	-	107	-	-

Experiment: 79 (D3, pH3, S1, T3) System: Jar test Coagulant type: moringa powder Date:24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal, %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	90	45	45	420	0.015	95.2	0.24	76.8	45.45	3.9	96.35	8.87
2	1.5	10	90	45	45	420	0.019	93.9	0.22	70.4	50	3.5	96.7	9.45
3	1.5	10	90	45	45	420	0.016	94.87	0.18	57.6	59.1	3.8	96.45	8.96
							Average,%	94.6	-	-	51.5	-	96.5	-
Control	0	5.8	-	-	-	420	0.312	-	0.44	140.8	-	107	-	-

Experiment: 80 (D3, pH3, S2, T3) System: Jar test Coagulant type: moringa powder Date: 24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	60	45	45	420	0.022	92.9	0.26	83.2	36.58	3.4	96.8	10.74
2	1.5	10	60	45	45	420	0.0023	99.2	0.21	67.2	48.78	3.1	97.1	10.29
3	1.5	10	60	45	45	420	0.0019	99.4	0.20	64	52.1	3.1	97.1	10.76
							Average,%	97.17	-	-	45.8	-	97.0	-
Control	0	5.8	-	-	-	420	0.312	-	0.41	131.2	-	107	-	-

Experiment: 81(D3, pH3, S3, T3) System: Jar test Coagulant type: moringa powder Date: 24/12/2010(22/8/2018) Day: Thursday

Surface water Treatment		pH	Floc Speed	Floc time	Settling time	Color Removal			COD removal			Turbidity removal,	Turbidity removal	PH after treatment
Beakers 1000ml	Dose (g/l)	-	(rpm)	(min)	(min)	Wave length, (nm)	Absorbance	Color removal %	FAS (ml)	COD(mg/l)	COD removal, %	NTU	%	-
1	1.5	10	90	45	45	420	0.025	91.98	0.22	70.4	51.1	3.6	96.6	10.27
2	1.5	10	90	45	45	420	0.00195	99.3	0.21	67.2	53.3	3.3	96.9	10.23
3	1.5	10	90	45	45	420	0.00178	99.4	0.22	70.4	51.1	3.4	96.8	10.57
							Average,%	96.9	-	-	51.8	-	96.77	-
Control	0	5.8	-	-	-	420	0.312	-	0.45	144	-	107	-	-