



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)
SCHOOL OF CHEMICAL AND BIO-ENGINEERING
ENVIRONMENTAL ENGINEERING POST GRADUATE
PROGRAM
GARAGE WASTEWATER TURBIDITY REMOVAL USING LOW COST
SOIL COAGULANT

By: Mohammed Berhanu Serjabo

Advisor: Mr Teshome Worku

November 2016

Addis Ababa, Ethiopia



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Acronyms

ANOVA	Analysis of Variance
APHA	American public health association
ASTM	American society of testing material
AWWA	American water work association
COD	Chemical oxygen demand
EC	Electrical conductivity
EPA	Environmental protection authority
EC	Electrical conductivity
MEFCC climate change	Ministry of environment, forest and
NOC	Natural organic carbon
NOM	Natural organic matter
NTU	Nephelometry turbidity unit
US EPA authority	United state environmental protection

Abstract

Garages or vehicle service stations release very turbid, darkened effluent. They majorly composed of clay, phosphors and oil and grease which are potential to cause harm to aquatic life, give way to invasive species and gradually dead water bodies. Garage wastewater discharge and spillage is wide spreading but Overlooked section of pollution. Turbidity of the effluent wastewater is one and more general parameter manifesting wastewater's pollution. Though the conventional methods like skimming tanks and oil-grease traps remove turbidity including the oil and grease, but not up to the desired extent. Keeping in view of this, an effective and efficient method of turbidity removal study was made by coagulating turbid composite sample wastewater, by a jar test using locally available activated soil coagulant. And also it was analyzed then compared with the dominantly used alum coagulant which is possible to pose environmental and health impacts. The efficiency of turbidity removal by coagulation of both of these coagulants was observed considering parameters of coagulant type (Alum and Soil), dose (50 mg/l, 500 mg/l and 1000 mg/l), pH (5,7 and 9) and settling or sedimentation and time(15min, 30 min and 60 min). The results showed that soil from Buka was a potential coagulant with turbidity removal efficiency 97% while Alum has 98% removal efficiency turbidity in wide range of pH (5-9) and reduced Electrical Conductivity. Both of the coagulants better performed with 50 mg/l dose and neutral (7) pH conditions. After the coagulation the alum treated wastewater drops the initial pH 1.87 to acidic pH and the soil changed the pH 0.77 which is 0.53 to acidic pH and 0.24 to basic pH. In addition the use of these coagulants has changed the electrical conductivity of the raw wastewater significantly. As result this indigenous technology may be adopted at the source to remove oil and grease containing garage wastewater since it was found efficient and effective. Therefore Indigenous knowledge search and application for native problems is very important.

1. Introduction

1.1. Background

Vehicle service stations use large quantities of water, oil and detergents for washing and servicing vehicles. Careful management of these effluents could minimize the ultimate disposal of untreated wastewater to the environment. Though there are legitimate controls imposed by the Central environmental authority (MEFCC), the disposals of untreated wastewater to the environment are kept on increasing. This is witnessed by the distinctive oil spills seen in and around vehicle service stations in many parts of the country including the capital Addis Ababa. These days it has come to be obvious to release garage waste water to mix with to the nearby water bodies.

In the capital city alone there are numerous small scaled vehicle service stations or garages without waste water treatment providing high amount of solids (TSS), oil and grease to the water body around. According to a report by Addis Ababa EPA in the year 2012 there were more than 430 garages in the city. Due to improper land uses, lack of infrastructures, poor waste collection, transport and disposal system and low environmental awareness in the city the waste generation uses rivers, drainage line, river side and open land as dumping site for their wastes (Bethlehem, 2012). Subsequently most of those the stations are not well equipped for their own garage services. Even those equipped garages are failing to discharge the waste water because of finance, space, operational knowledge and also unwillingness to treat and cure their own wastes. Among the four main sources of pollutions entering to urban surface water in the city, wastewaters from garages and fuel stations are two of them (Gebre, 2009). On observing the situation of wastewater discharge from vehicle service stations simple low cost treatment mechanisms are essential. In the arena of public water use, water and wastewater treatment is provided to remove constituents from raw water which may pose a risk to public health or are undesirable in discharged water.

Turbidity is a characteristic related to the concentration of suspended solid particles in water and has been adopted as an easy and reasonably accurate measure of overall water quality. It can be used to measure the performance of individual treatment processes as well as the performance of an overall water treatment system. It can also be measure of the amount of suspended particles

in a sample that cause cloudiness. So removing turbidity unwanted test and odor compounds and lower rate of turbidity increases for higher rate disinfection (USEPA 1999).

Coagulation and flocculation is turbidity removing process whose goal is to remove turbidity in water, expending coagulants. Coagulant mainly is a chemical that is added to turbid water that causes small particles come together to form larger particles that can settle due to gravity. The pre dominant coagulant is alum or Aluminum sulfate.

Therefor this study will try to provide information on turbidity removal from garage waste water effluent by using local, low cost soil material as coagulant which will be collected from Oromia region, western hararghe, area commonly known “Buka” and compare with the common coagulant alum or aluminum sulfate. On the course of this research jar test method was applied.

1.2. Objectives of the study

The general objective of this study is to determine the potential of soil material for garage waste water turbidity removal as alternative coagulant.

1.2.1. Specific objectives

- ✓ To characterize the soil material for coagulant.
- ✓ To assess the turbidity removal potential of the soil with different settling time, coagulant dose and pH condition.
- ✓ To determine pH and conductivity results from turbidity removal.
- ✓ To compare removal efficiency of the soil material with that of conventional coagulant (Alum).

1.3. Statement of the problem

Garages for vehicles servicing including fuel servicing which have parts cleaning and car wash systems create wastewater that can have a great impact on the environment, if not properly managed and discharged. Contaminants in the wastewater include dust, oil and grease, detergents, including biodegradable detergents, phosphates and other potential pollutants. (Debabrata, 2011).

Environmental pollution of garage wastewater is noisy issue which has not yet given attention. Vehicle service stations are of pollution source firms which most of those are established on river banks. The discharge of most of these establishments don't receive treatments and the situation become worse when it is rainy season, where rain fall leaches toxic chemicals from upstream to downstream.

There are many forms and causes of contamination of water which needs treatment methods of wastewater. Similarly vehicle service stations spillages result in pollution of land and water bodies. It is observed that wastewater from vehicle service stations which are run by state and private entities contributes significantly to pollution. Improper and unscientific methods adopted in the disposal and treatment has resulted in excessive pollution. This has become matter of great concern over the years. In addition there are no efforts being made to treat this wastewater efficiently to the maximum extent and save it and reuse for different purposes (Ajith, 2013).

On-site wastewater treatment is a prospective direction towards the reduction of pollution load to the municipal or combined urban wastewater. One of such areas is automobile service station and car-washings which are discharging enormous amount of cloudy waste water. Some of the existing petrol pumps, fuel service stations are facilitated with car-washing. The large Car washing pools of garage and service stations are insisted upon by the respective pollution control boards to provide necessary treatment for the effluents (Debabrata, 2011).

Wastewater treatment typically includes coagulation, sedimentation, filtration, and disinfection. Coagulation is a critical step in water treatment processes not only because it removes particles but also removes microbes attached to the particles. Thus by removing turbidity, coagulant also has the potential to remove the pathogens and to significantly improve water quality and in turn have no ill effects on human health (Choubey et al, 2012).

As mentioned in the above back ground of this paper among the four main sources of pollution for urban surface water oily wastes from garage and fuel stations are the two beside industrial and municipal solid wastes (Gebre, 2009). In 2011 it was recorded that 549,000 l/month liquid waste was released from garages of the capital Addis Ababa (Tibebu, 2008). In 80.39 % of garages high oil leakage and contaminate was observed in portion of the cases used oil was

collected by illegal used oil collectors which uses the oil as energy source. 61.4 % of them mix waste solvent from part cleaning with the used oil, 35% of them discharge the waste water from part cleaning activity to the garage floor and drainage line. Incredibly greater number of them (56.37%) of the respective garage contact persons express they have no idea about environmental pollution and human health problems caused by vehicle service stations waste (Bethlehem, 2012).

The available information shows that used motor oil is a very dangerous polluting product. As a consequence of its chemical composition, world-wide dispersion and effects on the environment, used motor oil must be considered a serious environmental problem (Rafael et al, 1989). This oil and grease containing organic toxic wastes can cause ecology damages for aquatic organisms (Lan et al., 2009) plant, animal, and equally, mutagenic and carcinogenic for human being (Islam et.al, 2103). Since oil is virtually insoluble in water, with the cloudy dust it floats and spreads rapidly and forms thin film on the water surface. By itself Oil and grease is toxic to some aquatic organisms, The oil film also prevents oxygen transfer from the atmosphere and leads to low dissolved oxygen levels in the water due to microbial oxidative attack on hydrocarbon molecules.(Ajith, 2013).

On the other hand, Phosphates, which are plant nutrients, can cause excessive growth of nuisance plants like water hyacinth which has come know a hot issue by invading important water bodies such as Lake Tana. Moreover a study showed its conclusion that vehicle service stations' Waste water effluent exceeded the tolerance limits by high margin due to the presence of Total Suspended Solids (TSS), Oil and Grease in wastewater effluents. In addition high values were indicated for Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Munasinghe and Athapattu 2013).

Mainly turbidity due to a large volume of suspended sediment will reduce light penetration, thereby suppressing photosynthetic activity of phytoplankton, algae, and macrophytes, especially those farther from the surface. If turbidity is largely due to algae, light will not penetrate very far into the water, and primary production will be limited to the uppermost layers of water. Cyanobacteria (blue-green algae) are favored in this situation because they possess flotation mechanisms (McCabe et al., 1985). Overall, excess turbidity leads to fewer photosynthetic

organisms available to serve as food sources for many invertebrates. As a result, overall invertebrate numbers may also decline, which may then lead to a fish population decline. A report of the European Inland Fisheries Advisory Commission lists five ways that Turbidity can have a harmful impact on freshwater (2008).

- acting directly on fish, killing them or reducing their growth rate, resistance to disease, etc.;
- preventing successful development of fish eggs and larvae;
- modifying natural movements and migrations;
- reducing the amount of food available; and
- affecting the efficiency of methods for catching fish.

It is very important to measure and control the turbidity of domestic water supplies. For example, during the rainy season when mud and silt are washed into rivers and streams, high turbidity can quickly block filters and stop them from working effectively. High turbidity will also fill water bodies like drinking water dams and complimenting systems with mud and silt, and can cause damage. Where chlorination of water is practiced, even quite low turbidity will prevent the chlorine killing the germs in the water efficiently.

According to environmental inspectors' interview both at the federal (MEF) and Addis Ababa city administration (EPA) level; most of these stations are disposing their waste without treatment. The inspectors thought existing vehicle service stations lack space, finance and operating knowledge to have wastewater treatment plant.

Though the conventional methods like skimming tanks and oil-grease traps remove turbidity including the oil and grease, Coagulant based turbidity removal of these pollutants has a roll on maintaining and preventing the listed problems occurrence. For this study purpose a common and widely used coagulant aluminum sulfate is considered for comparison which is selected due to its abundant application and market availability to turbidity removal.

Aluminum sulfate (Alum) is a common coagulant globally used in water and wastewater treatment. It can achieve 90-99% removal under optimal conditions (Anuja.et al, 2014). However alum addition has many drawbacks. It produces a large sludge volume, reacts with the

natural alkalinity present in the water leading to the pH reduction and show low coagulation efficiency in cold waters. In addition to this alum has raised concerns due to eco-toxicological impacts when introduced into the environment. With aluminum salts there is always the concern about residuals in the treated water and its impact on human health. It also raises the cost of chemicals in case of developing countries.

With aluminum salts, there is a concern about residuals in the treated water and Alzheimer disease and the cost of any imported in addition processed and chemicals can be a serious problem for developing countries (Diaz. et al, 1999). The first investigations about harmful influence of coagulant chemicals like aluminum sulfate on human health were published in the 60's of the 20th century. Those and later publications showed that the residues of aluminum salts in the water can cause Alzheimer's disease (Marina.et al, 2010).

Besides these difficulties, implementation of Alum requires technical skills and training. By using natural coagulants the method of treating water may be a less expensive, inherently benign, renewable, locally available and readily implementable (Biniyak.et al, 2013, Somani.et al, 2011, Eman, N.A.et al.2014).

2. Literature Review

2.1. Introduction

Vehicle service stations are among major users of water, each stations particularly incorporating car washing service produces a large volume of wastewater, varying in composition and pollutant concentration, including oil containing wastewater. For example the fuel and vehicle service station entity the study bases on discharges huge volume of turbid wastewater daily which carries high garage water pollution to the sewage stream and urban environment. Oil means liquid hydrocarbons of crude petroleum, tars, vegetable and mineral oils, animal fats, light and heavy fuel, as well as their mixtures, which are insoluble or poorly soluble in water (Thamer et.al, 2007).

Oil/water mixtures may involve two distinct phases, or they may be present in an emulsified form. In general, emulsions are stable mixtures of two immiscible liquids consisting of a discrete phase that is dispersed in a continuous phase in the form of microscopic droplets. Emulsions are further classified as either oil-in-water emulsions (i.e., oil is the discrete phase dispersed in water, the continuous phase) or as water-in-oil emulsions (i.e., water dispersed in oil). The typical droplet size for emulsified oil is 0.1 to 5.0 microns. Above 5.0 microns, droplets coalesce into free oil. Below 0.1 micron, oil droplets tend to be solubilized in water and needs treatments like biological treatment. The stability of an emulsion is dependent upon the free energy of coalescence, which is a function of oil droplet surface area. The total surface area of oil will decrease when two drops coalesce into one larger drop. Other factors affecting emulsion stability include pH, Viscosity, density, temperature, mechanical shear, agitation, amount of water in the emulsion, and retention time (Mikel, 2014).

Oil and grease content are required to be pretreated before discharged to the city or storm drain systems. The most common treatment methods for treating oily wastewater are sedimentation, centrifugal separation, coagulation and flocculation, sorption, flotation, filtration ultra-filtration, and reverse osmosis. These methods can be used separately or in combinations to separate the oil from the water (Pushkarev et al, 1983).

The process by which emulsion is destabilized is Demulsification. It is a two-step process, flocculation followed by coalescence. Coagulation/flocculation neutralizes repulsive forces that stabilize the emulsion, creating discrete droplets. The droplets coalesce, increasing in size so that they can no longer be dispersed in the continuous phase (Mikel, 2014).

The study was conducted using the sample taken from a garage at Torahayloch in the West of Addis Ababa, Ethiopia. The vehicle service station is private owned enterprise and usually handles the operation of small to heavy vehicles in the garage. The activities of the Garage yard include the following: (1) Tyre repairing section, (2) Vehicle running Maintenance section, (3) Break down maintenance section, (4) Vehicle washing and servicing section, (5) Ancillary section, and (6) oil and fuel service.

2.2. Turbidity removal

One of the wastewater treatment operator's primary jobs is controlling turbidity. Turbidity is a principal physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is synonymous with cloudiness and measured in NTU (nephelometric turbidity units) or occasionally JTU (Jackson turbidity units).

Colloids are small suspended particles in water which cannot be settled or removed naturally due to their light weight and stability. These particles pose some degree of stability and cause water turbidity or cloudiness. Turbidity may contain many contaminants like pathogenic organisms. Many pollutants of concern to human health e.g., metals or some synthetic organic chemicals are also associated with turbidity.

The first practical attempts to quantify turbidity date to 1900 when Whipple and Jackson developed a standard suspension fluid using 1,000 parts per million (ppm) of diatomaceous earth in distilled water (Sadar, 1996). Dilution of this reference suspension resulted in a series of standard suspensions, which were then used to derive a ppm-silica scale for calibrating turbidimeters.

Lately, turbidity measurement standards changed in the 1970's when the nephelometric turbid meter, or nephelometer, was developed which determine turbidity by the light scattered at an angle of 90° from the incident beam. A 90° detection angle is considered to be the least sensitive to variations in particle size. Nephelometry has been adopted by Standard Methods as the preferred means for measuring turbidity because of the method's sensitivity, precision, and applicability over a wide range of particle size and concentration. The nephelometric method is calibrated using suspensions of formazin polymer such that a value of 40 nephelometric units (NTU) is approximately equal to 40JTU. The preferred expression of turbidity is NTU (EPA, 1999).

Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity is a hide providing food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the United States and the world. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa.

It is very important to measure the turbidity of domestic water supplies, as these supplies often undergo some type of water treatment which can be affected by turbidity. For example, during the rainy season when mud and silt are washed into rivers and streams, high turbidity can quickly block filters and stop them from working effectively. High turbidity will also fill water bodies like drinking water dams and complimenting systems with mud and silt, and can cause damage. Where chlorination of water is practiced, even quite low turbidity will prevent the chlorine killing the germs in the water efficiently.

Turbidity removal or control at source is a cost effective and efficient way to eliminate multiple levels of treatment (Zane, 2006). Thus, effective turbidity elimination is necessary to ensure removal of many health related contaminants. In addition effective removal of turbidity may ease subsequent water treatment processes.

As mentioned coagulation and flocculation are commonly used methods for water turbidity removal, and are usually conducted by adding chemicals such as salts of aluminum and iron (Marina.B et.al, 2010). In water treatment plants, the coagulant is dosed upstream of the flocculation and/or sedimentation basin under a turbulent flow to ensure adequate contact with suspended particles. The turbulent flow path induced in the flocculation basin ensures adequate contact between destabilized particles and promotes floc formation. Detention time in sedimentation basins allow flocculated particles to settle out of the system.

2.3. Coagulation

In the area of wastewater treatment, clarification of water with coagulating agents has been practiced since ancient times, using a variety of substances the most notable among them being crushed seeds. The Egyptians, as early as 2000 BC, used almonds smeared around a vessel to clarify river water. The early Romans were also familiar with alum, though it may not have been for water treatment (Bratby, 2006).

Nevertheless, its use of a coagulant by the Romans was mentioned in ca. 77 AD. By 1757, alum was used as a coagulant in water treatment in England, and more formally for the treatment of public water supplies in 1881(Bratby, 2006). In modern water treatment, coagulation and flocculation are still essential steps in the treatment processes.

The process of coagulation is one of the most important physicochemical operations used in water, and waste-water treatment can be achieved by chemical and electrical means (Pernitsky and Edzwald, 2006). it has been defined as the addition of a positively charged ion of metal salt or catalytic polyelectrolyte that results in particle destabilization and charge neutralization. Coagulation targets the colloid particles of size 10^{-7} to 10^{-4} cm in diameter. The colloid particles exhibit Brownian movement through the water; their surface is negatively charged so they repel one another, and they form a stable dispersed suspension (Bache et al., 1999).

Effective coagulation is a function of many factors, the complete list of which is detailed in Table (2) as cited by luu. Some of the most important factors influencing the effectiveness of coagulation are coagulant type and dosage as well as mixing times. There is a range of optimum dosages for a coagulant at which maximum settling and removal of suspended particles is most

efficiently and effectively achieved. Below this range, the amount of coagulant added is insufficient to adequately destabilize the particles. Above this range, the coagulant essentially serves as a chemical coating which re-stabilizes the particle. The window of acceptable dosages varies with every coagulant and with many of these factors, making some less sensitive to imprecisely measured dosages (Kim, 2000).

Table2.1. Factors affecting effective coagulation

Coagulant Characteristics	Physical Characteristics	Raw Water Characteristics
<ul style="list-style-type: none"> • Coagulant type • Coagulant dose • Proper solution makeup and dilution • Proper coagulant age 	<ul style="list-style-type: none"> • Settling time • Mixing intensity • Mixing time • Coagulant addition Point • Proper coagulant feed 	<ul style="list-style-type: none"> • Suspended solids • Temperature • pH • Alkalinity • Presence of microorganisms and other colloidal species • Ionic constituents (sulfate, fluoride, sodium, et

Source: - Murcott, susan

2.4. Flocculation

Intending to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc, coagulation and flocculation occur in successive steps. Flocculation is the physical process of agglomerating small particles into larger ones that can be more easily removed from suspension. It is almost always used in conjunction with, and preceded by coagulation. During the coagulation process the repulsive forces between solids particles are reduced or eliminated. The process brings the destabilized particles into contact with one another to form micro flocks which is turned into visible flock masses. These larger particles are more readily removed from the water in subsequent processes. Generally flocculation is accomplished

by mixing the destabilized suspension to provide the opportunity for the particles to come into contact with one another and stick together (George 2003, Gregory 2006, and Kerry 2012).

2.5. Coagulant

There are varieties of coagulants for coagulation purpose but for this study we will focus on Alum (aluminum sulfate) and the soil material from Oromia region western Hararge Buka area.

2.5.1. Aluminum sulfate

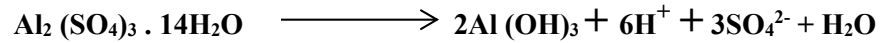
Aluminum sulfate (Alum) is a common coagulant globally used in water and wastewater treatment. It can achieve 90-99% microbial removal under optimal conditions. A feasible removal was showed on oily garage waste water treatment coagulation by using alum coagulant (Debabrata and Somnath).

As Alum is added to water the hydrolysis reactions form a number of dissolved monomeric aluminum species and aluminum hydroxide precipitates. The theoretical effective hydrolyzing pH range for Alum is 5.5 to 7.7 with optimal pH values near 6.0. At the optimum pH, the solubility is minimal and the maximum amount of coagulant is converted to solid floc particles.

As pH decreases from 6.0, dissolved

Positively charged aluminum species are formed. As pH increases above 6.0, the concentrations of negatively charged aluminum species increase. Researchers have found the distribution of aluminum species to be greatly affected by pH (Pernitsky & Edzwald, 2006).

The aluminum species present in the water are of concern because of the implications they have with the adsorption of NOM. NOM removals tend to increase at lower pH values where highly charged aluminum species are prevalent. NOM is typically composed of organic compounds with negatively charged functional groups. These groups react with the highly charged aluminum species to form precipitants which can then be settled out of the water. Although NOM removals as high as 70% have been attained at low pH values, the characteristics (charge, molecular weight, pH, etc.) of the NOM will affect the efficiency of the coagulation process. Thus, high NOM removals have been observed at lower pH values and do not necessarily correspond with the pH at which minimum solubility of a coagulant occurs. Equation below is the overall reaction of Alum and water.



The hydrolysis reactions between water and metal salts produce hydrogen ions which lower the pH and consume alkalinity at a 1:1 equivalent basis. Neutralizing the hydrogen ions with base during manufacturing has led to the development of pre-hydrolyzed coagulants, such as those made with aluminum chloride (Crittenden et al, 2005).

The resultant sludge from using alum is a potential environmental hazard if not treated before disposal (George et al., 1991, Atkor, 1994). The sludge is predominantly amorphous aluminum ion. These ions bind strongly to the hydroxides, inorganic ions, phosphates and organic compounds in water resulting in insoluble compounds which are then removed from solution. The sludge is characterized by high water content (low solid concentration), high resistance to mechanical dewatering and is difficult to dispose of or handle (Knocke and Walkeland, 1983).

A key concern regarding the direct discharge of Aluminium residuals to waterways is Aluminium toxicity. Toxic components of alum sludge other than Aluminium come either from the commercial alum or from the original raw water source. Aluminium may have several direct effects on plants according to a review of available literature indicates that (Taylor, 1989). Aluminium has been classified as having a medium level of phytotoxicity in terrestrial plants with concentrations from 5 to 200mg/g dry weight plant tissue shown to be toxic to terrestrial plants that are neither highly sensitive nor tolerant to Aluminium (McBride, 1994). The aluminate ion has been found to be toxic to fish, at levels >0.5mg/l (Freeman and Everhart, 1971). Aluminium is toxic to marine bacteria, algae and benthic organisms (George et al., 1991) and when it is mobilized in streams, swamps and lakes it may be a threat to aquatic life.

On the other hand it's very binding character strongly with phosphorus result, the unnatural presence of aluminum in the environment which will have an impact on the phosphorus cycle. The available phosphorus in Wetlands cycles between the biota, sediment and water. The available phosphorus acts as an essential nutrient for aquatic vegetation, plankton, periphyton and microbes and in higher concentrations it can cause eutrophication (Rose et al, 2000).

2.5.2. Soil coagulant

Different soil types have been used for waste water treatment. Clay soil material is one of soil types which have played an important role in the environmental protection. These minerals have been used in the disposal and storage of hazardous chemicals as well as for remediation of polluted water. The use of clay minerals as the adsorbents for the adsorption of various hazardous substances (heavy metals, dyes, antibiotics, biocide compounds, and other organic chemicals) has been widely studied by a large number of researchers.

Clay soil has been studied for its coagulation activity and coagulant aid ability. A study on clay soil performance effectiveness and optimum working condition on two soil types called Shendi and Sinja soil coagulants by which local people in Sudan who live nearby Blue Nile are using. Both soil coagulants has performed properly in wide range of pH ranging from 3-10 at coagulation dosage of 300-400 mg.L⁻¹ whereas the optimum settling time is 30 minutes for Sinja and one hour for Shendi the removal efficiency was 92.2 % and 87.3 % for Shendi and Sinja respectively (Mohammed et al., 20013). Apart from sole use of clay soil coagulant in oily waste water, clay coagulation improves the coagulation and flocculation with alum as coagulant aid (Thamer et al, 2007).

Moreover the locally available low cost material has important practical implications for removal of dyes from textile waste water (Bizuneh et al, 20011). Therefore, there are quite promising perspectives for its utilization on an industrial scale, keeping in mind that it is very abundant coagulant, whose price may be considered negligible when compared with that of alum.

3. Materials and Methods

3.1. Coagulant soil

In this study, a locally available soil-type or geo-material was used as coagulant. This natural, soil geo-material is being used among the rural community of Buka in one of a water deficit part of western Hararghe to clarify/purify flood water collected for drinking and other domestic uses. To this study purpose the soil was purchased from the local market and washed with distilled water, to remove any attached dirt and soluble impurities, dried in the open air and then pulverized using mortar. The powder was sieved using laboratory sieve and the coagulant soil remaining between 25-32mesh (500 μm) fractions was separated to get the intended clay soil material . The powder was dried in the oven and kept in the desiccators until later uses.



Figure 3.1: soil coagulant in Buka Saturday market

3.2. Soil activation

The natural coagulating power of the raw soil is relatively low. This can greatly increase by an acid treatment which generates the so-called “activated earth.” The acid treatment was carried out by using sulfuric acid (H_2SO_4). Calcium oxide was used for the neutralization of the spent acid. The process of the soil activation essentially involves the following operations. The 100 grams sieved, powdered clay soil was mixed with distil water to form a suspension to which 200 mL of H_2SO_4 (analytical grade) is added and magnetically stirred in addition to 50 mL CaO . The mixture is then heated by steam in a round-bottom flask up to a temperature of 40°C and kept at

this temperature for about 4 hours. Then the mixture was heated to 180°C for one hour. After cooling the slurry was oven dried then crushed by mortar and piston and washed twice with distilled water in order to eliminate excess acidity.

3.3. Collection and Preparation of Waste water Sample

The investigation was carried out by grab sampling from the vehicle wastewater collection pit of washing area of the garage. The Supernatant wash was collected in a 2 liters capacity plastic container after settling for 1 hr. Another 2 liters sample was collected in the other container during the next vehicle service and washing operation. The sampling process was carried out for five successive vehicle services and washing operations in the morning and five in the afternoon. This was repeated for three days for one run of investigation. The samples collected from ten operations were thoroughly mixed in a separate bucket of 20 liters capacity and then 60 liters container which is allowed to settle for 24 hrs.

3.4. Waste water characterization

Different parameters like pH, conductivity, and Total suspended solid, COD of the composite sample collected from the vehicle service station was measured in Laboratory for both raw waste water sample and zero treated waste water.

3.5. Experimental procedure

3.5.1. Jar test

The removal of oil from garage wastewater was investigated by the coagulants treatment. The method of coagulation and flocculation was carried out by standard “Jar Test” apparatus. In this set-up, three samples with different doses of coagulant added were treated simultaneously or separately as required in the beaker of 1000ml capacity. 500 ml of the composite sample in each beaker was flocculated by individual stirrer rotated by a common driving shaft connected to a variable speed electric motor. The mixing and settling time will be adjusted to find out the optimum turbidity removal for a specified coagulant dose by measuring it using turbidity meter.

The coagulation, flocculation, sedimentation and filtration processes were done for both Alum (aluminum sulfate) and the soil material and their respective measure for the pH and conductivity by pH and conductivity meter for the two coagulants respectively was recorded.

The beakers commonly referred to as jars, will be cleaned. The jars filled with half-liters of mixed raw sample water. The jar testing equipment was programmed using the ASTM International standard jar testing sequence of 120 revolutions per minute (RPM) for 1 minute (min), 50 RPM for 20 min and 15 min in Imhoffcone settling cone, simulating a coagulation time of 1 min, a flocculation time of 20 min, and a settling time of 15,30 and 60 min (ASTM, 2003) for the two coagulant comparison at the desired pH(5,7and 8) levels..

The other experimental run was varying the settling time to optimize the preferable settling time. In this run Batch sludge settling will be performed following a similar method to that found in research conducted. Jar tests are dosed and conducted as described in the previous section. However, immediately following the flocculation sequence, water from each jar is carefully transferred into one-liter graduated cylinders, inverted once, and allowed to settle. The inversion step is performed to re-suspend flock particles and minimize interference from transferring the water. The sludge interface height will be recorded over time and used to compare the settling time of the solids and settling velocities for each coagulant dose (15 min, 30 min, and 60 min).

3.5.6. pH – analysis

pH value of water was determined by the relative concentrations of H^+ ion and OH^- ion. pH analysis was measured using pH meter. More ever pH test was carried out to determine the optimum range of the pH value which gives the highest turbidity removal. Sodium Hydroxide (NaOH) 0.1N and Sulfuric acid (H_2SO_4) 0.1 N were used for adjusting the pH at the desired levels of 5, 7 and 9.

3.5.7. Turbidity analysis

Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended materials in water (EPA, 1993). Turbidity measurements were conducted using turbidity meter (HACH, 2100P). After the sedimentation phase, samples for turbidity measurement were collected from upper depth. The sample's vial was washed once with distilled water and once with the supernatant before recording the turbidity. In order to eliminate any differences in turbidity due to different sedimentation times, two samples were taken according to the following order: 1-2-3-3-2-1 and the average values were recorded.

Turbidity removal efficiency was determined as following:

$$\text{Turbidity removal efficiency} = \left(\frac{\text{turbidity for raw water} - \text{turbidity of treated water}}{\text{turbidity for raw water}} \right) * 100$$

3.5.8. Conductivity analysis

Conductivity is a measure of electrical conductance of water or the mineral content of water. It gives a qualitative measure of the total dissolved solids in water. It is important to measure conductivity of water in order to know the likelihood of the water becoming corrosive (US EPA, 1992). Conductivity was measured in milli Siemens per centimeter (mS/cm) using Conductivity meter

3.6. Data analysis

MS Excel and R software were used to analyse data. Mean variance, kruskal and Shapiro test were used to assess the spread of the data. The mean of parameters, one-way and three-way analysis of variance (ANOVA) followed by a post hoc multiple comparison (Tukey's test) were calculated to compare the mean values of observation based on sites. Differences in mean values obtained were considered significant if calculated P-values were < 0.05.

4. Result and Discussion

4.1. Waste water characterization

In order to evaluate important physico-chemical parameters of the garage wastewater quality before application of wastewater treatment, collected composite samples at the discharge point were analyzed for different pollutant parameters. The results of these pollution values before application of the soil coagulant which is raw wastewater and wastewater sample for control that is zero wastewater are presented and compared in table 4.1. The zero wastewater has passed through coagulation; flocculation and sedimentation steps treated along with tree randomly selected jar test procedures.

The pH of garage raw wastewater is a slight basic solution. pH of the garage zero waste water is almost the same. Likewise, E.C value of both waste waters is close. However, turbidity and COD shows countable differences. Without any treatment the zero waste water shows improvement in the turbidity removal. Since there are cases where COD amount is solely impacted by turbidity, zero wastewater characterization show reduced turbidity sources like sawdust which probably reduce COD. The turbidity and COD reduction might be due to the time it was given for sedimentation.

Table4.1: Garage waste water characterization

Starting samples	pH	E.C(mS/cm)	Turbidity(NTU)	COD
Raw wastewater	8.2	8.3	2300	9700
Zero wastewater	8.1	7.8	1132	7200

4.2. Soil coagulant characterization

Supplemental to garage waste water quality parameters, grain and silicate analyses of soil were examined in this research and have compared the soil coagulant with alum. Though the test

results of the raw soil gradation show 5.70% clay soil, the crushed, sieved and prepared soil for treatment is clay soil as confirmed by texture test.

A chemical analysis of coagulant was performed using a complete silicate analysis method by Geo-Chemical Laboratory(Addis Ababa, Ethiopia) and the result is shown in Table .The major constituent in the sample soil are Silicon oxide, calcium oxide, aluminum oxide and iron oxide, by weight. The loss on ignition (LOI) was found to be 16.8% by weight.

Table4.2. Soil silicate analysis

Chemical composition	Percent (wt. %)
SiO ₂	38.92
CaO	23.94
Al ₂ O ₃	9.98
Fe ₂ O ₃	4.66
MgO	2.28
TiO ₂	1.07
H ₂ O	0.45
Na ₂ O	0.4
K ₂ O	<0.01
MnO	<0.01
LOI	16.8

4.3. Turbidity removal

Turbidity removal potential of the soil was tested in the laboratory on jar tester. Primarily the process looked at turbidity removal efficiency, considering the three treatments of initial pH of waste water, dose of coagulant, type of coagulant and settling time. The data obtained from over 108 jar tests conducted throughout the study have been provided in Appendix (B). The statically tests has portrayed that settling time after 15 min of sedimentation for the treated water after flocculation is not by itself significance (p-value =0.26) to the process of turbidity removal

of garage wastewater as showed in appendix C4 . As result settling time is omitted from interpretation and comparison due its insignificancy.

The results were selected to be represented by a box plot shown in Figures below through Figure (4.1 up to 4.16).

The laboratory results have been presented in this chapter using graphical representations and it is was found proper if they are presented by a box plot. So that Box plots were developed to depict the percent removals of turbidity, the results of pH and EC of treated wastewater up on the application of the coagulants. The star shown on those boxplot of graphical expression was set to display the mean turbidity removal performance and the dark bold line stands for the median.

The Figures Through 4.1 - 4.4 attempts to show the turbidity removal efficiency along with different initial pH points and dose levels of soil coagulant. The pH points during the jar test are 5, 7 and 9 labeled pH1, pH2 and pH3 respectively on the box plot in order to represent acidic neutral and basic condition of wastewater. On the other hand dose levels are 50 mg/l, 500 mg/l and 1000 mg/l labeled D1, D2 and D3 respectively. pH and dose denotation remain the same to the entire document.

4.4. Effect on turbidity

Turbidity removal based on coagulation can be affected due to number of factors as tried to mention in table 2.1. Different coagulants chose specific pH conditions while others are effective in extensive ranges of pH levels for the process of coagulation.

The figure below shows the turbidity removal efficiency of the soil coagulant considering pH levels of 5, 7 and 9. Turbidity removal at 5 PH was $95.3\% \pm 2.72$, $98.54\% \pm 1.29$ at 7 pH and $98.04\% \pm 2.87$ at pH 9. As shown in figure 4.1 at pH 7(pH2) and 9 (pH3) the soil has better turbidity removal of garage waste water. This result of removal might show extended variance among pH levels, if initial turbidity of the wastewater was smaller than the one used for this study. So bearing in mind higher initial turbidity all pH levels of turbidity removal using soil coagulant has showed significance turbidity removal.

Highly acidic coagulants may drive the pH down and consequently decrease the efficiency of the coagulation. However, clay coagulants work efficiently in wide range of pH (3-10) according to

(Mohammed et al., 2013) and therefore can be used for wastewater treatment without adjusting the pH. So we could use this coagulant of soil in wide range of pH (5-9) but it would be more efficient to use the soil coagulant at those pH of 7 and 9, which may need adjustments on the waste water.

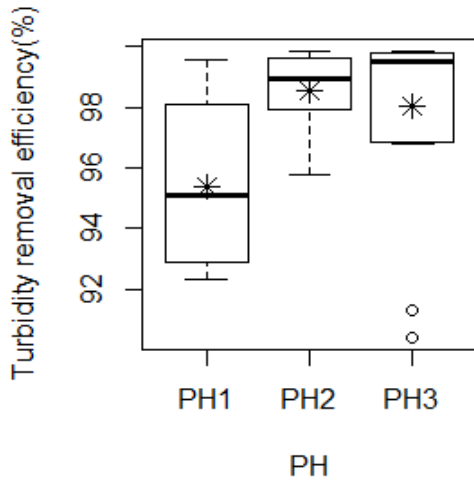


Figure4.1. Turbidity removal efficiency of soil with different pH levels

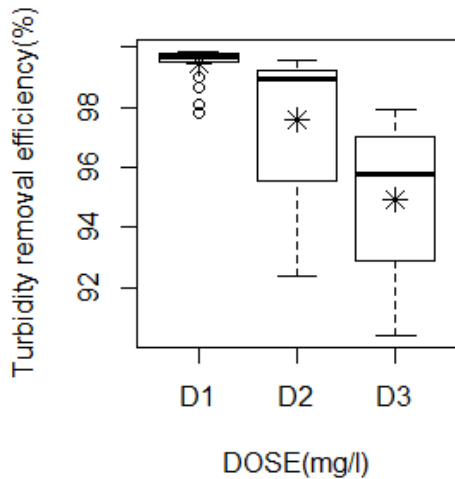


Figure 4.2: Turbidity removal efficiency of buka soil different dose level

The above figure shows the turbidity removal efficiency of the soil with different dose levels where D1, D2 and D3 stands for 50 mg/l, 500mg/l and 1000 mg/l respectively. Removal

efficiency of soil at 50 mg/l was $99.43\% \pm 0.63$, $97.57\% \pm 2.48$ at 500 mg/l and $94.92\% \pm 2.48$ mg/l at 1000 mg/l of dose levels.

Amount of coagulant added to wastewater affect the coagulation activity for turbidity removal. According to the experiment the increase in dose of coagulant could not necessarily increased the turbidity removal efficiency of the soil instead the increase in soil coagulant resulted in turbidity removal decrement with an extended range of difference while going from lower dose level to higher.

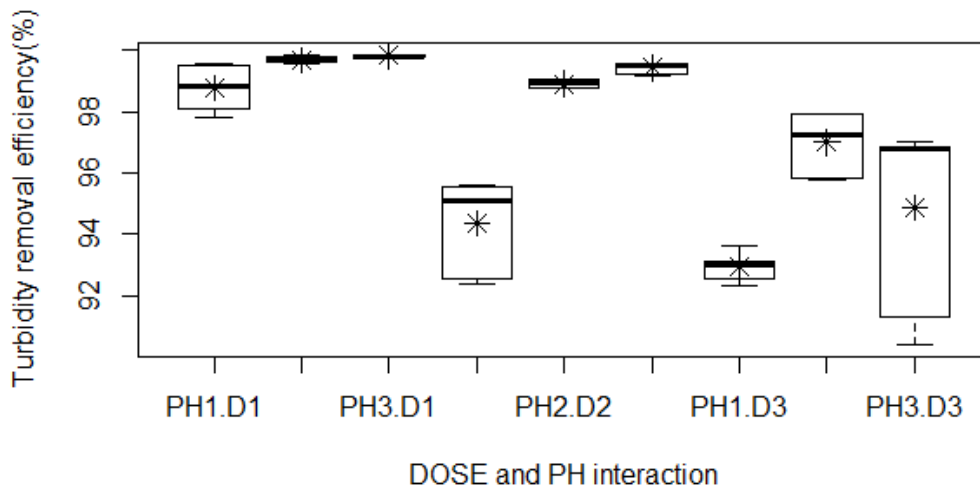


Figure 4.3: the combined effect of pH and Dose on buka soil turbidity removal efficiency

Since it was known from the data analysis that the settling time has low significance only the combination of the two factors (i.e. DOSE and pH) impact on the removal efficiency was analyzed. So as it is shown in the figure 4.3 above. By the treatment that combines minimum dose of 50 mg/l with pH levels of 5, 7 and 9 (D1:pH1, D1:pH2, D1:pH3) the turbidity removal efficiency of the soil coagulant is 98.76%, 99.7% and 99.83% respectively. Similarly for medium dose of 500 mg/l of those PH combinations (D2:pH1, D2:pH2, D2:pH3) removal efficiency is 94.36%, 98.91% and 99.43 and for maximum dose 100mg/l the analogs combination (D3:pH1, D3:pH2, D3:pH3) turbidity removal is 92.92%, 96.99% and 94.86% respectively.

As it is looked on the figure turbidity removal has decrease with increasing dose and decreasing pH. However it has known from the statistical tastings and the figure above that dose has more significant impact than pH. If it is considered in the plot though it is said decrease in removal

with decreasing pH for generality, the dose has up lifted the removal efficiency with its decreasing out performance and yet the pH is not capable to have the comparable impact in its increasing. Nonetheless the removal efficiency of the soil coagulant is Steel better at pH level 5 when the dose was 50 mg/l only.

From the experiment it is possible to conclude the soil has optimum coagulation effect when it is coagulated dominantly with 50 mg/l, the lower dose and higher pHs that is 7 and 9 conditions. From the best performing pH circumstances pH 7 has lower margin of giving efficient turbidity removal. And the turbidity removal resulted minimum at conditions where Dose is highest and pH is lowest (i.e. 1000 mg/l and 5 pH). Therefore even if the soil executed well in those all conditions of the experiment, it is better to use 50 mg /l soil coagulant from buka at 7 pH garage waste water condition to have pleasing turbidity removal.

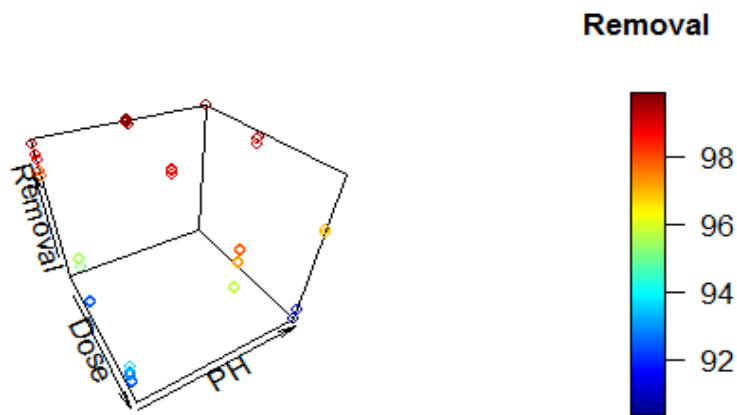


Figure 4.4: 3d show of combined effect of Dose and pH

The figure above point out circumstances of turbidity removal efficiency alongside dose and pH. It represents the more efficient with darkened red and the minimums with darkened blue from the spectrum of colors. In most the conditions 50 mg/l has good performance particularly with higher PHs. The removal efficiency goes down when dose level is increasing and pH is decreasing.

Generally it is preferable to select the combination of the minimum dose with higher pH. In addition from the laboratory experiment and statistical analysis, for this study it is found that the soil coagulant has garage wastewater turbidity removal efficiency of 97.31% which has extended up to 99.86 to the maximum and 90.39 to the minimum.

4.5. Coagulant comparison

4.5.1. Turbidity Removal

1. Dose comparison

Dose consumption is crucial for selecting appropriate coagulants which would be feasible in the field of wastewater treatment. Removal efficiency of soil at 50 mg/l was $99.43\% \pm 0.63$, $97.57\% \pm 2.48$ at 500 mg/l and $94.92\% \pm 2.48$ mg/l at 1000 mg/l of dose levels. On the other hand for alum it was $99.2\% \pm 0.8$, $96.6\% \pm 4.09$ and $99.4\% \pm 0.3$ for D1, D2, and D3 respectively.

As it shown in the figure below the turbidity removal for soil coagulant from buke is adequately comparable even better at D1 and D2 dose levels with alum coagulant. The coagulation activity was very good while feeding the turbidity removal process with the lower dose of 50 mg/l. The higher dose levels of 500 mg/l and 1000 mg/l has lowest performance.

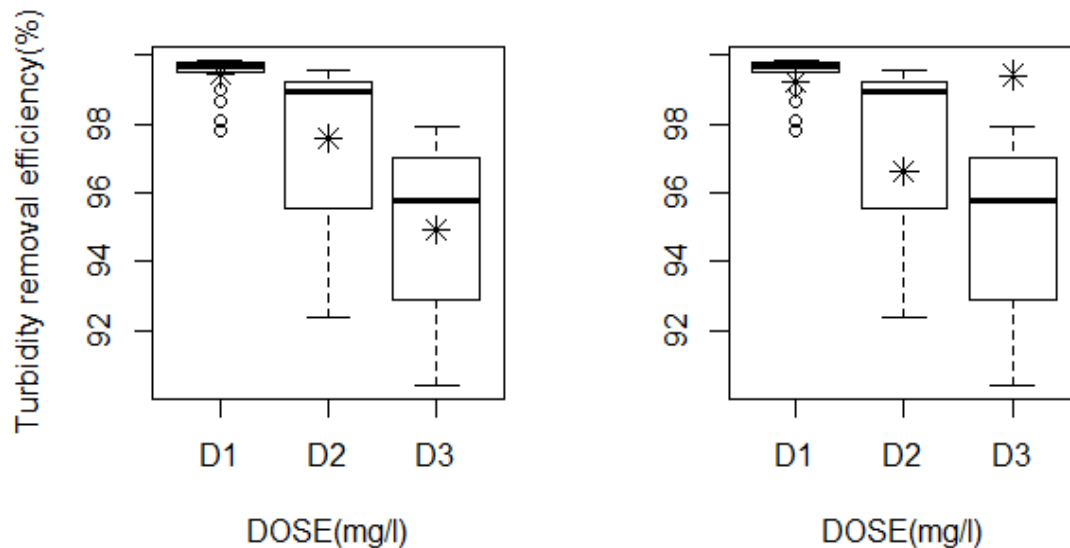


Figure4.5: Alum (right) and Soil (left) turbidity removal efficiency comparison with different dose levels

2. pH comparison

pH is a measure of the acid balance of a solution. The pH of water affects the solubility of many toxic and nutritive chemicals. As well pH of a solution discharged determines favorability of aquatic environment. Turbidity removal of soil at 5 pH was $95.35\% \pm 2.72$, $98.54\% \pm 1.29$ at 7 pH and $98.04\% \pm 2.87$ at pH 9. As well for alum removal efficiency is $96.24\% \pm 3.88$ at PH 5, $99.55\% \pm 0.30$ at pH 7 and $99.44\% \pm 0.33$ at pH 9. Like dose effective pH level was similar for the Buka soil and Alum. Both coagulants get 7 pH more favorable.

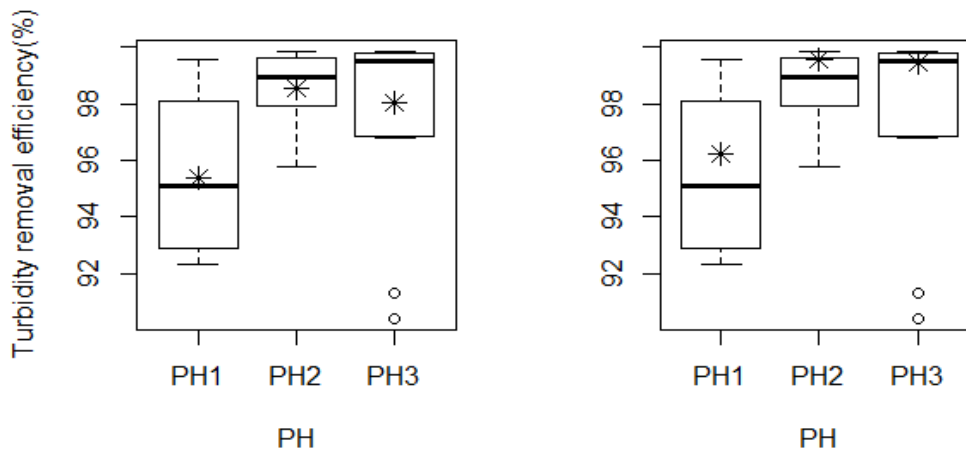


Figure4.6: Alum (right) and Soil (left) turbidity removal efficiency with different pH levels

So as it is shown in the figure 4.7 that combines minimum dose of 50 mg/l of alum with pH levels of 5, 7 and 9(D1:pH1, D1:pH2, D1:pH3) the turbidity removal efficiency of the alum coagulant is 98.11%, 99.77 % and 99.72% respectively similarly for medium dose of 500 mg/l of those combinations (D2:pH1, D2:pH2, D2:pH3) removal efficiency is 91.26%, 99.55% and 98.99% and for maximum dose of 1000mg/l the analogs combination (D3:pH1, D3:pH2, D3:pH3) turbidity removal is 98.94%, 99.32% and 99.6% respectively.

For soil by the treatment that combines minimum dose of 50 mg/l with pH levels of 5, 7 and 9(D1:pH1, D1:pH2, D1:pH3) the turbidity removal efficiency of the soil coagulant is 98.76%, 99.7 % and 99.83% respectively similarly for medium dose of 500 mg/l of those combinations

(D2:pH1, D2:pH2, D2:pH3) removal efficiency is 94.36%, 98.91% and 99.43 and for maximum dose 100mg/l the analogs combination (D3:pH1, D3:pH2, D3:pH3) turbidity removal is 92.92%, 96.99% and 94.86% respectively.

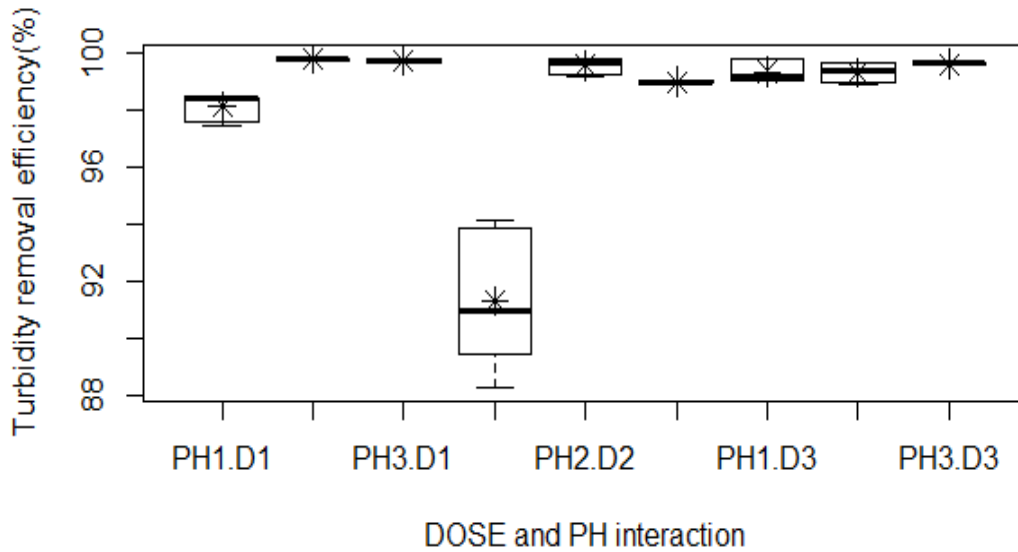


Figure4.7: the combined effect of PH and Dose on Alum turbidity removal efficiency

As it is shown on the box plot the combination of the two factors has better performance on those combinations of initial pH conditions of waste solution paired with 50 mg/l dose of soil coagulant. On the contrary each dose levels including the smaller D1 (50 mg/l) is decreasing in Removal efficiency while going from smaller pH (5) to higher. Moreover the larger pH circumstances (7 and 9) have performed well for both alum and soil. On both cases of coagulants D1 has pH tolerating performance consistency is showed in the pH conditions whereas D2 especially D3 has larger variation of turbidity removal efficiency.

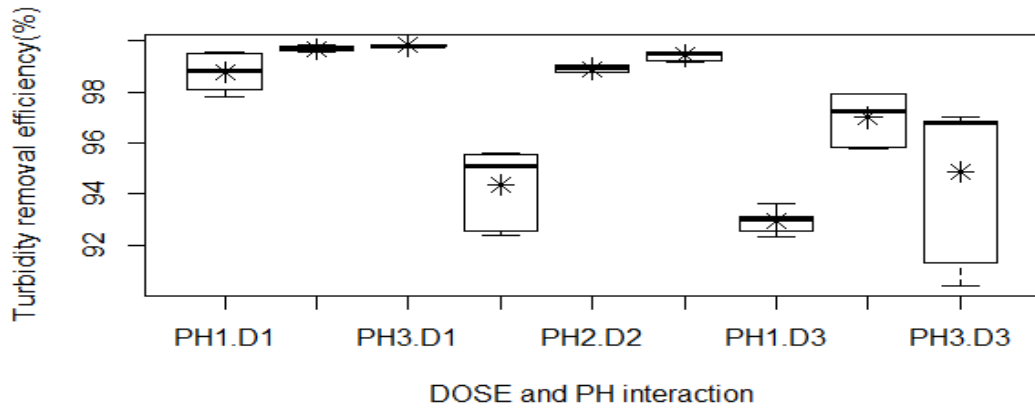


Figure 4.8: the combined effect of pH and Dose on buka soil turbidity removal efficiency

4.5.2. Resultant pH

The figures through 4.9-4.12 try to show the pH consequence of the coagulants on treated waste water. The resulting pH of the treated waste water may find pH adjustment if the used coagulants cause extreme acidity and alkalinity to the effluent waste water in order to release nearly neutral, pH conditioned effluent. As shown on Figure 4.9 the amount of pH change up on application of coagulants from initial pH levels of 5, 7 and 9 was -0.97, +0.72, -0.63 for soil and -0.79, -2.27 and -2.57 for alum respectively. The negative signs on the values of pH change are meant to say decrease in pH while plus is increase. The mean pH after using soil coagulant was 6.07 and it was 5.12 for alum.

Alum coagulant changed the pH of the waste water 1.87 to the negative (i.e. acidic) consuming alkalinity. On the other hand soil changed the pH with 0.77, which is 0.53 to negative and particularly for pH 7 it changed the pH 0.24 to the positive (i.e. basic). Therefore the use of buka soil coagulants showed relative calm to the pH of the treated wastewater to the initial pH value than alum does. From the soil pH 7 and 9 conditions showed better stability.

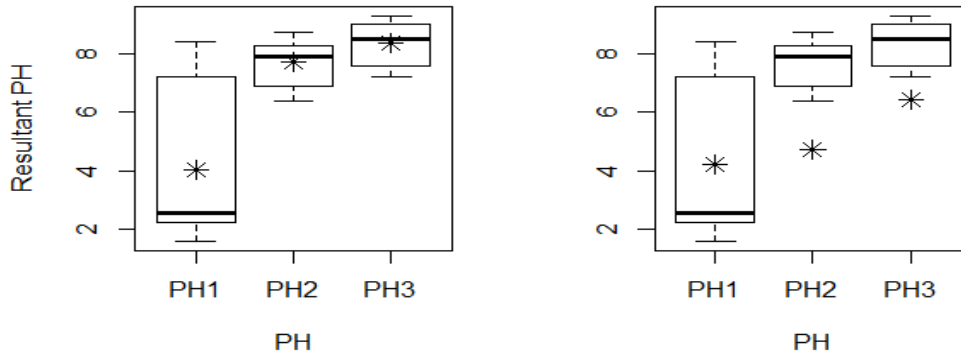


Figure4.9: Alum (right) and soil (left) resultant pH with different initial pH levels

As shown on Figure 4.10 the pH change up on application of coagulants with different dose levels of 50mg/l, 500 mg/l and 1000 mg/l was 8.3,6.3 and 5.4 for soil and 8.04, 4.31 and 3.01 for alum respectively.

From the result it is known that decreasing application of dose end with increasing in the resulting pH. So adding more coagulant per volume of garage waste water may result acidic discharge. However as mentioned earlier in this chapter the minimum dose that is 50 mg/l has performed better, so it is no need to add more coagulant. Both of coagulants reduced the pH however the alum coagulant relatively pulls the pH towards acidic state more than the buka soil and also soil coagulant has closer pH resultant than alum to the neutral pH condition.

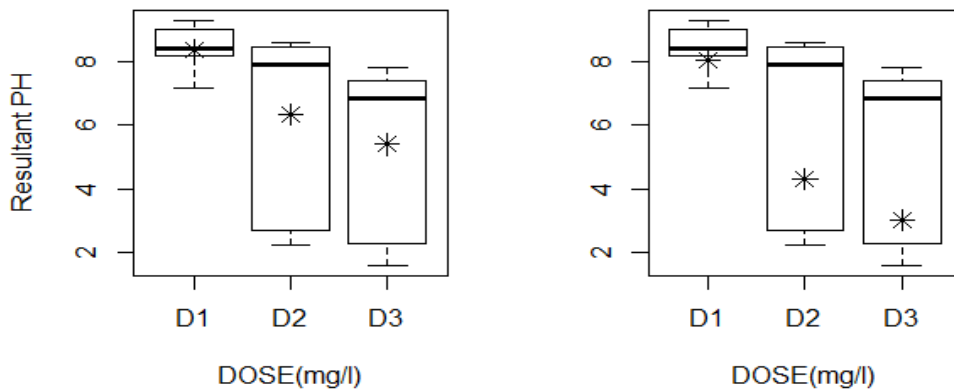


Figure 4.10: Alum (right) and soil resultant pH (left) with different dose levels

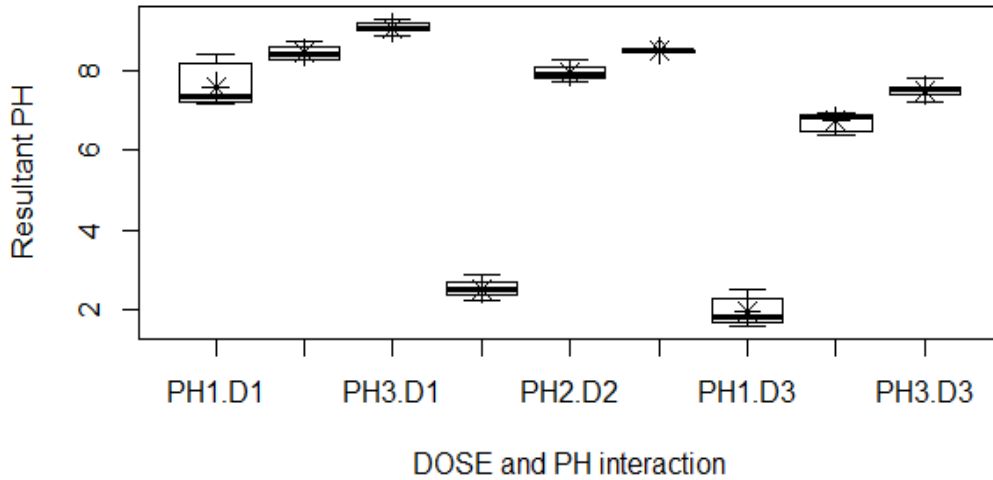


Figure 4.11: the combined effect of pH and Dose on buka soil resultant pH

For the soil by the treatment that combines minimum pH of 5 with dose levels of 50 mg/l, 500 mg/l and 1000 mg/l (D1:pH1, D2:pH1, D3:pH1) the resultant pH of the treated waste water is 7.61, 8.45 and 9.08 respectively. Similarly for medium dose of 500 mg/l of those combinations (D2:pH1, D2:pH2, D2:pH3) resultant pH is 2.54, 7.96 and 8.50 and for maximum dose 100mg/l the analogs combination (D3:pH1, D3:pH2, D3:pH3) resultant pH is 1.95, 6.7 and 7.52 respectively.

On the other hand the resultant pH change from the initial pH of waste water

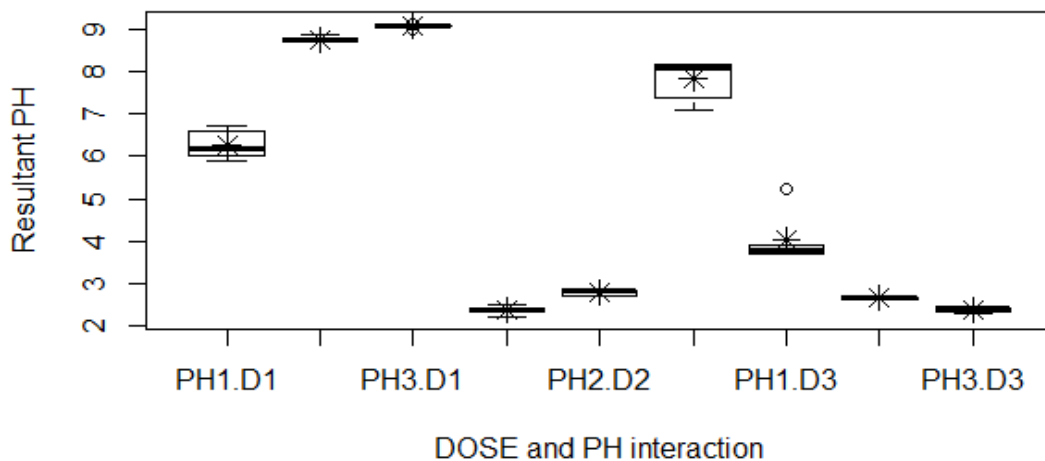


Figure 4.12: the combined effect of pH and Dose on Alum resultant pH

So as it is shown in figure 4.12 that combines minimum dose of 50 mg/l of alum with pH levels of 5, 7 and 9(D1:pH1, D1:pH2, D1:pH3) the resultant pH of the alum coagulant treated waste water is 6.27, 8.77 and 9.09 respectively. Similarly for medium dose of 500 mg/l of those combinations (D2:pH1, D2:pH2, D2:pH3) the resultant pH is 2.35, 2.76 and 7.83 and for maximum dose of 1000mg/l the analogous combination (D3:pH1, D3:pH2, D3:pH3) resultant pH is 4.02, 2.65 and 2.37 respectively.

Resultant pH of alum treated waste water was altered 1.04 towards the basic when using 50 mg/l (D1), 2.68 to the acidic when using 500 mg/l(D2) and 3.99 when using 1000 mg/l(D3). On the contrary resultant pH of soil treated waste water was altered 1.38 towards the basic when using 50 mg/l (D1), the initial pH changes 1.3 which is 0.99 to the acidic and 0.32 to the basic when using 500 mg/l (D2) and 1.59 to acidic state when using 1000 mg/l (D3). The minimum change on pH was looked at D1 combination with pH3 (i.e. 50mg/l and pH 9) which has magnitude of 0.09 for alum and 0.08 for soil. In both cases of coagulants the pH resultant change is greater tending towards acidic when using bigger quantities of coagulants which extends up to 6.63(D3:pH3) and 3.04(D3:pH1) for alum and soil respectively.

Generally the mean value of resultant pH when using soil coagulant is 6.707 and 5.124 using alum. Moreover the soil impacts a pH change of 1.42 and 2.6 pH change from the initial waste water for alum, dominantly to the acidic condition in the case of alum. This infers alum coagulant needs more pH adjustment before discharge by using adjustment chemicals like lime.

4.5.3.E.C comparison

Electrical Conductivity is a measure of how much total salt is present in the water. The more the ions, the higher the conductivity will be (Mosley et al., 2004). it is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water (Tariq et al., 2006). The soil coagulant has comparable effect result on electrical conductivity of garage wastewater treatment.

The electrical conductivity for soil coagulant is minimum at pH 7 that is PH 2 in the box plot shown on figure 4.13 with 4.2 mS/cm conductivity and maximum at pH 5 with 5.71 mS/cm. for alum the minimum and maximum results after its addition to the waste water is 3.9 mS/cm and

5.08 mS/cm at pH 7 and 5 respectively from which we can suggest that both have similar response to E.C considering initial pH of the solution.

For both coagulants pH has minimum value of E.C at 7 pH level. For the soil it was 5.71 and for alum it was 3.91. E.C get maximum when the pH is 5 which is 5.7 mS/cm and 5.09 mS/cm for soil and alum respectively.

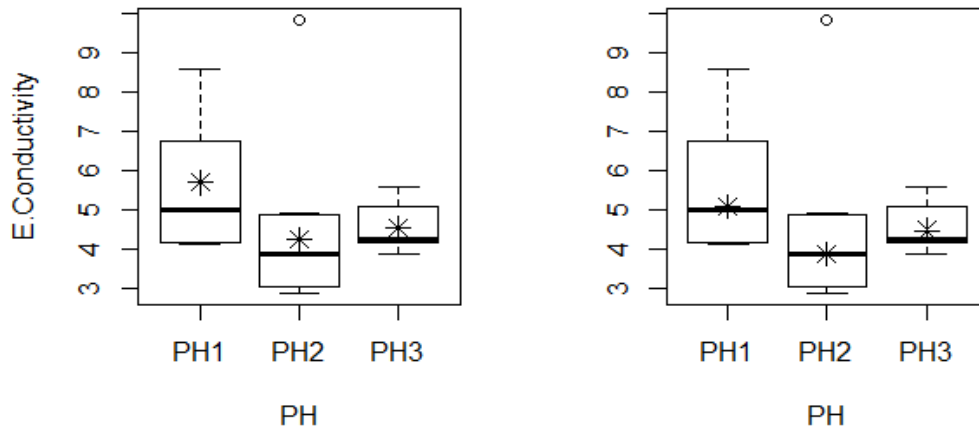


Figure 4.13: Resulting Electrical conductivity in mS/cm of soil (left) and alum (right) with pH levels

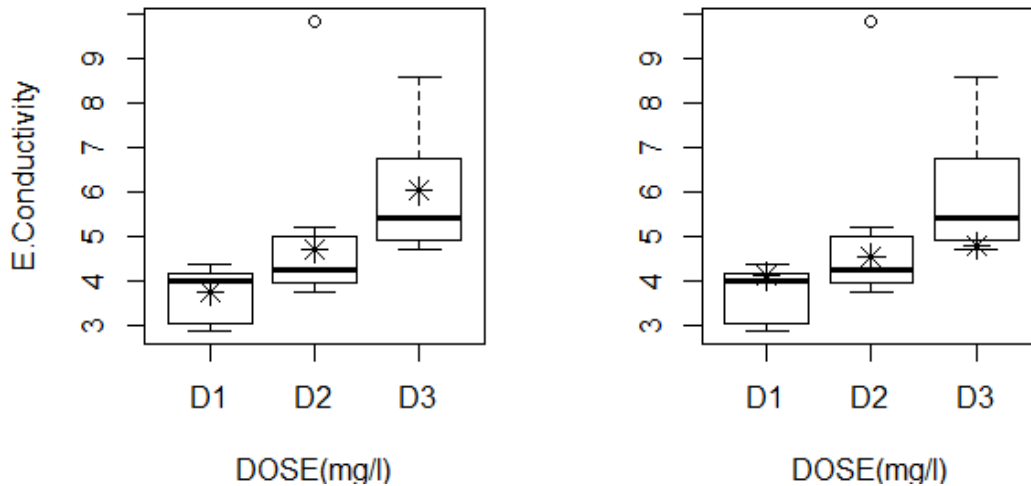
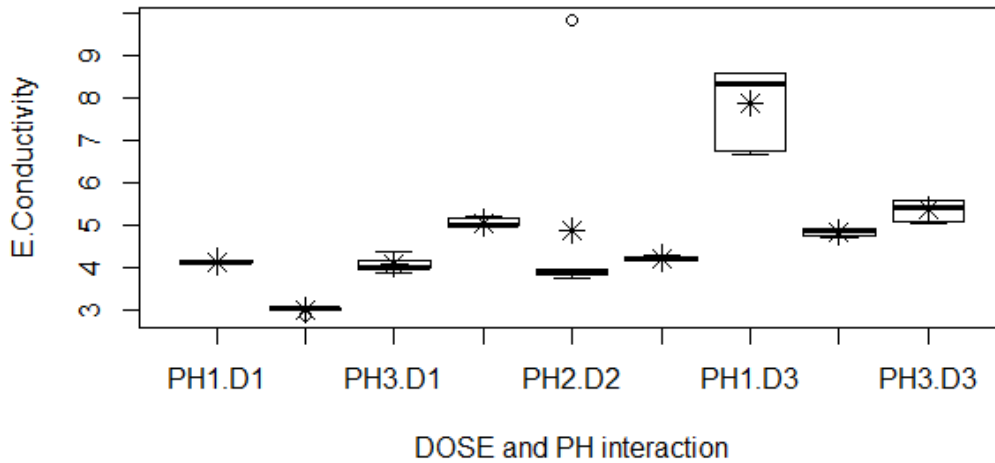


Figure 4.14: Resulting Electrical conductivity in mS/cm of soil (left) and alum (right) with Dose

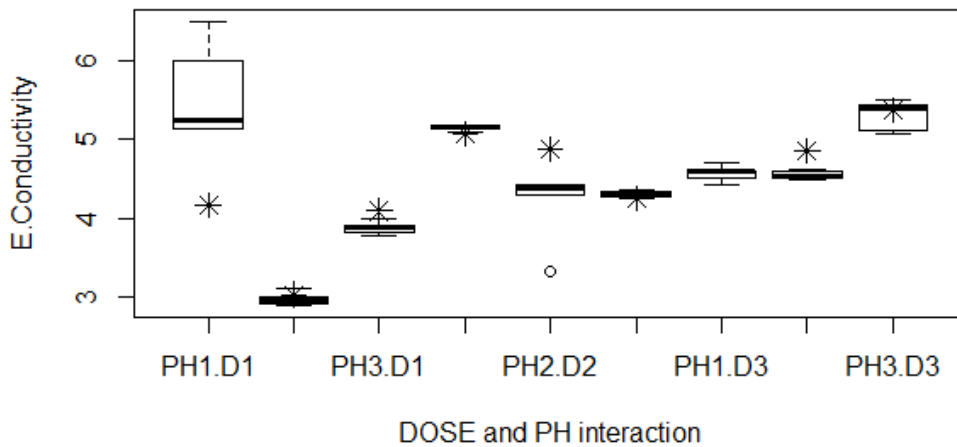
Figure 4.14 shows when the E.C of the soil treated wastewater of compared with alum, considering different dose levels. As it is shown in the figure the E.C increased with increasing dose levels. The mean reading was 3.76 mS/cm, 4.7 mS/cm and 6.04 mS/cm for soil dose order

of 50 mg/l (D1), 500mg/l (D2) and 1000mg/l (D3) correspondingly. And also for alum it was 4.12 mS/cm, 4.55 mS/cm and 4.8mS/cm.

As shown in the figure above the coagulant dose increment results in electrical conductivity increase. However extent of electrical conductivity still does not vindicate threat up on the addition of both the soil and alum coagulants.



(a)



(b)

Figure4.15: Resulting Electrical conductivity in mS/cm of soil (a) and alum (b) with combined pH and Dose

Figure 4.15 represent the E.C of treated waste water considering pH and dose combinations. As it was shown in the figure it was 4.15 mS/cm, 3.03 mS/cm and for 50 mg/l dose of soil D1 and

5.078 mS/cm, 4.88 mS/cm and 4.2 mS/cm for 500 mg/l dose of soil D2, also for 1000 mg /l dose of soil D3 it was 7.89 mS/cm, 4.86 mS/cm and 5.38 mS/cm for every pH 5(pH1),7(pH2) and 9(pH3) respectively. Similarly the mean E.C reading for alum coagulant shown in figure b was found to be 5.54 mS/cm, 2.96 mS/cm and 3.87 mS/cm for 50 mg/l dose of alum D1 and 5.15 mS/cm, 4.20 mS/cm and 4.3 mS/cm for 500mg/l dose of alum D2 likewise for 1000 mg /l dose of alum D3 it was 4.57 mS/cm, 4.55 mS/cm and 5.320000 mS/cm for every pH 5(pH1),7(pH2) and 9(pH3) respectively.

Generally the mean E.C of the treated waste water which was using soil coagulant has mean E.C of 4.85 mS/cm, in the same way the E.C for alum was 4.5 mS/cm. By the treatment which considers dose and pH combination most of the E.C results are lower than the zero and raw waste water which in turn shows minimum dissolved solid would be found after the treatment, as it is by alum coagulant so does to soil coagulant.

5. Conclusion and Recommendation

5.1. Conclusion

To investigate the coagulation potential and compare it with the widely available Alum coagulant a coagulation experiment was done for both Alum and Soil material using a jar test. Wastewater treatment factors influencing the process of coagulation majorly were expected to be type of the coagulant, pH condition of the solution and settling time of wastewater after gentle mixing. According to the analysis, from those factors apart from settling time have showed considerable impact on the process.

Turbidity of the raw waste ater discharge, as it was possible to now from the characterization experiment was high. This high turbidity result might have presented inflated removal result. Nevertheless almost all of the turbidity removal readings of Alum and Soil coagulant are far more efficient than the zero (blank) wastewater treatment mean turbidity reading.

Beside to this the soil coagulant material has performed better when pH condition is neutral and higher and minimum dose levels. Alum coagulant also performed better on those conditions of pH and dose levels. Nevertheless the impact of dose was higher, even on the lower pH minimum dose levels scored good turbidity removal efficient.

Relatively to Alum coagulant the soil coagulant doesn't as such alter the initial wastewater pH. Instead Alum changed the initial pH of the waste water towards acidic pH. So it may not need pH adjustment chemicals after garage waste water treatment while using the soil coagulant that could have increased the expense of the treatment process. In addition, electrical conductivity of the waste significantly decreased from the raw wastewater from which we can deduce the relative healthiness of the treated garage wastewater.

This study has found the soil coagulant has comparable potential even improved in some circumstance with Alum coagulant in its efficiency of turbidity removal from garage wastewater. The soil coagulant has increasing and decreasing patterns with the treatments of selected influencing conditions of dose and pH levels nearly similar to that occurs with alum coagulant provided for comparison.

Both of these coagulants experience pleasing turbidity removal, due to their coagulation activity. Dose has to be one of the factors predetermined in order to perform effective coagulation activity. Even though the remaining amounts (500mg/l and 1000) of coagulant added for treatment throughout the study has satisfactory result, for this paper purpose the study found 50 mg/l is the effective dose level for both of the coagulants.

Generally the soil from Buka is potential coagulant which has promising efficiency to remove garage wastewater turbidity. Moreover the soil coagulant could be effective and economical due to its abundance and inexpensiveness. Plus to that it might be an additional source of income for the local community.

5.2. Recommendation

- Detail soil research have to be done on the driving causes for the buka soil coagulating capacity
- Since coagulation produces sludge, the buke soil coagulation processes needs sludge remediating method
- Toxicity test for the product because the bukae soil is a new coagulant product
- For the sake of simplification, scope and limitation this study was restricted to certain factors which were thought to be crucially influencing the process of coagulation.so broader studies capable of considering multi factors which would have effect in the process have to be researched with more spectrum of levels. Example different levels of initial turbidity of the waste water could be a treatment factor which would have impact on the process.
- Different garages have variety of vehicle services, as result inclusive characterization of garage wastewater is crucial.

6. References

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7. APPENDIXS

Appendix A. Soil characterization

Appendix A.1 Silicate Analysis

Geological Survey of Ethiopia; Geoscience Science Laboratory Center Form G0004
Geochemical Laboratory Complete Silicate Analysis Report Format
FILE ID :- 3068/16pvt Originator ; **Mohammed Berhanu**
Sample type:- Soil Date submitted 03-10-16
Preparation: -200 MESH **Element to be determined Major Oxides & Minor Oxides**
NUMBER OF SAMPLES: 1
Analytical Method: LIBO2 FUSION , HFattack, GRAVIMETERIC and AAS
Analytical Results in PERCENT

FIELD NO	Lab No	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI
MB-01	3068/16	38.92	9.98	4.66	23.94	2.28	0.4	<0.01	<0.01	0.23	1.07	0.45	16.8

Analysts
Getahun Bikila
Tamiru Siraye
Dessie Abebe
H/gebriel Asmare
Yirgalem Abreham

Checked By

Gosa Haile

Approved by

Demisew Lema

QUALITY CONTROL DATE REPORTED

Worede Sahilu 22/3/2016



Appendix A.2 Grain size distribution curve

በውሃ ሥራዎች ዲዛይንና ቁጥጥር
ድርጅት የላብራቶሪ አገልግሎት ገዢ
የሥራሂደት



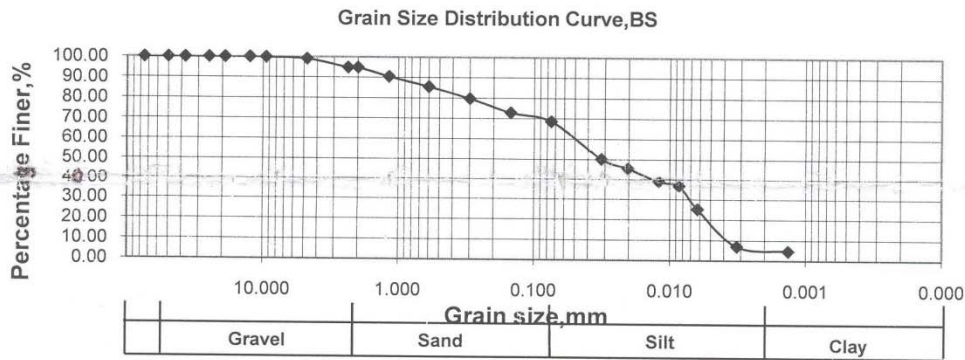
Water Works Design and
Supervision Enterprise Laboratory
service Sub Process

የአፈር ምህንድስና ክፍል

Soil & Material Testing Section

Project : Garage waste water turbidity removal using soil material Coagulant
Client : Ato Mohammed berehanu
Location : Buka Wester Hararega
T.Pit. No. : —
Depth(m) : 1.5

Sample Type : Disturbed
Test Type : Hydrometer +Wet Sieve
Date :20/7/2016
Lab-No : 137/09



Tested by : [Signature]
Processed by : [Signature]



Checked by : [Signature]
Approved by : [Signature]

Appendix A.3 Grain size

Ato Mohammed Berehanu
Summary of Test Result of Soils
Date: 28/07/2016

Parameter	G.W.W.T.R.U.S. M.C Lab No:137/09
Grain Size Analysis	
Clay %	5.70
Silt %	62.82
Sand %	26.38
Gravel %	5.10

Checked by: 

Approved by: 



Appendix A.4 Hydrometer and wet sieve analysis

የኢትዮጵያ ኮንስትራክሽን ዲዛይንና
ሱፐርቪዥን ሥራዎች ኮርፖሬሽን
የውሃና ኢነርጂ ዲዛይንና
ቁጥጥር ሥራዎች ዘርፍ



Ethiopian Construction Design
& Supervision Works
Corporation Water & Energy Design
& Supervision Works Sector
Soil & Material Testing Section

የአፈር ምህንድስና ክፍል

Project : Garage waste water turbidity removal using soil material Coagulant
Client : Ato Mohammed berehanu Sample Type : Disturbed
Location : Buka Wester Hararega Test Type : Hydrometer + Wet Sieve
T.Pit. No. _ Date : 20/7/2016
Depth(m) : 1.5 Lab-No : 137/09

Total mass of sample before wash, g 370.40
Total mass of sample after wash, g 116.60

Sieve Opening(mm)	Mass of Sieve(g)	Mass of sieve + Ret. soil(g)	Mass of Ret. soil (g)	Percentage Retained	Cumulative % Retained	Percentage Passing
75.00	1800.00	1800.00	0.00	0.00	0.00	100.00
50.00	1203.50	1203.50	0.00	0.00	0.00	100.00
37.50	1087.80	1087.80	0.00	0.00	0.00	100.00
25.00	1191.20	1191.20	0.00	0.00	0.00	100.00
19.00	718.50	718.50	0.00	0.00	0.00	100.00
12.50	586.10	586.10	0.00	0.00	0.00	100.00
9.50	598.40	599.10	0.70	0.19	0.19	99.81
4.75	578.10	581.00	2.90	0.78	0.97	99.03
2.36	533.00	548.30	15.30	4.13	5.10	94.90
2.00	551.10	551.10	0.00	0.00	5.10	94.90
1.18	538.90	555.70	16.80	4.54	9.64	90.36
0.60	516.70	535.10	18.40	4.97	14.61	85.39
0.30	488.20	509.50	21.30	5.75	20.36	79.64
0.15	481.90	507.30	25.40	6.86	27.21	72.79
0.08	459.20	475.00	15.80	4.27	31.48	68.52
PAN	425.50	679.30	253.80	68.52	100.00	0.00

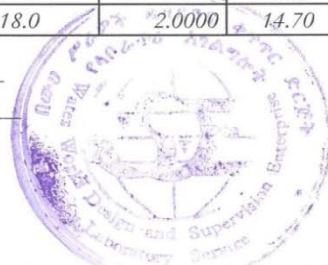
370.40

Hydrometer Analysis

Specific Gravity of soil		2.77	Test Temperature, deg.c					18.0
Elapsed Time (min)	Actual Hydrometer Reading	Temperature deg.c	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Percentage Finer Combined	
2	30.0000	18.0	22.0000	11.40	0.01334	0.0319	50.13	
5	28.0000	18.0	20.0000	11.70	0.01334	0.0204	45.58	
15	25.0000	18.0	17.0000	12.20	0.01334	0.0120	38.74	
30	24.0000	18.0	16.0000	12.40	0.01334	0.0086	36.46	
60	19.0000	18.0	11.0000	13.20	0.01334	0.0063	25.07	
250	11.0000	18.0	3.0000	14.50	0.01334	0.0032	6.84	
1440	10.0000	18.0	2.0000	14.70	0.01334	0.0013	4.56	

Tested by :
Processed by :

Checked by :
Approved by :



Appendix B. turbidity removal data

	Coagulant		geo-material(soil)	
	Variation (%) at pH = 5			
Settling time	0 min	15 min	30 min	60 min
Dose mg/l				
0				
50				
500				
100				

Appendix C. Syntax and significance result on R

Appendix C.1 syntax on R for turbidity removal efficiency analysis

to install libraries

```
library("car")
```

```
library("lattice")
```

```
library("sciplot")
```

#To import data

```
setwd("C:/Users/user/Desktop/tes")
```

```
Turbidity<-read.table("Thesis.csv",sep="," ,header=TRUE )
```

```
attach(Turbidity)
```

```
mean(removal)
```

To diagnose the data

```

View(Turbidity)
str(Turbidity)
#coding
Turbidity$DOSE[Turbidity$DOSE==50]<-"D1"
Turbidity$DOSE[Turbidity$DOSE==500]<-"D2"
Turbidity$DOSE[Turbidity$DOSE==1000]<-"D3"
Turbidity$PH[Turbidity$PH==5]<-"PH1"
Turbidity$PH[Turbidity$PH==7]<-"PH2"
Turbidity$PH[Turbidity$PH==9]<-"PH3"
Turbidity$PH<-as.factor(Turbidity$PH)
Turbidity$DOSE<-as.factor(Turbidity$DOSE)
# adding tur . removal
Turbidity$removal<- ((2300-Turbidity$Turbidity.E)/2300)*100
# code to deffrenciate between alum and soil
soil<- Turbidity[Turbidity$TYPE=="soil",]
Alum<- Turbidity[Turbidity$TYPE=="Alum",]
# separating blocks
Tur.b1<-Turbidity[Turbidity$BLOCK==1,]
Tur.b2<-Turbidity[Turbidity$BLOCK==2,]
View(Tur.b1)
mean(removal)
attach(Tur.b1)
soil.b1<-soil[soil$BLOCK==1,]
soil.b2<-soil[soil$BLOCK==2,]
# preparation for anova (soil)

```

```

mod.1<- lm (log10(Tur.b1$removal)~Tur.b1$DOSE+Tur.b1$PH+Tur.b1$SETTLING.T)
hist(log10(soil$removal))
qqPlot(resid(mod.1))
shapiro.test(resid(mod.1))

# Conclusion: the data is not normal.

# Therefore, we decide to use non parametric test (soil)

kruskal.test(soil$removal,soil$DOSE)
kruskal.test(soil$removal,soil$PH)
kruskal.test(soil$removal,soil$SETTLING.T)

# Therefore, we decide to use non parametric test (Alum)

kruskal.test(Alum$removal,Alum$DOSE)
kruskal.test(Alum$removal,Alum$PH)
kruskal.test(Alum$removal,Alum$SETTLING.T)

# Anova test was implimented for interaction impact of PH and DOSE (soil)

mod<- aov(soil$Turbidity.E~soil$DOSE:soil$PH)
Anova(mod)

mod.1<- aov(soil$Turbidity.E~soil$DOSE)
Anova(mod.1)

mod.2<- aov(soil$Turbidity.E~soil$PH)
Anova(mod.2)

mod.3<- aov(soil$Turbidity.E~as.factor(soil$SETTLING.T))
Anova(mod.3)

mod.4<- aov(soil$Turbidity.E~soil$PH:soil$DOSE)
Anova(mod.4)

```

```
TukeyHSD(mod.1)
```

```
TukeyHSD(mod.2)
```

```
TukeyHSD(mod.3)
```

```
TukeyHSD(mod.4)
```

```
anova(mod.4)
```

```
# Anova test was implimented for interaction impact of PH and DOSE (Alum)
```

```
mod.5<- aov(Alum$Turbidity.E~Alum$DOSE)
```

```
Anova(mod.5)
```

```
mod.6<- aov(Alum$Turbidity.E~Alum$PH)
```

```
Anova(mod.6)
```

```
mod.7<- aov(Alum$Turbidity.E~as.factor(Alum$SETTLING.T))
```

```
Anova(mod.7)
```

```
mod.8<- aov(Alum$Turbidity.E~Alum$PH:Alum$DOSE)
```

```
Anova(mod.8)
```

```
mod.9<- aov(Alum$Turbidity.E~Alum$DOSE:Alum$PH)
```

```
Anova(mod.9)
```

```
TukeyHSD(mod.5)
```

```
TukeyHSD(mod.6)
```

```
TukeyHSD(mod.7)
```

```
TukeyHSD(mod.8)
```

```
TukeyHSD(mod.9)
```

```
anova(mod.4)
```

```
# compare between blockes
```

```
mod.10<- aov(Alum$Turbidity.E~as.factor(Alum$BLOCK))
```

```
mod.11<- aov(soil$Turbidity.E~as.factor(soil$BLOCK))
```

```
Anova(mod.10)
```

```
Anova(mod.11)
```

#graphics for comparison (soil)

```
par(mfrow=c(1,2))
```

```
boxplot(soil$removal~soil$PH,main="Soil",xlab="PH",ylab="Turbidity removal efficiency(%)"
```

```
means<-tapply(soil$removal,soil$PH,mean)
```

```
points(means,pch=8,cex=1.4)
```

```
boxplot(soil$removal~soil$PH,main="Alum",xlab="PH",ylab="")
```

```
means1<-tapply(Alum$removal,Alum$PH,mean)
```

```
points(means1,pch=8,cex=1.4)
```

```
par(mfrow=c(1,2))
```

```
boxplot(soil$removal~soil$DOSE,main="Soil",xlab="DOSE(mg/l)",ylab="Turbidity removal efficiency(%)"
```

```
means<-tapply(soil$removal,soil$DOSE,mean)
```

```
points(means,pch=8,cex=1.4)
```

```
boxplot(soil$removal~soil$DOSE,main="Alum",xlab="DOSE(mg/l)",ylab="")
```

```
means1<-tapply(Alum$removal,Alum$DOSE,mean)
```

```
points(means1,pch=8,cex=1.4)
```

```
par(mfrow=c(1,1))
```

```
boxplot(soil$removal~soil$DOSE:soil$PH,main="Soil",xlab="DOSE and PH interaction",ylab="Turbidity removal efficiency(%)"
```

```
means<-tapply(soil$removal,soil$DOSE:soil$PH,mean)
```

```
points(means,pch=8,cex=1.4)
```

```
boxplot(Alum$removal~Alum$DOSE:Alum$PH,main="Alum",xlab="DOSE and PH interaction",ylab="Turbidity removal efficiency(%)"
```

```
means1<-tapply(soil$removal,soil$DOSE:soil$PH,mean)
```

```
points(means1,pch=8,cex=1.4)
```

```
attach()
```

3 D analysis

```
setwd("C:/Users/user/Desktop/tes")
```

```
Turbidity<-read.table("Thesis.csv",sep="," ,header=TRUE )
```

To diagnose the data

```
setwd("C:/Users/user/Desktop/tes")
```

```
Turbidity<-read.table("Thesis.csv",sep="," ,header=TRUE )
```

```
Turbidity$removal<- ((2300-Turbidity$Turbidity.E)/2300)*100
```

```
soil<- Turbidity[Turbidity$TYPE=="soil",]
```

```
Alum<- Turbidity[Turbidity$TYPE=="Alum",]
```

```
library("plot3D")
```

```
par(mfrow = c(1, 1))
```

```
x<- soil$DOSE
```

```
y<-soil$PH
```

```
z<-soil$removal
```

```
grid<- mesh(x, y,z)
```

```
colvar<-with(grid,x^2+y)
```

```
slice3D (x, y, z,colvar=colvar, theta = 60)
```

```
scatter3D(x, y, z, clab = c("Removal"),theta = 60, cex = 0.9,xlab="Dose",ylab="PH",zlab="Removal")
```

```
scatter3D(x, y, z, colvar = NULL, col = "blue",pch = 19, cex = 0.5)
```

```
x<- soil$DOSE
```

```
y<-soil$PH
```

```
z<-soil$removal
```

```
grid<- mesh(x, y, z)
colvar <- with(grid,soil$removal)
p<-array(soil$removal)
slice3D (x, y, z,colvar=colvar, theta = 60)
isosurf3D(x, y, z, colvar = p, level = 0, col = "red")
slicecont3D(x, y, z,colvar=p, theta = 60)
```

```
grid<- mesh(x, y,z)
colvar<-with(grid,z)
```

Appendix C.2 syntax on R for E.C analysis

#To install libraries

```
library("car")
library("lattice")
library("sciplot")
```

#To import data

```
setwd("C:/Users/user/Desktop/tes")
phvalue<-read.table("Thesisph.csv",sep=";",header=TRUE )
```

To diagnose the data

```
View(phvalue)
str(phvalue)
```

#coding

```
phvalue$DOSE[phvalue$DOSE==50]<-"D1"
phvalue$DOSE[phvalue$DOSE==500]<-"D2"
phvalue$DOSE[phvalue$DOSE==1000]<-"D3"
phvalue$PH[phvalue$PH==5]<-"PH1"
```

```

phvalue$PH[phvalue$PH==7]<-"PH2"
phvalue$PH[phvalue$PH==9]<-"PH3"
phvalue$PH<-as.factor(phvalue$PH)
phvalue$DOSE<-as.factor(phvalue$DOSE)

# adding tur . removal no need for phvalue analysis
Turbidity$removal<- ((2300-Turbidity$Turbidity.E)/2300)*100

#PH.result mean adding
phvalue$PH.mean<-

# code to deffrenciate between alum and soil
soil<- phvalue[phvalue$TYPE=="soil",]
Alum<- phvalue[phvalue$TYPE=="Alum",]

# separating blocks
Phv.b1<-phvalue[phvalue$BLOCK==1,]
Phv.b2<-phvalue[phvalue$BLOCK==2,]

soil.b1<-soil[soil$BLOCK==1,]
soil.b2<-soil[soil$BLOCK==2,]

# preparation for anova (soil)
mod.1<-lm(log10(Phv.b1$E.C)~Phv.b1$DOSE+Phv.b1$PH+Phv.b1$SETTLING.T)
hist(log10(soil$E.C))
qqPlot(resid(mod.1))
shapiro.test(resid(mod.1))

# Conclusion: the data is normal.

# Anova test was implimented for interaction impact of PH and DOSE (soil)
mod<- aov(soil$E.C~soil$DOSE)

```

```

Anova(mod)
mod.1<- aov(soil$E.C~soil$DOSE)
Anova(mod.1)
mod.2<- aov(soil$E.C~soil$PH)
Anova(mod.2)
mod.3<- aov(soil$E.C~as.factor(soil$SETTLING.T))
Anova(mod.3)
mod.4<- aov(soil$E.C~soil$PH:soil$DOSE)
Anova(mod.4)
mod<- aov(soil$E.C~soil$DOSE:soil$PH)
Anova(mod)
TukeyHSD(mod.1)
TukeyHSD(mod.2)
TukeyHSD(mod.3)
TukeyHSD(mod.4)
anova(mod.4)
# Anova test was implimented for interaction impact of PH and DOSE (Alum)
mod.5<- aov(Alum$E.C~Alum$DOSE)
Anova(mod.5)
mod.6<- aov(Alum$E.C~Alum$PH)
Anova(mod.6)
mod.7<- aov(Alum$E.C~as.factor(Alum$SETTLING.T))
Anova(mod.7)
mod.8<- aov(Alum$E.C~Alum$PH:Alum$DOSE)
Anova(mod.8)

```

```

mod.9<- aov(Alum$E.C~Alum$DOSE:Alum$PH)
Anova(mod.9)
TukeyHSD(mod.5)
TukeyHSD(mod.6)
TukeyHSD(mod.7)
TukeyHSD(mod.8)
TukeyHSD(mod.9)

# compare between blockes
mod.10<- aov(Alum$E.C~as.factor(Alum$BLOCK))
Anova(mod.10)
mod.11<- aov(soil$E.C~as.factor(soil$BLOCK))
Anova(mod.11)

#graphics for comparison (soil)
par(mfrow=c(1,2))
boxplot(soil$E.C~soil$PH,main="Soil",xlab="PH",ylab="E.Conductivity")
means<-tapply(soil$E.C,soil$PH,mean)
points(means,pch=8,cex=1.4)
boxplot(soil$E.C~soil$PH,main="Alum",xlab="PH",ylab="")
means1<-tapply(Alum$E.C,Alum$PH,mean)
points(means1,pch=8,cex=1.4)
par(mfrow=c(1,2))
boxplot(soil$E.C~soil$DOSE,main="Soil",xlab="DOSE(mg/l)",ylab="E.Conductivity")
means<-tapply(soil$E.C,soil$DOSE,mean)
points(means,pch=8,cex=1.4)
boxplot(soil$E.C~soil$DOSE,main="Alum",xlab="DOSE(mg/l)",ylab="")

```

```

means1<-tapply(Alum$E.C,Alum$DOSE,mean)
points(means1,pch=8,cex=1.4)
par(mfrow=c(1,1))
boxplot(soil$E.C~soil$DOSE:soil$PH,main="Soil",xlab="DOSE and PH
interaction",ylab="E.Conductivity")
means<-tapply(soil$E.C,soil$DOSE:soil$PH,mean)
points(means,pch=8,cex=1.4)
par(mfrow=c(1,1))
boxplot(Alum$E.C~Alum$DOSE:Alum$PH,main="Alum",xlab="DOSE and PH
interaction",ylab="E.Conductivity")
means1<-tapply(Alum$E.C,Alum$DOSE:Alum$PH,mean)
points(means,pch=8,cex=1.4)

```

Appendix C.3 syntax on R for turbidity Resultant PH analysis

To install libraries

```

library("car")
library("lattice")
library("sciplot")

```

#To import data

```

setwd("C:/Users/user/Desktop/tes")
phvalue<-read.table("Thesisph.csv",sep=";",header=TRUE )

```

To diagnose the data

```

View(phvalue)
str(phvalue)

```

#coding

```

phvalue$DOSE[phvalue$DOSE==50]<-"D1"
phvalue$DOSE[phvalue$DOSE==500]<-"D2"

```

```

phvalue$DOSE[phvalue$DOSE==1000]<-"D3"
phvalue$PH[phvalue$PH==5]<-"PH1"
phvalue$PH[phvalue$PH==7]<-"PH2"
phvalue$PH[phvalue$PH==9]<-"PH3"
phvalue$PH<-as.factor(phvalue$PH)
phvalue$DOSE<-as.factor(phvalue$DOSE)
# code to deffrenciate between alum and soil
soil<- phvalue[phvalue$TYPE=="soil",]
Alum<- phvalue[phvalue$TYPE=="Alum",]

# separating blocks
Phv.b1<-phvalue[phvalue$BLOCK==1,]
Phv.b2<-phvalue[phvalue$BLOCK==2,]
soil.b1<-soil[soil$BLOCK==1,]
soil.b2<-soil[soil$BLOCK==2,]

# preparation for anova (soil)
mod.1<-lm(log10(Phv.b1$PH.result)~Phv.b1$DOSE+Phv.b1$PH+Phv.b1$SETTLING.T)
hist(log10(soil$PH.result))
qqPlot(resid(mod.1))
shapiro.test(resid(mod.1))

# Conclusion: unlike turbidity analysis the data is normal

# Anova test was implimented for interaction impact of PH and DOSE (soil)
mod<- aov(soil$PH.result~soil$DOSE)
Anova(mod)
mod.1<- aov(soil$PH.result~soil$DOSE)

```

```

Anova(mod.1)
mod.2<- aov(soil$PH.result~soil$PH)
Anova(mod.2)
mod.3<- aov(soil$PH.result~as.factor(soil$SETTLING.T))
Anova(mod.3)
mod.4<- aov(soil$PH.result~soil$PH:soil$DOSE)
Anova(mod.4)
mod<- aov(soil$PH.result~soil$DOSE:soil$PH)
Anova(mod)
TukeyHSD(mod.1)
TukeyHSD(mod.2)
TukeyHSD(mod.3)
TukeyHSD(mod.4)
anova(mod.4)
# Anova test was implimented for interaction impact of PH and DOSE (Alum)
mod.5<- aov(Alum$PH.result~Alum$DOSE)
Anova(mod.5)
mod.6<- aov(Alum$PH.result~Alum$PH)
Anova(mod.6)
mod.7<- aov(Alum$PH.result~as.factor(Alum$SETTLING.T))
Anova(mod.7)
mod.8<- aov(Alum$PH.result~Alum$PH:Alum$DOSE)
Anova(mod.8)
mod.9<- aov(Alum$PH.result~Alum$DOSE:Alum$PH)
Anova(mod.9)

```

```
TukeyHSD(mod.5)
```

```
TukeyHSD(mod.6)
```

```
TukeyHSD(mod.7)
```

```
TukeyHSD(mod.8)
```

```
TukeyHSD(mod.9)
```

```
# compare between blockes
```

```
mod.10<- aov(Alum$PH.result~as.factor(Alum$BLOCK))
```

```
Anova(mod.10)
```

```
mod.11<- aov(soil$PH.result~as.factor(soil$BLOCK))
```

```
Anova(mod.11)
```

```
#graphics for comparison (soil)
```

```
par(mfrow=c(1,2))
```

```
boxplot(soil$PH.result~soil$PH,main="Soil",xlab="PH",ylab="Resultant PH")
```

```
means<-tapply(soil$PH.result,soil$PH,mean)
```

```
points(means,pch=8,cex=1.4)
```

```
boxplot(soil$PH.result~soil$PH,main="Alum",xlab="PH",ylab="")
```

```
means1<-tapply(Alum$PH.result,Alum$PH,mean)
```

```
points(means1,pch=8,cex=1.4)
```

```
par(mfrow=c(1,2))
```

```
boxplot(soil$PH.result~soil$DOSE,main="Soil",xlab="DOSE(mg/l)",ylab="Resultant PH")
```

```
means<-tapply(soil$PH.result,soil$DOSE,mean)
```

```
points(means,pch=8,cex=1.4)
```

```
boxplot(soil$PH.result~soil$DOSE,main="Alum",xlab="DOSE(mg/l)",ylab="")
```

```
means1<-tapply(Alum$PH.result,Alum$DOSE,mean)
```

```
points(means1,pch=8,cex=1.4)
```

```

par(mfrow=c(1,1))

boxplot(soil$PH.result~soil$DOSE:soil$PH,main="Soil",xlab="DOSE      and      PH
interaction",ylab="Resultant PH")

means<-tapply(soil$PH.result,soil$DOSE:soil$PH,mean)

points(means,pch=8,cex=1.4)

par(mfrow=c(1,1))

boxplot(Alum$PH.result~Alum$DOSE:Alum$PH,main="Alum",xlab="DOSE      and      PH
interaction",ylab="Resultant PH")

means<-tapply(Alum$PH.result,Alum$DOSE:Alum$PH,mean)

points(means,pch=8,cex=1.4)

```

Appendix C.4 kruskal test and ANOVA results on R

```

> kruskal.test(soil$removal,soil$DOSE)

      Kruskal-Wallis rank sum test

data:  soil$removal and soil$DOSE
Kruskal-Wallis chi-squared = 31.123, df = 2, p-value = 1.745e-07

> kruskal.test(soil$removal,soil$PH)

      Kruskal-Wallis rank sum test

data:  soil$removal and soil$PH
Kruskal-Wallis chi-squared = 14.516, df = 2, p-value = 0.0007046

> kruskal.test(soil$removal,soil$SETTLING.T)

      Kruskal-Wallis rank sum test

data:  soil$removal and soil$SETTLING.T
Kruskal-Wallis chi-squared = 2.6759, df = 2, p-value = 0.2624

```

Appendix C.5 Statistical analysis using ANOVA for the experimental results Turbidity Removal

```

Anova(mod.2)
Anova Table (Type II tests)

```

Response: soil\$Turbidity.E
Sum Sq Df F value Pr(>F)
soil\$DOSE 97570 2 21.824 1.42e-07 ***
Residuals 114006 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.2)
Anova Table (Type II tests)

Response: soil\$Turbidity.E
Sum Sq Df F value Pr(>F)
soil\$PH 55794 2 9.133 0.0004072 ***
Residuals 155782 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.3)
Anova Table (Type II tests)

Response: soil\$Turbidity.E
Sum Sq Df F value Pr(>F)
as.factor(soil\$SETTLING.T) 14476 2 1.8728 0.1641
Residuals 197101 51

Anova(mod.4)
Anova Table (Type II tests)

Response: soil\$Turbidity.E
Sum Sq Df F value Pr(>F)
soil\$PH:soil\$DOSE 175183 8 27.077 8.998e-15 ***
Residuals 36393 45

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.5)
Anova Table (Type II tests)

Response: Alum\$Turbidity.E
Sum Sq Df F value Pr(>F)
Alum\$DOSE 46743 2 7.5487 0.001344 **
Residuals 157899 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.6)
Anova Table (Type II tests)

Response: Alum\$Turbidity.E
Sum Sq Df F value Pr(>F)
Alum\$PH 67323 2 12.502 3.818e-05 ***
Residuals 137319 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.7)
Anova Table (Type II tests)

Response: Alum\$Turbidity.E
Sum Sq Df F value Pr(>F)
as.factor(Alum\$SETTLING.T) 4243 2 0.5399 0.5861
Residuals 200399 51

Anova(mod.8)
Anova Table (Type II tests)

Response: Alum\$Turbidity.E
Sum Sq Df F value Pr(>F)
Alum\$PH:Alum\$DOSE 188692 8 66.547 < 2.2e-16 ***
Residuals 15950 45

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.9)
Anova Table (Type II tests)

Response: Alum\$Turbidity.E
Sum Sq Df F value Pr(>F)
Alum\$DOSE:Alum\$PH 188692 8 66.547 < 2.2e-16 ***
Residuals 15950 45

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Resultant PH

Anova(mod.1)
Anova Table (Type II tests)

Response: soil\$PH.result
Sum Sq Df F value Pr(>F)
soil\$DOSE 83.661 2 8.5502 0.0006277 ***

Residuals 249.510 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.2)

Anova Table (Type II tests)

Response: soil\$PH.result

	Sum Sq	Df	F value	Pr(>F)
soil\$PH	196.71	2	36.759	1.302e-10 ***
Residuals	136.46	51		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.3)

Anova Table (Type II tests)

Response: soil\$PH.result

	Sum Sq	Df	F value	Pr(>F)
as.factor(soil\$SETTLING.T)	0.35	2	0.027	0.9734
Residuals	332.82	51		

Anova(mod.4)

Anova Table (Type II tests)

Response: soil\$PH.result

	Sum Sq	Df	F value	Pr(>F)
soil\$PH:soil\$DOSE	329.69	8	532.71	< 2.2e-16 ***
Residuals	3.48	45		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.5)

Anova Table (Type II tests)

Response: Alum\$PH.result

	Sum Sq	Df	F value	Pr(>F)
Alum\$DOSE	245.51	2	40.707	2.715e-11 ***
Residuals	153.80	51		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.6)

Anova Table (Type II tests)

Response: Alum\$PH.result

	Sum Sq	Df	F value	Pr(>F)
Alum\$PH	48.62	2	3.5351	0.0365 *
Residuals	350.69	51		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.7)

Anova Table (Type II tests)

Response: Alum\$PH.result

	Sum Sq	Df	F value	Pr(>F)
as.factor(Alum\$SETTLING.T)	0.17	2	0.0107	0.9893
Residuals	399.14	51		

Anova(mod.8)

Anova Table (Type II tests)

Response: Alum\$PH.result

	Sum Sq	Df	F value	Pr(>F)
Alum\$PH:Alum\$DOSE	395.66	8	609.06	< 2.2e-16 ***
Residuals	3.65	45		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.9)

Anova Table (Type II tests)

Response: Alum\$PH.result

	Sum Sq	Df	F value	Pr(>F)
Alum\$DOSE:Alum\$PH	395.66	8	609.06	< 2.2e-16 ***
Residuals	3.65	45		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Electrical Conductivity

Anova(mod.1)

Anova Table (Type II tests)

Response: soil\$E.C

	Sum Sq	Df	F value	Pr(>F)
soil\$DOSE	47.254	2	16.513	2.955e-06 ***
Residuals	72.973	51		

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.2)
Anova Table (Type II tests)

Response: soil\$E.C
Sum Sq Df F value Pr(>F)
soil\$PH 21.054 2 5.4137 0.007378 **
Residuals 99.172 51

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.3)
Anova Table (Type II tests)

Response: soil\$E.C
Sum Sq Df F value Pr(>F)
as.factor(soil\$SETTLING.T) 3.149 2 0.6859 0.5082
Residuals 117.077 51

Anova(mod.4)
Anova Table (Type II tests)

Response: soil\$E.C
Sum Sq Df F value Pr(>F)
soil\$PH:soil\$DOSE 85.863 8 14.055 5.425e-10 ***
Residuals 34.363 45

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.5)
Anova Table (Type II tests)

Response: Alum\$E.C
Sum Sq Df F value Pr(>F)
Alum\$DOSE 4.3025 2 3.7895 0.02922 *
Residuals 28.9520 51

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.6)
Anova Table (Type II tests)

Response: Alum\$E.C
Sum Sq Df F value Pr(>F)
Alum\$PH 12.555 2 15.467 5.619e-06 ***

Residuals 20.699 51

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.7)

Anova Table (Type II tests)

Response: Alum\$E.C

	Sum Sq	Df	F value	Pr(>F)
as.factor(Alum\$SETTLING.T)	0.185	2	0.1428	0.8673
Residuals	33.069	51		

Anova(mod.8)

Anova Table (Type II tests)

Response: Alum\$E.C

	Sum Sq	Df	F value	Pr(>F)
Alum\$PH:Alum\$DOSE	30.3835	8	59.528	< 2.2e-16 ***
Residuals	2.8711	45		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Anova(mod.9)

Anova Table (Type II tests)

Response: Alum\$E.C

	Sum Sq	Df	F value	Pr(>F)
Alum\$DOSE:Alum\$PH	30.3835	8	59.528	< 2.2e-16 ***
Residuals	2.8711	45		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

DECLARATION

I declare that this thesis entitled “ Garage Waste Water Turbidity Removal Using Low Cost Soil Coagulant” is my own, original work done under the supervision of Ato Teshome Worku at Addis Ababa Institute of Technology in 2015/16 academic year for partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering and that I have not previously submitted it entirely or in part for obtaining any qualification at any other university and all references used in this work have been properly sited and accredited.

Mohammed Berhanu

Signature

Date