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SCHOOL OF GRADUATE STUDIES

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SCHOOL OF CIVIL AND ENVIROMENTAL ENGINEERING

ENVIROMENTAL ENGINEERING CHAIR

REMOVAL OF IRON FROM GROUNDWATER BY FILTRATION USING NATURAL ZEOLITES. THE CASE OF ASSOSA TOWN PUBLIC WATER SUPPLY, BENISHANGUL GUMUZ REGIONAL STATE, WESTERN ETHIOPIA

BY

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REMOVAL OF IRON FROM GROUND WATER USING FILTRATION BY NATURAL ZEOLITES. THE CASE OF ASSOSA TOWN POTABLE WATER SUPPLY, BENISHANGUL GUMUZ, WESTERN ETHIOPIA

BY

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JIMMA, ETHIOPIA

Declaration

I, the undersigned, declare that this research paper is my original work and has not been presented for a degree in any other university and that all sources of materials used for the research thesis has been duly acknowledged.

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Abstract

Groundwater is the only Water Supply for Asossa Town. Small amounts of iron are often found in water supply because of the large amount of iron present in the soil and corrosive water will pick up iron from pipes. The problems caused by the presence of large concentration of iron impart a metallic taste to the water, Industrial products such as paper, textiles, or leather may be discolored .Ground water samples collected from Asossa Town deep well relatively with higher iron (Fe) concentration than the permissible limits as specified in WHO. The naturally available environmentally and economically acceptable zeolites were obtained from the surrounding area of the Town. It was a powerful Adsorbent for the removal of iron. The aim of study was to design the most efficient, easily available, economical and environmentally acceptable iron removal technology from ground water using natural zeolites. The study was carried on Laboratory-scale columns experiment by sand filters with variable depths of 10, 15, 20, 25, 30 cm and three graded types of sand (course, fine and graded) were used. The course sand (E=1.0 mm, U=1.117, depth of sand =30cm, filtration rate 2.4 $m^3/m^2/hr$.) was the best type of filter media. Iron concentration measured in groundwater was 5.15 mg/l before filtration and decreased to concentration of 0.85 mg/l following filtration. Hence, iron removal efficiency of 83.49 % with a correlation coefficient of $R^2 >0.98$ was obtained during aeration process. The result compared with chlorination and aeration depending on sand filtration, chlorination was better removal efficiency in natural zeolites than aeration filtration process. According to Ethiopian standard water quality procedure and WHO guideline states that Fe concentration <0.3 mg/l is permissible level for drinking water. In this study also chlorination treated water initial concentration 6.20 mg/l after sand filtration 0 mg/l iron concentration ,then the removal efficiency of course sand was 100% , its correlation coefficient,$R^2 >0.97$. Advantage of such treatment were simplicity, easily available natural zeolites, low cost design at house hold and a community level, and without the need of chemical addition. Finally, periodic washing for sand filter or replacement of sand by other sand was needed in order to get sufficient flow rate.

Key words*: Asossa Town, filter materials, groundwater, Natural Zeolites, potable water, removal of iron*

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Acronyms

AO	Aesthetic Objective
BGREB	Benishangul Gumuz Regional Educational Bureau
BGRS	Benishangul Gumuz Regional State
BSFZ	Bio-sand filtration zeolites
CSA	Central Statistical Agency
D_{10}	Grain size 10% by weight passing (mm).
D_{60}	Grain size 60% by weight passing (mm).
DBPs	Disinfection by Products
E	Effective size
EPA	Environmental Protection Agency
ERA	Ethiopian Road Authority
EWQS	Ethiopian Water Quality Standard
FAO	Food Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
Fe	Chemical symbol of Iron
HH	House Hold
IOB	Iron oxidizing bacteria
JiT	Jimma Institute of Technology.
$KMnO_4$	Potassium permanganate
MCL	Maximum contaminant level
mg/d	milligram per day
mg/l	milligram per liter

MH	Minister of Health
Mn	Chemical symbol of Manganese
NTU	Nephelometric Turbidity Unit
pH	Power of Hydrogen
PPM	Part per million
QA	Quality Assurance
R^2	Correlation of Coefficient
RSF	Rapid sand filter
SD	Standard Deviation
TCU	True Color Unit
THMs	Trihalomethanes
U	Uniformity Coefficient
μs/cm	microseimen per centimeter
WHO	World Health Organization

CHAPTER ONE

1. Introduction

1.1 Background of the Study

Groundwater is generally considered as the best source for potable water as it is well protected from contamination. Wells are often used to draw groundwater. Some groundwater can be free of turbidity and microorganisms because the water has been naturally filtered as it percolates through the soil. Other groundwater sources can be influenced by surface conditions and porous soils. The bacteriological and chemical quality of this source can fluctuate with nature of human activities, surface condition of porous soil. Turbidity of groundwater is caused by very finely divided particles held in suspension. This gives the water a cloudy appearance. The color of groundwater can be caused by dissolved and colloidal particles, a result of organic or inorganic material in the water *(*Architects & Engineer*, 2003).*

Iron and manganese are common in groundwater supplies used by many small water systems. Exceeding the suggested maximum contaminant levels (MCL) usually results in colored water, laundry, and plumbing fixtures. This, in turn, results in consumer complaints and a general dissatisfaction with the water utility (Tech brief, 1998)

According to Ahmed *et al*., (2010) state in their report that the pollution of ground water can be grouped into three main categories, namely: - organic compounds, microorganisms and inorganic pollutants. The pollution of ground water with metals of inorganic metals is a great environmental health concern because of these metals are not bio-degradable. This means that it is not discomposed by natural process and will thus remain in the water and pose a health risk to those who use the water.

Zeolites are excellent minerals to use in cation exchange applications because their alumino-silicate configuration results in an overall negative charge which is balanced by loosely held cations. In addition, zeolites can function as ionic sieves capable of selectively absorbing certain ions, depending on the size of the cavities forming the porous structure and on the size of the ions entering the zeolite structure. Other properties of importance

include a high degree of hydration/dehydration, low density, good crystal stability when dehydrated, and their ability to adsorb ions in gaseous form (Christian *et al*., 2010). Common zeolite applications include their use as pet litter, oil/chemical and odor absorbents, wastewater treatment, and their use as slow release fertilizers (Natural Zeolite, 2006).

Groundwater is the most common source of drinking water in Benishangul Gumuz Regional State (more than 90% of the population is supplied with drinking water from ground resources). First, iron is rapidly in the presence of oxygen oxidized at neutral pH followed by precipitation and filtration. For many years, research has been focused on the biological removal of manganese and iron, due to the associated energy and chemical savings *(Burger, 2008; Mouchet, 1992; Tekerlekopoulou et al., 2008).*

The start-up of new filters is often based on "rules of thumb" procedures. New filters are often inoculated with sand from existing filters or backwash sludge, but this result in unpredictable start-up of filter performances. To obtain a well-functioning filter with biological manganese or iron removal, it is essential to ensure that the required microorganisms are present and that both the physical and the nutritional requirements of those organisms are satisfied. However, the knowledge on the microbiology and processes in rapid sand filters is limited, especially on which parameters that affect the biological processes and the interaction between them. Some studies have indicated direct competition between iron and ammonium removal when oxygen is limited, and both processes may have a negative effect on the manganese removal. The removal of dissolved manganese and iron is important. If manganese and iron enter the distribution system, the water will become colored and have a metallic taste, and it may cause problems in the distribution network due to precipitation and corrosion *(*Tekerlekopoulou *et al.,* 2008).

The aim of this study was to test the removal efficiency of iron by using natural zeolites and to investigate the effect of interactions between the chlorine and effective sand size of iron removal processes.

1.2 Statement of the problem

According to Linde *et al., (*2005) state that iron which naturally occurs in ground water is most often removed aesthetic reasons since the substances may cause problems such as water turbidity, precipitation in the distribution pipes, discolored laundry and alter taste and odor of the water.

Small amounts of iron are often found in water supply because of the large amount of iron present in the soil and because corrosive water will pick up iron from pipes. Laundering with water containing excessive iron may become stained a brownish color. The presence of significant amounts of metals in a water supply can create several problems for the consumers. The problems caused by the presence of large concentration of iron impart a metallic taste to the water, Industrial products such as paper, textiles, or leather may be discolored, Household fixtures such as porcelain basins, bathtubs, glassware, and dishes are stained, Iron precipitates clog pipes and promote the growth of gelatinous masses of iron oxidizing bacteria. These bacteria slough off and create "red water" thus, Iron bacteria may cause odor and taste problems, particularly, when the flow in pipes is low due to the formation of color and taste, consumers in rural areas may go to other unprotected sources. The rusty or brown stains on plumbing fixtures, fabrics, dishes, and utensils cannot be removed by soaps or detergents. Bleaches and alkaline builders (often sodium phosphate) can make the stains worse. In addition the taste of beverages, such as tea and coffee, may also be affected by iron (Metcalf, 1998).

The metal is quite harmful to aquatic life, as evidenced by laboratory studies, but in nature the degree of toxicity may be lessened by the interaction of the iron with other constituents of a water. Once the metal is converted to an insoluble form then the iron deposits will interfere with fish food and spawning (MH, 2011).

In Assosa Town the groundwater iron concentration was treated by using environmental safe natural zeolites for reduced or minimized the aesthetical and chronic effect for a long time ago there is no project or experimental laboratory investigation were not done. This study has been conducted to inhibit the problem of excess concentration of Iron from the Town.

1.3 Objectives of the study

I. General Objective

❖ The general objective of this study is to design the most efficient iron removal technology from groundwater supply of Assosa Town using natural zeolites.

II. Specific objectives. The specific objectives of the study were to:

a. Investigate the effect of pH, temperature, Nitrate, manganese, conductivity, color and turbidity on the removal of iron using natural zeolites
b. Analyze the effect of chlorination on the removal of iron using natural zeolites
c. Determine iron removal efficiency of natural zeolites

1.4 Significance of study

Groundwater has been treated using chlorination for a long time. Even when clear water meets the drinking water standard, the water quality in the distribution system can deteriorate due to settling of iron (hydroxide) particles or post-treatment flocculation of dissolved iron. Concentration of Iron was not sufficiently minimize below the permissible level .Therefore, it is important to remove dissolved and particulate iron to a large extent. This study aims was experimental work for improving removal of dissolved and particulate iron from potable water. And also reduce customer compliant due to taste, rust, and staining clothing and other house hold materials. Oxidation followed by filtration is a relatively simple process and also low cost, and easily available in the environment. Aeration followed by sand filtration was used for the removal of iron from ground water. The source of water must be monitored to determine proper oxidant dosage, and the treated water should be monitored to determine if the oxidation process will be success. Finally, it was reduced chemical cost.

1.5 Research questions

1. What are the factors that influence the removal efficiency of iron?

2. How to influence the effect of chlorination on the removal of iron from groundwater?

3. What are the zeolites removal efficiency of iron from the public water supply?

CHAPTER TWO

2. Literature Review

2.1 Nature and Occurrence of Iron

Iron is the second most abundant metal in the earth's crust, of which it accounts for about 5%. Elemental iron is rarely found in nature, as the iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen and sulfur containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron exists in several oxidation states -2, 0, +1, +2, +3, +4, and +6. However, the oxidation states of +2 and +3 are the most common forms in drinking water supplies. Iron in the +2 oxidation state (ferrous iron) or iron (II) is the soluble form while iron in the +3 oxidation state (ferric iron) is the insoluble form. Iron (III) is the most common form of the metal because of its stability. Iron (II) is readily oxidized in the presence of oxygen or any other oxidant to form iron (III) (Benjamin, 2002).

In drinking-water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust colored silt. Anaerobic groundwater may contain iron(II) at concentrations of up to several milligrams per liter without discoloration or turbidity in the water when directly pumped from a well, although turbidity and color may develop in piped systems at iron levels above 0.05-0.1 mg/l. Staining of laundry and plumbing may occur at concentrations above 0.3 mg/l. Iron also promotes undesirable bacterial growth ("iron oxidizing bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping*(Ottawa, 1990)*.

2.2 Iron in groundwater

Groundwater quality comprises the physical, chemical, and biological qualities of ground water. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Since most ground water is colorless, odorless, and without specific tastes are typically most concerned with its chemical and biological qualities. Although spring water or groundwater products are often sold as "pure," their water quality is different from that of pure water. Naturally, ground water contains mineral ions. These ions

slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer (Thomas, 2003).

The presence of iron in groundwater is generally attributed to the dissolution of iron bearing rocks and minerals, chiefly oxides (hematite, magnetite, limonite), sulphides (pyrite), carbonates (siderite) and silicates (pyroxene, amphiboles, biotites and olivines) under anaerobic conditions in the presence of reducing agents like organic matter and hydrogen sulphide .Iron usually exists in two oxidation states, reduced soluble divalent ferrous (Fe^{2+} or iron(II)) and oxidized trivalent ferric (Fe^{3+} or iron(III)). Iron may be present in groundwater in the five forms namely: dissolved as iron, inorganic complexes, organic complexes, colloidal, and suspended *(*Hamoda *et al.,* 2004*)*.

In drinking-water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust-colored silt. Anaerobic groundwater may contain iron (II) at concentrations of up to several milligrams per liter without discoloration or turbidity in the water when directly pumped from a well, although turbidity and color may develop in piped systems at iron levels above 0.05–0.1 mg/l. Staining of laundry and plumbing may occur at concentrations above 0.3 mg/l (Department of National Health and Welfare in Canada, 1990).

The median iron concentration in rivers has been reported to be 0.7 mg/l. In anaerobic groundwater where iron is in the form of iron (II), concentrations will usually be 0.5–10 mg/l, but concentrations up to 50 mg/l can sometimes be found .Concentrations of iron in drinking-water are normally less than 0.3 mg/l but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution (Baltimore, 1979). Occurrence of iron in ground water can threat human health and even lead to chronic diseases. Further the occurrence of iron in ground water which eventually become drinking water is a serious environmental issue and its removal of the two substances is essential *(*Ahmed *et al.,*2010*).*

Filtration is a natural process for the removal of particulate materials in water including clays and silts, micro-organisms and precipitates of organics and metal ions from water. It is a process in which the suspended particles are removed from a flow by passing it through a porous media *(*Tebutt, 1998; Iritani*, 2003; Hamoda *et al.,* 2004). The removal of particle will depend on the particle size and the porosity of the medium *(*Classen, 1998*).* The latter is a factor of filter effective size and uniformity coefficient. According to Punmia *et al., (*2002*),* the effective size and uniformity coefficient for rapid sand filters are 0.35 - 1.5mm and 1.2-1.7 respectively

2.3 Effect of Iron on Water Quality

Purified water is essential for a healthy life and everyone should have access to it. Drinking water conditions have great impacts on people's everyday life, especially in the rural and remote areas where access to safe drinking water is very crucial. Surface water often is the only source, thus water contaminations are difficult to avoid due to rigorous and reckless use of surface water. Unsafe drinking water may result in fatal diseases. Statistics shows that these diseases resulted in ninety percent of all deaths of children under five years old in developing countries, due to low immunization of children to infections (Priyadarsini, 2013).Adverse effects of higher Fe concentrations in drinking water can be summarized as follows:

1. Iron (II) is oxidized to higher forms in a water distribution system and this results in the formation of hydroxide suspensions causing undesirable turbidity and colored water,

2. The presence of iron oxidizing bacteria in water supply system causes change in water quality (smell) and bacterial growth in pipes,

3. In the case of the occurrence of iron (II) ions at the consumer's point, iron is oxidized and precipitated under suitable conditions (e.g. in washing machines, boilers).

Thus, higher concentrations of iron in water cause, failure of water supply systems operation, water quality deterioration and, in water with slightly higher concentrations of oxygen, it forms undesirable incrustations that result in the reduction of pipe flow cross-section (Barlokova and Ilavsky, 2010).

Table 1: Comparison of Slow sand filter and Rapid sand filter in water quality process

Source: http://www.comparision slow sand filter and rapid sand filter September, 2016.

Item	Slow sand filter	Rapid sand filter
Pre treatment	Not required except plain sedimentation	Coagulation, Flocculation and Sedimentation
Base materials	Gravel base of 30 to 75 cm depth with 3 to 65 mm size graded gravel	Gravel base of 45 to 50 cm depth with gravel size varies from 3 to 50 mm in 4 or 5 layers
Filter sand • Effective size • Uniformity coefficient • Thickness of sand deph	• 0.25 to 0.35 mm • 3 to 5.0 • 80 to 100 cm	• 0.45 to 0.70 • 1.2 to 1.7 • 60 to 75 cm
Under drainage	Open jointed pipes of drains covered with perforated blocks	Perforated pipe laterals discharging into main header
Size of each unit	50 to 200 m^2	10 to 100 m^2
Rate of filtration	100 to 200 Lph/m^2	4800 to 7200 Lph/m^2
Cost • Installation • O & M	• High • Low	• Low • High
Efficiency • Turbidity of feed water • Removal of bacteria	• Low;<30 NTU • 98 to 99%	• Any level of turbidity of feed water;(with pre-treatment) • 80 to 90%
Suitability	For water supply to rural areas and small Town	For public water supply to Towns and cities
Post treatment	Slight disinfection	Complete disinfection is must
Ease of construction	Simple	Complicated
Skilled supervision	Not essential	Essential
Loss of head • Initial • Final	• 10 cm, • 80 to 120cm	• 30 cm • 250 to 350 cm
Method of cleaning	• Scrapping and removing schmutzedecke and 1.5 to 3 cm thick sand layer • laborious	• Back washing with or without compressed air agitation • simple and easy
Quantity of wash water required	0.2 to 0.5 % of total water filtered	1 to 5% of the total water filtered
Cleaning interval	3 to 4 months	1 to 2 days

2.4 Nature of Natural Zeolites

The name zeolite comes from the two Greek words "zein" and "lithos" which mean "boiling stone". It was first applied by Granstedt, a Swedish geologist, in 1756 to describe a certain class of natural minerals which when heated, swelled and gave off their water of hydration. These zeolites are hydrated double silicates consisting of an alkali or alkali earth oxide, alumina, silica and water. In 1818 Fuchs, a German chemist, produced the first synthetic zeolite by mixing solutions of sodium aluminate and sodium silicate. Zeolites are hydrated aluminosilicate minerals made from interlinked tetrahedral of alumina (AlO_4) and silica (SiO_4). In simpler words, they are solids with a relatively open, three-dimensional crystal structure built from the elements aluminum, oxygen, and silicon, with alkali or alkaline-Earth metals (such as sodium, potassium, and magnesium) plus water molecules trapped in the gaps between them. Zeolites form with many different crystalline structures, which have large open pores (sometimes referred to as cavities) in a very regular arrangement and roughly the same size as small molecules. There are many natural zeolites identified in the world. Clinoptilolite, mordenite, phillipsite, chabazite, stilbite, analcime and laumontite are very common forms whereas offretite, paulingite, barrerite and mazzite, are much rarer. Among zeolites, clinoptilolite is the most abundant natural mineral. The structural formula of zeolite is based on the crystallographic unit cell (Bekkum *et al.,* 1991).

Natural zeolites are environmentally and economically acceptable hydrated alumino-silicate materials with exceptional ion-exchange and sorption properties. Their effectiveness in different technological processes depends on their physical-chemical properties that are tightly connected to their geological deposits. The unique three dimensional porous structure gives natural zeolites various application possibilities. Because of the excess of the negative charge on the surface of zeolite, which results from isomorphic replacement of silicon by aluminum in the primary structural units, natural zeolites belong to the group of cationic exchangers. It may be concluded that better knowledge of natural zeolite properties together with growing needs for selective, stable ion exchangers in pollution reduction, water treatment, energy production, agriculture,

Aquaculture, animal nutrition, metal processing, biomedical applications and other uses have contributed to the exciting practical development of these unique minerals (figure 1).
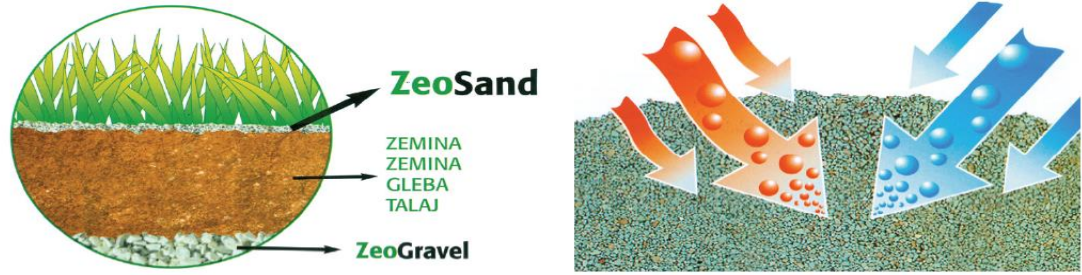
Figure 1: Various agricultural clinoptilolite based substrates produced for soil fertilizing (Galarneau *et al.,* 2001).
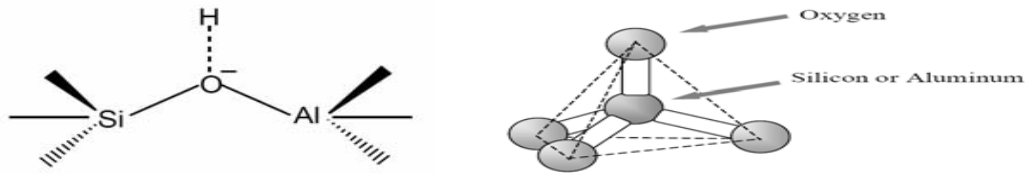
Figure 2: Chemical structure of zeolite (left) and Primary building unit of zeolite structure (Right) Haag *et al.,* (1984).

Natural zeolites are characterized with high cation-exchange ability and molecular sieve properties; they are low-cost materials, easily available in large quantities. That is why zeolites are widely used for drinking water and wastewater treatment (Wang, 2010*)* .Natural zeolites or modified zeolites can be used as a adsorption material for removal of iron and manganese from water *(*Barlokova *et al., 2010).*

Natural zeolite minerals are recovered from deposits by selective opencast or strip mining methods. The raw material is then processed by crushing, drying, powdering and screening. Some beneficiation processes for zeolites have been developed but these are not yet employed commerciality. Natural zeolite minerals used for ion-exchange applications are usually sold as screwier products in the -10 to +50 mesh (equivalent to 2 mm and 0.297 mm, respectively) size range. ln Hungary, where zeolite ore is used for catalysts, ore containing about 70% c1inoptilolite and mordenite is ground to the 0.1-1.6 mm size range and subsequently modified by ion exchange with ammonium ions and treated with hydrogen. For use in adsorption applications, natural zeolites such as chabazite or mordent are ground to + 200 mesh (0.074 mm), mixed with a binder, extruded or pelletized and activated by heating for 1 h at a temperature of 427 ^{0}C. These activated products are then marketed in sealed drums (Roskil Information Services Ltd, 1988).

2.5 Physical Quality of Iron in Groundwater

Consumer perception and acceptability of their drinking water quality depends on user sense of taste, odor and appearance (Sheat 1992; Doria, 2010). That is why consumers have different reaction about the aesthetic values of water quality. Relying on their own senses may lead to avoidance of highly turbid or colored but otherwise safe waters in favor of more aesthetically acceptable but potentially unsafe water sources (WHO, 2004).Taste and odor can originate from various natural chemical contaminants, biological sources, microbial activity, from corrosion or as a result of water treatment (e.g., chlorination) (WHO, 2004).Color, cloudiness, particulate matter and visible organisms can also contribute to unacceptability of water sources. These factors can vary for each community and are dependent on local conditions and characteristics.

The following lists a number of primary aesthetic indicators that can cause water to be perceived as unacceptable: True color (the color that remains after any suspended particles are removed); Turbidity (the cloudiness caused by particulate matter present in source water, re suspension of sediment in the distribution system, the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system (WHO, 2004). Unusual taste, odor and feel problems (usually due to total dissolved solids).

Turbidity is the most important problem for the aesthetic value of water quality. Although it doesn't necessarily adversely affect human health, it can protect microorganisms from disinfection effects, can stimulate bacterial growth, and indicate problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004). An important operational water quality parameter is pH, although within typical ranges it has no direct impact on consumers. Low pH levels can enhance corrosive characteristics resulting in contamination of drinking-water and adverse effects on its taste and appearance (WHO, 2004). Higher pH levels can lead to calcium carbonate deposition. Careful consideration of pH is 6 necessary to ensure satisfactory water disinfection with chlorine, which requires pH to be less than 8 (WHO, 2004).

2.6 Health Effects of Iron

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day (FAO, 1988)

Iron is an essential mineral necessary for human health. The Dietary Reference Intakes (DRIs) developed by the Institute of Medicine of the National Academy of Sciences created Recommended Daily Allowances (RDA) for iron intake.

Table 2: Recommended Dietary Allowances for Iron for Infants, Children, and Adults (Institute of Medicine Food and Nutrition Board, 2001).

Age	Males (mg/d)	Females (mg/d)	Pregnancy (mg/d)	Lactation (mg/d)
7 to 12 months	11	11	NA	NA
1 to 3 years	7	7	NA	NA
4 to 8 years	10	10	NA	NA
9 to 13 years	8	8	NA	NA
14 to 18 years	11	15	27	10
19 to 50 years	8	18	27	9
51 + years	8	8	NA	NA

NB: NA =   Not Available

According to the EPA, iron does not exhibit direct, adverse health effects. In fact, if the Appropriate intake of iron is not met, iron deficiency or anemia can develop. Although iron is necessary and essential, increased levels can accumulate in the body as little iron is released through excretion from the human body (Institute of Medicine Food and Nutrition Board, 2001).

Although iron may not have any adverse health effects, it does have negative aesthetic effects. Iron concentrations greater than 0.3 mg/L result in noticeable metallic taste and a rusty color. The colored water can cause staining of laundry and household appliances. Iron in water also results from problems with corrosion as it oxidizes and leaches into distribution systems from iron based piping materials (US EPA, 2012); (Chakroff *et al.,* 2000).

Health based iron regulations have not been officially mandated by the EPA because iron does not directly cause adverse health effects. However, the EPA has implemented an MCL as a guideline for water treatment facilities. Because metallic taste and staining are

observed at iron concentrations of 0.3 mg/L or greater, the MCL has been set at this level (US EPA, 2012).

2.7 Conventional Iron Treatment Processes

Conventional iron treatment processes involve removal by oxidation and precipitation. For example, water can be aerated to oxidize soluble iron (II) to particulate form. Common oxidants used in the iron removal process include oxygen, potassium permanganate, chlorine, or ozone. Following oxidation, particulate iron is removed from water most commonly by sand, anthracite or dual-media filtration. Concentrations of iron exceeding levels of 6 mg/L may require an additional step such as clarification where particles can settle prior to filtration (Siemens Water Technologies, 2009).

2.7.1 Sequestration

As an alternative to oxidation and filtration processes to remove iron and manganese, Sequestration can be used in specific situations to slow the process of particulate metal formation. During sequestration, metals are complexed with polyphosphates, but not removed. Sequestering agents, typically polyphosphates, complex Fe (II) and Mn (II) to prevent oxidation/precipitation and subsequent water quality problems (turbidity, color, staining, etc). Complexion occurs when a ligand or an electron donor binds to a metal therefore forming a complex. These stable strong, complexes form by either strong ion association or covalent bonding (Rashchi and Finch, 2000).

In Klueh and Robinson's study (1989) sequestration was not as effective for lower dosages of 1 mg of phosphate per 4 mg of iron. Also, when the pore size of the filter decreased, less filterability was observed. Experiments also showed that polyphosphate depolymerization should not be a problem in distribution systems since depolymerization does not occur until well after 5 days. Lastly, the experiments proved that polyphosphate addition should occur prior to chlorine addition.

The American Water Works Association Research Foundation (AWWARF) published a report in 1990 on Sequestering Methods of Iron and Manganese Treatment. In this report, research was conducted at the University of Tennessee to further understand sequestration. Results showed that when sodium silicate and chlorine were added nearly simultaneously, the effectiveness of iron sequestration was improved. However, sodium silicate does not

effectively sequester manganese. Manganese is sequestered more effectively by polyphosphates.

Additionally, sequestering becomes less effective as time increases, so distribution systems with long detention times may require a higher dose of sodium silicate. The study also concluded that higher hardness levels and higher iron levels require addition of more sodium silicate. Temperature also effects sequestering ability. Sequestering by sodium silicate became less effective at higher temperatures.

In 1992 a study conducted by Robinson, Reed, and Frazier examined Iron and Manganese Sequestration Facilities using Sodium Silicate. Similarly to the previous studies mentioned, Sequestration effectiveness was measured by the filterability of iron and manganese after sodium silicate addition. Conclusions drawn from this study indicated that iron and manganese precipitated in hot water heaters even with sodium silicate addition. Also, manganese is not as effectively sequestered by sodium silicate as iron. Lastly, sequestration was unsuccessful at a facility where the sodium silicate and chlorine were not added simultaneously.

2.8 Heavy metals

The term heavy metals refer to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (WHO and ILO, 1995). Heavy metals are natural components of the Earth's crust. Heavy metals cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals such as copper, selenium, zinc are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination, high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bio-accumulate. Bio-accumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by industrial and

consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater (Qureslii *et al*., 2001).

Some effects of heavy metals on human health such as arsenic, lead, zinc, copper, cadmium and chromium are well known for their acute toxicity. For example, an ingested dose of 70-180 µg of arsenic trioxide (As_2O_3) is lethal to humans (Kortenkamp *et al*., 1996).

Heavy metals cause acute effects in the respiratory, gastrointestinal, cardiovascular, and nervous systems. Chronic exposure to heavy metals in drinking water has been linked to serious dermatological conditions, including Blackfoot disease (Park and Jung, 2001).

Epidemiological studies have linked heavy metals in drinking water with cancer of the skin, bladder, lung, liver, and kidney. Some heavy metals adsorbed in the human body tend to accumulate in the tissues, whereas others such as organic arsenic are rapidly and almost completely eliminated via the kidneys (Kortenkamp *et al*., 1996).

2.9 Iron in water distribution system

Iron is frequently used in water distribution systems, and its corrosion is of concern. While structural failure as a result of iron corrosion is rare, water quality problems (e.g., "red water") can arise as a result of excessive corrosion of iron pipes. The corrosion of iron is a complex process that involves the oxidation of the metal, normally by dissolved oxygen, ultimately to form a precipitate of iron (III). This leads to the formation of tubercles on the pipe surface. The major water quality factors that determine whether the precipitate forms a protective scale are pH and alkalinity. The concentrations of calcium, chloride and sulfate also influence iron corrosion. Successful control of iron corrosion has been achieved by adjusting the pH to the range 6.8–7.3, hardness and alkalinity to at least 40 mg/l (as calcium carbonate), oversaturation with calcium carbonate of 4–10 mg/l and a ratio of alkalinity to Cl^- + SO_4^{2-} of at least 5 (when both are expressed as calcium carbonate). Silicates and polyphosphates are often described as "corrosion inhibitors," but there is no guarantee that they will inhibit corrosion in water distribution systems.

However, they can complex dissolved iron (in the iron (II) state) and prevent its precipitation as visibly obvious red "rust." These compounds may act by masking the effects of corrosion rather than by preventing it. Orthophosphate is a possible corrosion inhibitor and, like polyphosphates, is used to prevent red water (WHO, 2006).

Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and

Distribution system, resulting in the deposition of a slimy coating on the piping (Department of National Health and Welfare (Canada), 1990).

Adsorption

Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or, more rarely, a liquid (adsorbent), forming a molecular or atomic film (adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process (Mustafiz *et al*., 2002).

Basically the adsorptive filtration is operated under anoxic conditions for removal of iron where oxidation of ferrous iron is suppressed i.e. in case of filtration of ground water (Sharma ,2001).Here we have taken aerobic conditions for filtration in the adsorption media. Among some well-known adsorption media like anthracite, olivine, magnetite, zeolite, sand, pumice, bituminous coal (George *et al.,*1977) carbonaceous shale (Malay *et al.,*2008).

Sand

Fine sand and gravel are naturally occurring glacial deposits high in silica content and low in soluble calcium, magnesium and iron compounds are very useful in sedimentation removal. But here the media is used for iron (Fe) removal from drinking water (Priyadarsini, 2013). Sand has been used to purify water over a thousand years. It has been used traditionally as the filter medium in water treatment plants because of: Its wide availability, low cost, and the satisfactory results that it has given.

Color

Natural color reflects the presence of complex organic molecules derived from vegetable (humic) matter such as peat, leaves, branches and soon. Its effect can be enhanced by the presence of suspended matter but this is normally eliminated in the analysis by filtration. Obviously, the more vegetable matter in the water the greater is the color. Exceptionally, natural color may arise from the presence of colloidal iron/manganese in a water but organic matter is almost always the cause.

Objections to high color are generally on aesthetic grounds rather than on the basis of a health hazard. Consumers are reluctant to drink water, however safe, which has a yellowish-brown color not unlike that of urine, and because of this revulsion any marked color is very undesirable. So strong may be the objection to color in water that occasional cases have been noted of people turning from colored but otherwise safe waters to alternative supplies without coloration, and of a much lower bacteriological quality.

Nonetheless, it must be noted that the presence of color on a persistent basis (i.e. with short term seasonal peak values discounted) in a water which is then disinfected by chlorination is highly undesirable. This is because of the readiness with which the color-causing substances reacted with the added chlorine giving rise to the presence of trihalomethanes (THM). The latter compounds are a potential hazard to public health.

Conductivity

Also referred to as electrical conductivity and, not wholly accurately, as specific conductance, the conductivity of a water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionized (and hence will not be reflected in the conductivity figures) for many surface waters the following approximation will apply: Conductivity (μS/cm) x 2/3 = Total Dissolved Solids (mg/l).

Manganese

As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is re aerated. A second effect of the presence of manganese much above the limits is an unacceptable taste problem.

Toxicity is not a factor, as water with high levels of manganese will be rejected by the consumer long before any danger threshold is reached.

Nitrate

Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilizers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centered on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia.

pH

pH is a measure of the hydrogen ion (H+) concentration. Solutions range from very acidic (having a high concentration of H^+ ions) to very basic (having a high concentration of OH^- ions). By definition pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale (derived from the ionization constant of water) ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0. Natural water varies in pH depending on its source. Pure water has a neutral pH, with an equal number H^+ and OH^-. Adding an acid to water causes additional positive ions to be released, so that the H^+ ion concentration goes up and the pH value goes down.

$$HCl \longleftrightarrow H^+ + Cl^- \tag{1}$$

Temperature

The natural variation in temperature found in Irish surface waters is of the order of 25°C - from freezing point to a summer maximum of around 25°C in occasional years. Thermal pollution would, of course, alter the position, possibly very significantly. The effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one. Where biochemical reactions are concerned, as in the uptake of oxygen by bacteria, a rise of 10°C in temperature leads to an approximate

doubling of the rate of reaction. Conversely, such reactions are retarded by cooling, hence the recommendation often made that waters be cooled to 4°C in the interval between sampling and analysis.

Turbidity

Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. The particles forming the turbidity may also interfere with the treatability of waters and in the case of the disinfection process the consequences could be grave. As turbidity can be caused by sewage matter in a water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant. The Directive states that. "In the case of surface water treatment, Member States should strive for a parametric value not exceeding 1.0 NTU (nephelometric turbidity units) in. the water ex treatment works."

Safe Water

Safe water is to say that drinking water need to be free of pathogenic organisms, toxic substances, an over dose of minerals and organic materials as well as it should be pleasant (free of color, turbidity, odor and taste). Unhygienic handling of water during transport or within the home can contaminate previously safe water. In particular, pathogens of fecal origin often recontamination water that is initially of an acceptable microbiological quality when unhygienic handling practices are carried out (WHO, 2008).

Effective Particle Size

The effective size (ES) is defined by the size of screen opening where 90 percent of a sample of granular media is retained on the screen and 10 percent passes through the screen, and is referred to as D_{10}. The larger the grain size, the faster the wastewater moves through the sand and the more wastewater that can be filtered. However, if the grain size is too large, treatment efficiency will be reduced. According to Boller *et al.,* (1994) observed larger breakthroughs of un oxidized matter due to short retention times and instantaneous

lack of oxygen when applying relatively large hydraulic loads to filter media with coarse grain size, especially above 1 mm.

The ideal sand for intermittent sand filters receiving domestic wastewater is coarse sand with an effective size between 0.3 mm and 0.5 mm (Crites and Tchobanoglous, 1998; Ohio State University, 1999).

"Dirty sand" (too much material passing #100 sieve) has been implicated as the cause of poor operation and clogging of sand-based systems on numerous occasions (Aqua Test and Stuth 1995;Newman, 1997; Crites and Tchobanoglous, 1998; Seattle-King County Department of Public Health,1999). The Weaver *et al*., (1998) recommends that sand used for constructing sand filters has no more than 4% fines passing the 100 sieve size. Ball (1997) indicates that sand with excessive fine particles lacks sufficient pore sizes for unsaturated flow, so that in a sand filter, dosing at a normal loading rate usually results in formation of a bio mat that quickly plugs the surface of the sand.

The most important feature of granular media is not the grain particles, but rather the pore space in the media. The treatment of wastewater occurs in the pores where suspended solids are trapped, microorganisms grow, and air and water flow (Emerick, 1997). Ball (1997) illustrated how the particle size of a filter media is related to the size of the void or pore space between the particles by calculating the surface area and void volume for packed spheres of various sizes (Table 3). The percentage of void volume generally remains the same even as the diameter of the spheres changes. However, the surface area of packed spheres increases and the size of the pores per unit volume area significantly decreases with smaller diameter spheres. A granular media filter can benefit from increases in the surface area per unit of volume, but can suffer when pore size becomes too small for unsaturated flow to occur (Ball. 1997).

Uniformity Coefficient

The uniformity coefficient (Uc) is a numeric estimate of how sand is graded, and is a dimensionless number or in other words it has no units. The term "graded" relates to where the concentrations of sand particles are located by size. Sand with all the particles in two size ranges would be defined as narrowly graded sand and would have a low Uc. Sand with near equal proportions in all the fractions would be defined as widely graded sand and would have a high Uc value.

The Uc is calculated by dividing D_{60} (the size of screen opening where 60% of a sample passes and 40% is retained) by D_{10} (the effective particle size- that size of screen opening where 10% of a sample passes and 90% is retained). The larger the Uc the less uniform the sand.

It is important that the sand grains all be about the same size; i.e. relatively uniform. A uniformity coefficient of 4 or less is recommended for all filter media (National Small Flows Clearinghouse, 1997; Crites and Tchobanoglous, 1998; EPA, 2002). This recommendation is intended to avoid clogging at higher loading rates (Darby *et al*., 1996). Sands from most natural sources are widely graded containing a variety of grain sizes, which results in a high Uc. If the grain sizes vary greatly, the smaller ones will fill the spaces between the larger particles, making it easier for the filter to clog (National Small Flows Clearinghouse, 1997).

An ideal sand media has both large surface area to permit wastewater to have maximum contact with the zoogleal film on the particles where most of the treatment is accomplished, and sufficient pore space to allow aeration and unsaturated flow (Ball, 1997). Because sand media treatment is aerobic in nature, the exclusion of fines from the filter media is extremely important to maintain open passages for air (Figure 3).

Low Uc   High Uc

Narrowly graded sand   widely graded sand
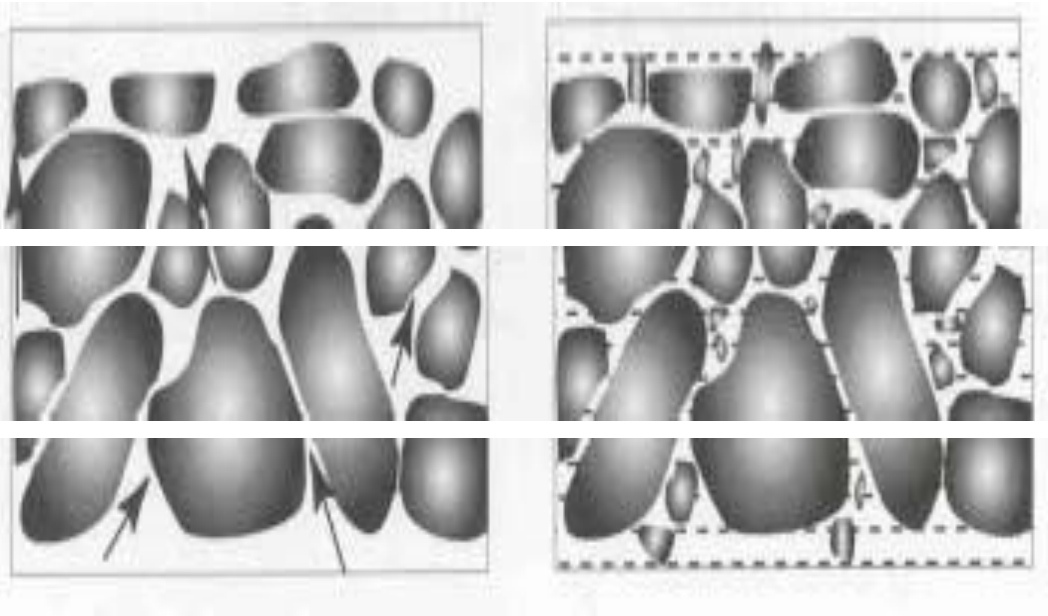
Large pore space allows rapid   Inclusion of small particles filling
Oxygen diffusion and unsaturated   interspaces between large particles
flow around the sand particles.   encourages clogging.

Figure 3: High and low uniformity coefficient of the particle size (Ball, 1997).

Concrete sands are designed to minimize voids, and usually have a high to pack and offer strength and stability (Dixon, 1994). This size distribution allows the smaller sand particles to fill interstices between large particles, resulting in smaller and more convoluted pores spaces. When used for filter media, this condition encourages clogging of remaining void spaces with suspended solids and biological growth (Boller and Kavanaugh, 1995; Darby *et al*. 1996).

Table 3. Shows how the physical performance of the granular media changes in response to different values in the Uc. Sands with higher Uc values have a more tortuous path (smaller and more convoluted pores spaces) for wastewater to move through and will have lower infiltration rates or permeability. Usually the water retention is also greater with sands that have a higher Uc due to smaller pore volumes and higher bulk densities. These conditions run counter to the objective for a good filter media, which should have sufficiently large pore spaces to allow oxygenation and unsaturated flow around the sand particles (Ball, 1997).

Table 3. Physical Performance Data for the Various Uc Values (Dixon, 1994)

Physical Properties	Sand Uc = 1.5	Sand Uc = 2.3	Sand Uc = 4.6
Infiltration Rate (in/hr)	41.1	34.9	12.7
Bulk Density (g/cc)	1.5	1.6	1.8
Total Pore Space (%)	42.4	39.5	32.4
Capillary Pore Space (%)	5.0	4.6	14.4
Saturation (%)	11.8	11.6	14.4

Media uniformity does not appear to have as much effect on treatment performance as the media's effective size does at a hydraulic loading rate of 4 gpd/ft^2 and high dosing frequencies (24 times/day) (Nor, 1991, Darby *et al*., 1996). The lower per-dose application rate supports thin-flow flow conditions and allows good treatment regardless of media uniformity. At a high dosing frequency of 24 times/day, Nor, 1991 observed that a sand with high uniformity (D_{10}=0.42 mm, Uc = 1.42) produced worse, but still good (3.9 log) total coliform removal compared to washed concrete sand (D_{10}=0.29 mm, Uc= 4.52), which produced a 4.7 log coliform removal. However, as the per-dose application rate increases (less frequent dosing), media uniformity becomes more significant because it affects pore geometry and conditions under which thin-film flow occur (Darby, 1996).

Chlorination

Chlorination can be achieved by using liquefied, chlorine gas, sodium hypochlorite solution or calcium hypochlorite granules and on-site chlorine generators. Liquefied

chlorine gas is supplied in pressurized containers. The gas is withdrawn from the cylinder and is dosed into water by a chlorinator, which both controls and measures the gas flow rate. Sodium hypochlorite solution is dosed using a positive-displacement electric dosing pump or gravity feed system. Calcium hypochlorite has to be dissolved in water, then mixed with the main supply. Chlorine, whether in the form of chlorine gas from a cylinder, sodium hypochlorite or calcium hypochlorite, dissolves in water to form hypochlorous acid (HOCl) and hypochlorite ion (OCl$^-$). Super chlorination/dechlorination is the addition of a large dose of chlorine to effect rapid disinfection and chemical reaction, followed by reduction of excess free chlorine residual. Removing excess chlorine is important to prevent taste problems. It is used mainly when the bacterial load is variable or the detention time in a tank is not enough. Marginal chlorination is used where water supplies are of high quality and is the simple dosing of chlorine to produce a desired level of free residual chlorine. The chlorine demand in these supplies is very low, and a breakpoint might not even occur. Chlorination is employed primarily for microbial disinfection. However, chlorine also acts as an oxidant and can remove or assist in the removal of some chemicals for example, decomposition of easily oxidized pesticides such as aldicarb; oxidation of dissolved species (e.g., Iron (II)) to form insoluble products that can be removed by subsequent filtration; and oxidation of dissolved species to more easily removable forms (e.g., arsenite to arsenate). A disadvantage of chlorine is its ability to react with natural organic matter to produce THMs and other halogenated DBPs. However, by-product formation may be controlled by optimization of the treatment system (WHO, 2006).

Aeration

Aeration processes are designed to achieve removal of gases and volatile compounds by air stripping. Oxygen transfer can usually be achieved using a simple cascade or diffusion of air into water, without the need for elaborate equipment. Stripping of gases or volatile compounds, however, may require a specialized plant that provides a high degree of mass transfer from the liquid phase to the gas phase (WHO, 2006).

For oxygen transfer, cascade or step aerators are designed so that water flows in a thin film to achieve efficient mass transfer. Cascade aeration may introduce a significant head loss; design requirements are between 1 and 3m to provide a loading of 10–30 m^3/m^2h.

Alternatively, compressed air can be diffused through a system of submerged perforated pipes. These types of aerator are used for oxidation and precipitation of iron and manganese. Air stripping can be used for removal of volatile organics (e.g., solvents), some taste- and odor-causing compounds and radon. Aeration processes to achieve air stripping need to be much more elaborate to provide the necessary contact between the air and water. The most common technique is cascade aeration, usually in packed towers in which water is allowed to flow in thin films over plastic media with air blown counter-current. The required tower height and diameter are functions of the volatility and concentration of the compounds to be removed and the flow rate (WHO, 2008).

Aeration effectively removes odor due to hydrogen sulphide but only partially removes, or leaves unaffected, tastes and odors caused by organic matter, biological growths or chlorination. Efficient aeration takes place in fast-flowing streams, particularly when the water splashes over rocks, weirs, etc., and it plays an important part in the self-purification of rivers. From stagnant streams and impounding reservoirs, and occasionally from underground sources, poorly oxygenated water is obtained, and aeration is then a valuable part of the purification processes and improves the palatability of the waters (Twort *et al.*, 1985).

Spray aerators are usually efficient with respect to gas transfer such as carbon dioxide removal or oxygen addition. However, they require a large installation area, are difficult to house, and pose operating problems during freezing weather. Spray aerators are effective provided they can be economically designed. As a decorative fountain they can be attractive. They do however have some limitations. To produce an atomizing jet, a large amount of energy is required. The losses and the nuisance problems from the wind carry-over of the spray can be considerable. Climatic conditions, particularly in cold regions, limit their usefulness (Sarah, 2002). Aeration of iron bearing water has three purposes:

a. To transfer oxygen to the water for oxidation of iron and manganese.
b. To remove any volatile organics that may be present and that reduce the efficiency of subsequent processes due to their oxidant demand
c. To remove carbon dioxide and hydrogen sulphide gases (Ahmed *et al.,* 2009).

CHAPTER THREE

3. Method and Material

3.1 Description of study area

The study was carried out in Asossa, the Town of Benishangul Gumuz Regional state, Western Ethiopia. The study area described that far 661 km from Addis Ababa , Latitude 10°04′N and longitude of 34°31′E and elevates 1570 m. a.s.l , climate condition, average annual temperature, 21.9 °C, Average annual rainfall 1222 mm. and he total Population of study area was 49,145, from these men ,25,172 and women ,23,973 (CSA, 2015)
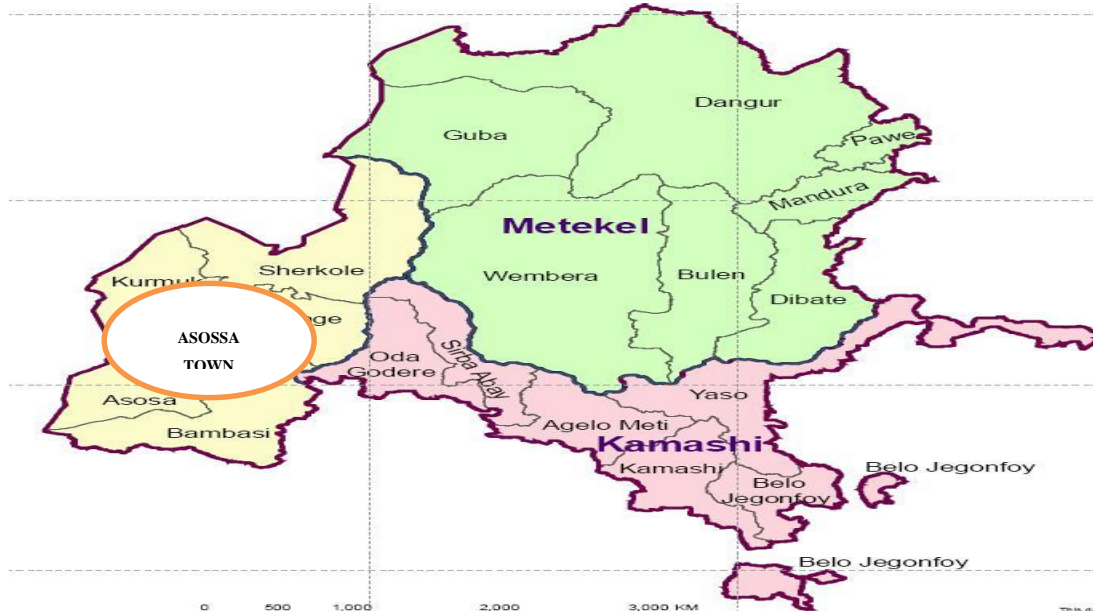
Figure (4): Map of Benishangul Gumuz Regional State (BGREB, 2004)

The principle of most methods used for iron removal is that originally dissolved iron transformed into undissolved compounds that can be removed through single stage or more than two stage separation.

| RESERVOIR (Source of water supply) | → | OXIDATION a. Aeration b. Chlorination | → | FILTRATION 1. Course Sand 2. Fine Sand 3. Graded Sand |

| Discharge (**safe water**) | ← | RESIDUAL 1. Direct Discharge 2. Equalization 3. Dry sand beds | ← | CLARIFICATION 1. Sedimentation 2. Flocculation 3. Plate settler |
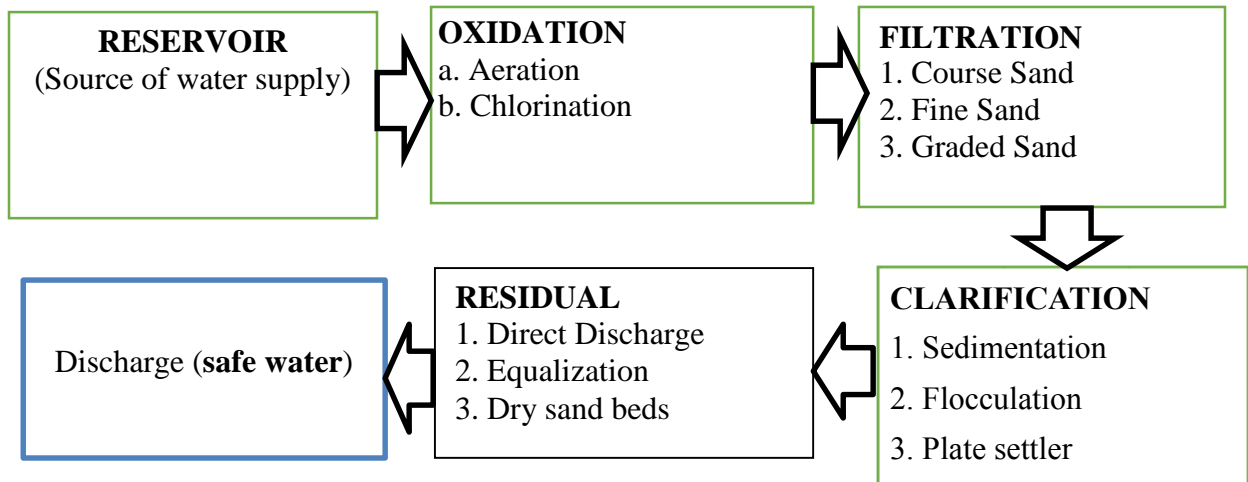
Figure 5: Procedural methodology of removal of iron from groundwater

3.2 Study Design and period

The study was conducted starting from **May, 2016 up to October, 2016**

Preparation of filter media:

As shown in figure (8), a laboratory-scale experimental runs conducted using 28 cm ID (internal diameter), 90 cm high plastic cylindrical column filled with mono-medium sand rested on under drain gravel. The bottom of the filter provided with a perforated porous plate acting as drain system to the filter. The raw ground water would be introduced into the columns through a distributor giving the water some duration time for aeration (Summerfield, 1999).

Figure (6): Types of sand after sieve analysis in the laboratory section.

Filter bed description

Three graded types of sand were prepared:

1. Course sand with size (1-1.18 mm), effective size (E) of 1.0mm, and uniformity coefficient (U) of 1.117.

2. Fine sand with size (0.3-0.425 mm), (E) of 0.5 mm, and (U) of 1.391.

3. Graded sand with size (0.15-1.18 mm), (E) of 0.25 mm, and (U) of 3.366.

The depths of the filter media can be variable depths of 10,15,20,25, 30 cm (rested on under drain gravel of 10 cm depth and (4-12) mm size to choose the optimum depth of sand filter for almost complete removal of iron (Summerfield ,1999).

Figure 7: Preparation of sand and gravel during mesh analysis
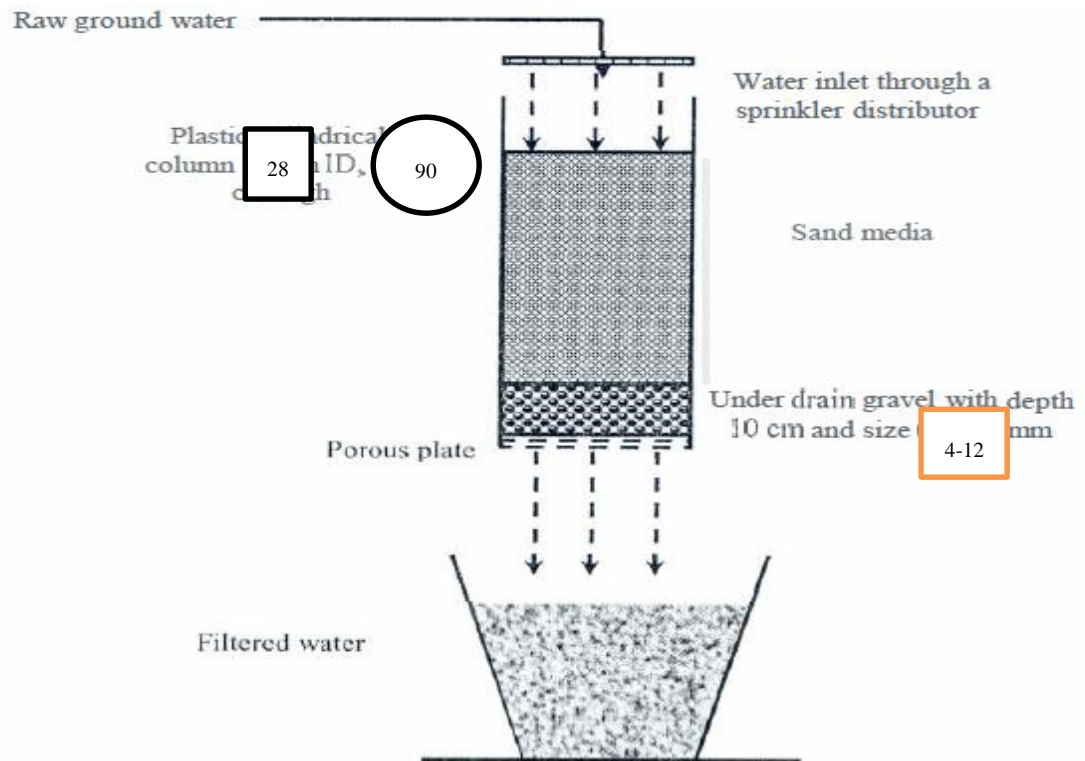
Figure 8: Process Schematics of Laboratory-Scale Colum Experiment (El-Naggar, 2010)

3.3 Sampling procedure

Before aeration, one liter sample was collected from the reservoir, 20 liters groundwater were collected after aeration from the reservoir, was checked the concentration of each parameter. After laboratory analyzed was filtered using different sand media, was made the filtrated finalized concentration.

In chlorination, 20 liter sample was fetched from treated water, were filtered using filter media by exchanged each media one by one, was analyzed the concentration of each parameters.

During the laboratory analysis was used aplastic bottle that have been washed and rinsed was concentrated HCl and rinse with deionized water. Great care was taken to obtain a representative sample. The water sample was shaken the sample bottle often when determining Fe in suspension (Miroslav *et al.,* 2006).

Finally, aeration and without aeration process was compared.

Figure 9: Procedure during sample collection and analysis

a. **Aeration**

Figure 10: Spray aerator from groundwater

Before the process of filtration of iron, it was required to oxidize them to a state in which turn into insoluble products. The process of oxidation involves the transfer of electrons from iron to oxidizing agent that were using. By the process of oxidation the ferrous ion (Fe^{2+}) were changed into ferric ion (Fe^{3+}), which readily forms insoluble hydroxide Fe $(OH)_3$ (Tech Brief,1998). Detention time before filtration should be more than 20 minutes, more if possible. The pH of the water influences how much time is needed for the reaction to be completed. After oxidation of the iron, the water must be filtered to remove the precipitated iron.

$$4Fe^{2+} + O_2 + 10H_2O \longrightarrow 4\ Fe\ (OH)_3\downarrow + 8H^+ \tag{2}$$
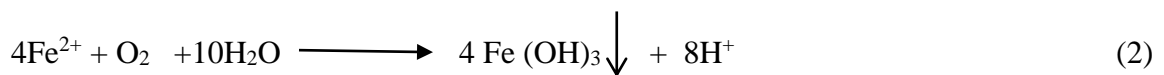
Spray aerator

Spray aerators direct water up wards, vertically or at an inclined angle in a manner that causes water to be broken in to small drops. Installations commonly consist of fixed mobile or a pipe grid located over an open-top tank. By spray aerators the water is sprayed in the form of fine droplets into the air, thus creating a large gas-liquid interface for gas transfer. Consists of stationary nozzles connected to a distribution grid through which the water is sprayed into the surrounding air at velocity of $5 - 7$ m/s.

The fine distribution of the water into the air is accomplished by pumping the water through orifices or nozzles mounted upon stationary pipes. Spray aerators are usually efficient with respect to gas transfer such as CO_2 removal or Oxygen addition. Provides a very simple and in expensive arrangement and it occupies little space (Alemayehu, 2015).

b. Oxidation with chlorine

Iron in water can also be oxidized by chlorine, converting to ferric hydroxide. The precipitated material can then be removed by filtration. The higher the amount of chlorine fed, the more rapid the reaction. Most treatment plants use $1 - 2$ parts of chlorine to 1 part of iron to achieve oxidation. Chlorine Dioxide reaction:

$$5Fe^{2+} + ClO_{2\,+}4H^+ \longrightarrow 5Fe^{3+}\downarrow + Cl^- + 2H_2O \tag{3}$$
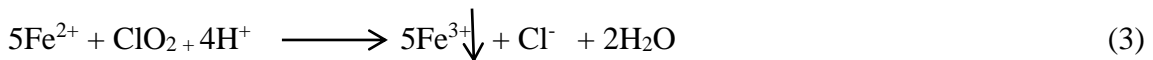
Ferrous iron oxidizes into ferric iron, which can be removed by filtration, chloride ion and water (Abode *et al.*, 2004).

Generally summarized as

Select the natural zeolites, dried the sand, filtered the sand with sieve analysis, wash, dry, wash gravel, dry, immersed gravel before sand, insert the sand, fill the water at optimum height, wait for 24 hr-30hr (retention time) if more than this better finding, filter the supernatant water, analysis the filtered sample, compare the analysis with other method (aeration versus chlorination), origin and excel done the analysis for more justification (annex 2).

3.4 Study variable

In this study have two main types of variable conducted in the removal of iron from the ground water by filtration using natural zeolites.

3.4.1 Independent variable

Measured pH, Turbidity, Color, Chloride, Nitrate, manganese, conductivity and Temperature

3.4.2 Dependent variable

Concentration of iron removal

3.5 Data collection

Before aeration, one liter sample was taken from the reservoir, after aeration 20 liters sample were collected,30 minutes later laboratory conducted, filtration was proceed, then in each medium 1 liter sample was fetched (in aeration process).

In chlorination process 20 liters sample were fetched in disinfected water reservoir without aeration process, laboratory was conducted before filtration, filtration was done, and one liter sample was collected in each filter media.

3.6 Data analysis

According to WHO and EWQS criteria, by using random sample method, was selected the natural zeolites around locally available, was dried the sand, were sieve analyzed the dry sand with in different sand type, was washed using sample collected at end rinsed with tap water, was prepared 4-12 mm size gravel to immerse under the media, were conducted the filtration after the fullfiment (completion) filtration material. During data collection process collected sample was performed its concentration after and before filtration in aeration and without aeration (both) cases. The following parameters were determined: Chloride, turbidity, nitrate, pH, color, iron (Fe), Nitrate (NO_3), manganese (Mn), and conductivity laboratory experimental analysis were conducted. After analyzed the

concentration, were analyzed statistically using origin pro.8 and Microsoft excel 2007, 2010 and 2013 version. At the end reported in the form of Mean ±Standard Deviation

3.7 Ethical considerations

Permission Jimma university institute of technology, environmental engineering chair investigation paper examiner were allowed. From regional water, mine and energy development bureau and Assosa Town water and Sewerage enterprise have be taken.

3.8 Data quality assurance

A quality assurance (QA) program was a system of documented checks which validate the reliability of a data set. QA procedures are used to verify that field and laboratory measurement systems operate within acceptable limits. These limits should be determined during sampling program design for each measurement which the program requires. The limits might be modified or refined as new information is gathered. However, a documented basis for evaluating the need for modification must be established if the expense and manpower involved in ground-water investigations are to yield cost-effective, high quality data. The QA program should be implemented as a set of basic measurement procedures and corresponding quality control checks (Michael *et al*., 1985)

3.9 Limitations of the study

This thesis was only justified removal of iron from ground water concentrated on Asossa Town not represented other Town. Types of rocks, lithological factor, types of natural zeolites, soil and climatic condition limitation.

3.10 Operational definitions

Filtration:-The process of allowing water to pass through layers of a porous material such as sand, gravel or cloth to remove suspended solids and pathogens. It is the second step of the household water treatment process, done after sedimentation and before disinfection.

Flow rate:-The time it takes to fill a specified container of water, often a 1 liter container. Flow rate is measured when the bio sand filter is filled with water.

Hygiene:-Practices, such as hand washing that help ensure cleanliness and good health

Pore:-The small spaces between the sand grains that allow water to pass through.

Sanitation:-Maintaining clean, hygienic conditions that help prevent disease through services such as garbage collection, wastewater disposal, and using latrines.

Sedimentation:-The process used to settle out suspended solids in water under the influence of gravity.

Suspended solids:-Small solid particles which float in water, causing turbidity. They can be removed by sedimentation or filtration.

The effective size (ES): The size opening read from the grain-size distribution graph that will just pass 10% of the sand.

Turbidity:-Caused by suspended solids, such as sand, silt and clay, floating in water. Turbidity is the amount of light that is reflected off these suspended solids which make the water look cloudy or dirty. Turbidity is measured in nephelometric turbidity units (NTU).

Uniformity coefficient: Size opening read from the grain-size distribution graph that will pass 60% of the sand (d_{60}value) divided by the size opening that will pass 10% of the sand (d_{10} value). It is a measure of how well or poorly sorted the sand is.

Water quality:-The chemical, physical, and microbiological characteristics of water. The quality of water to be used depends on the purpose for which it is intended.

3.11 Dissemination of plan

After data was analyzed, based on the finding obtained, conclusions and recommendations will be made. Then the results of the study will be submitted to the Environmental Engineering chair, Jimma Institute and Technology (Jimma University), Benishangul Gumuz water, Energy and Irrigation Bureau and Assosa Town water supply and Sewerage Enterprise. Finally, attempts will be made to present the results on scientific conferences and to publish the results of the study on national as well as international journals.

CHAPTER FOUR

4. Result and Discussion

Table (4): Physical and Chemical concentration of raw Samples Collected from reservoir.

No	Parameters	Unit	Min	Max	Mean	WHO Guideline	Ethiopian Standard
1	Turbidity	NTU	0	8	4	5	5
2	pH	-	7.75	7.75	7.75	6.5-8.5	6.5-8.5
3	Color	TCU	0	10	5	15	15
4	Chloride	mg/l	0	0.2	0.1	250	250
5	Temperature	^{o}C	22.8	25.5	24.15	NA	NA
6	Iron	mg/l	5.60	6.20	5.9	0.3	0.3
7	Manganese	mg/l	0.007	0.30	0.1535	0.5	0.5
8	Nitrate	mg/l	0.208	0.302	0.255	3	3
9	Conductivity	μs/cm	172	175.1	173.55	NA	NA

NB: NA=Not Available

The table representation of the raw water before aeration, iron is extremely high compared to WHO and Ethiopian standard water quality parameter. So, the way to solve this problem from the Town Experimental laboratory investigation are done by using natural zeolites around local available as well as low cost technology.

The ability to conduct electric current also good the conductivity parameter that mean easily ionizable total dissolved solid apparently effective in this water.

Table 5: Concentrations and Removal Percentage of iron in Ground Water Collected from Asossa Town after filtration.

Sand depth(cm)	Types of sand											
	Without aeration						With aeration					
	Course sand		Fine sand		Graded sand		Fine sand		Course sand		Graded sand	
	Fe (mg/l)	% of Fe removal	Fe (mg/l)	% of Fe removal	Fe (mg/l)	% of Fe removal	Fe (mg/l)	% of Fe removal	Fe (mg/l)	% of Fe removal	Fe (mg/l)	% of Fe removal
0	6.20	0	6.20	0	6.20	0	5.15	0	5.15	0	5.15	0
10	4.60	25.8	4.90	20.96	5.0	19.35	4.06	21.1	4.25	17.47	4.80	6.8
15	1.45	68.48	4.80	22.6	4.30	30.64	3.80	26.2	3.60	30.09	4.05	21.36
20	0.30	79.3	3.00	37.5	3.30	46.77	3.5	32.0	3.02	41.35	3.50	32.0
25	0.2	95.1	0.95	68.3	2.75	55.6	1.75	50	2.40	53.39	2.75	46.6
30	0	100	0.2	96.77	0.75	87.9	1.07	79.2	0.85	83.49	1.85	64.07

The type of treatment largely depends on the quality of the raw water, financial resources available and the philosophy of the water company. The methods used to control iron in the water supply are oxidation by aeration followed by precipitation then filtration, iron exchange or zeolite softening, stabilization or sequestering using silicates or polyphosphates, lime softening or limestone bed filtration. Among the different techniques mentioned above, aeration followed by sand filtration is most widely used (Summerfield, 1999).

Aeration then sand filtration is the preferred method in the Netherlands and in developing countries. Compared to other methods, this method is more economical, less complicated and generally avoids the use of chemicals, which is not usually welcomed in the water industry (Sharma, 2001).

Iron removal:

Table (5) illustrate the effect of different depths of sand on the removal of iron with and without aeration for the three types of sand. The effect of aeration was obvious: Fe concentration measured in ground water decreased with aeration from (5.15 mg/L) to (0.85 mg/L) with a removal percentage of 83.49% and its correlation coefficient, $R^2 > 0.98$. However, the iron concentration remained above the Ethiopian Standard for drinking water quality and WHO guideline value of 0.3 mg/l.

On the other hand, Fe concentration measured in ground water decreased without aeration (chlorination) from (6.20 mg/L) to (0 mg/L) with a removal percentage of 100%. However, the iron concentration below the Ethiopian Standard for drinking water quality and WHO guideline value of 0.3 mg/L. In comparison `between the effluent iron concentrations of the three types of sand, it was apparent that the course sand was the best type of filter media since it resulted in the highest percentage removal of iron at 30cm of sand depth.

This is due to the effectiveness removal of course sand after one day digestion time of the potable water. Hence, courses sand is the most effective for the removal of iron in Town.

Aerators fall into two general categories. They either introduce air into the water or water into the air. The air-to-water method creates small bubbles of air with enough oxygen that are injected into the water stream, but their cost is high due to the air pumps capital cost, operation and maintenance. The other category, the water-to-air method is designed to produce small drops of water that fall through the air through simple water distributer sprinkler with very low cost (the present study). The probable cause for lower iron removal in the present study may be due to inadequate aeration. Iron oxidation and its removal are based on the transformation of the soluble form of iron (Fe^{2+}) to an insoluble form (Fe^{3+}) (Appelo *et al*., 1999).

This experimental laboratory used the water-to-air method is designed to produce small drops of water that fall through the air through simple water distributer sprinkler with very low cost , it is effective in aeration.

percentage of Fe removal in aeration& without aeration

$y = -0.2017x^2 + 11.567x - 66.852$
$R^2 = 0.9761$

$y = 0.1021x^2 - 0.9778x + 18.762$
$R^2 = 0.9839$

KEY
◆ without aeration
■ with aeration
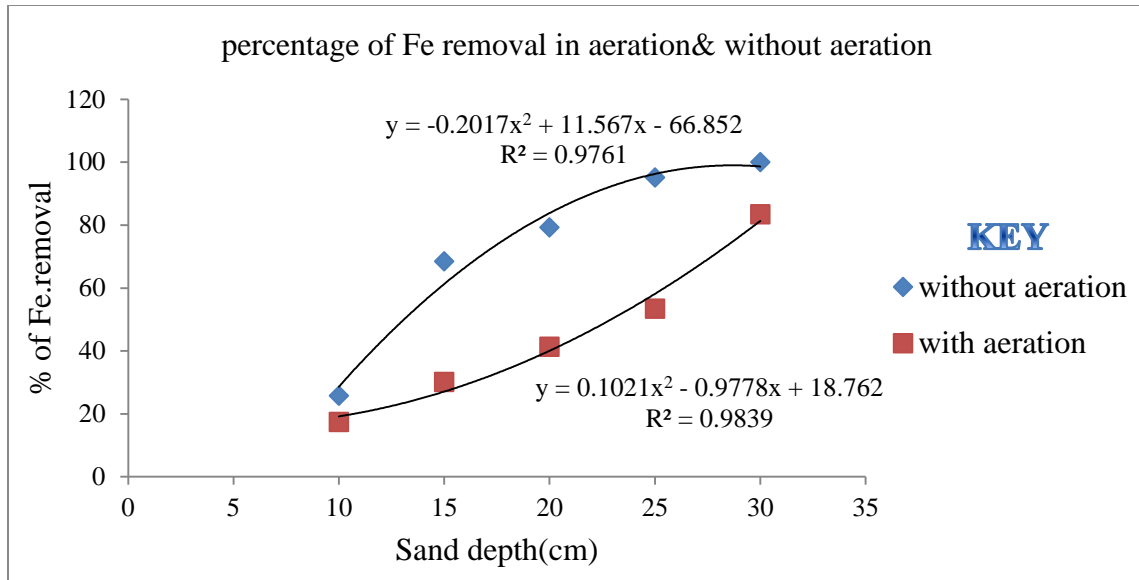
Figure 11: Removal Percentage of Iron after filtration in aeration and without aeration

The result compared from chlorination and aeration by using natural zeolites (sand) filtration ,chlorination then sand filtration was the most effective and efficient removal of iron from groundwater. Aeration then sand filtration better removal of iron, I recommended that aeration then filtration because it save economical cost, easily available no need chemical addition, health aspects and no need more labor cost.

4.1 Effect of sand depth

The effect of different filter sand depth on the removal of iron, It was obvious that the removal percentage of iron in aeration process (83.49, 79.2, and 64.07%) for the course, fine and graded sand respectively, in statistical significance $R^2 > 0.984$ at filter depth of 30 cm. On the other hand, the depths of sand to remove the Fe concentration to be under the permissible limits were at (25, 30 cm) for Fe concentration 0.20 mg/l and 0 mg/l respectively without aeration process.

Table 6: Percentage Removal of Iron from Groundwater without aeration process

	Course sand	Fine sand	Grain sand
Sand depth(cm)	% of removal	% of removal	% of removal
0	0	0	0
10	25.8	20.96	19.35
15	68.48	22.6	30.64
20	79.3	37.5	46.77
25	95.1	68.3	55.6
30	100	96.77	87.9

The result of removal efficiency of Iron from groundwater showed that the concentration of Iron decreased at the sand depth increased, the percentage of Iron removal also increased. In chlorination (without aeration) process it was the most efficient Iron removal by filtration using natural zeolites. However, in this case chlorination is highly oxidized with Ferrous (II) compounds, the formation of flocculation and coagulation is higher than aeration process. Due to these case the formation of Ferric (III) compounds were formed. These Ferric compounds were easily filtered by using different sand media individually like course sand, Fine sand and Graded sand. So, chlorination was more efficient for the removal Fe than aeration process.

In comparison with other article between the effluents of iron concentration of the three types of sand, it was apparent that the graded sand was the best type of filter media since it resulted in the highest percentage of removal of iron at filter depth 60 cm in Egypt (El-Nagger , 2010) were explained.

In Egypt the graded sand was best media for the removal of iron when compared to Ethiopia course sand best media for the removal of iron, this is due to the porosity, the particle size and the type rock formation difference.
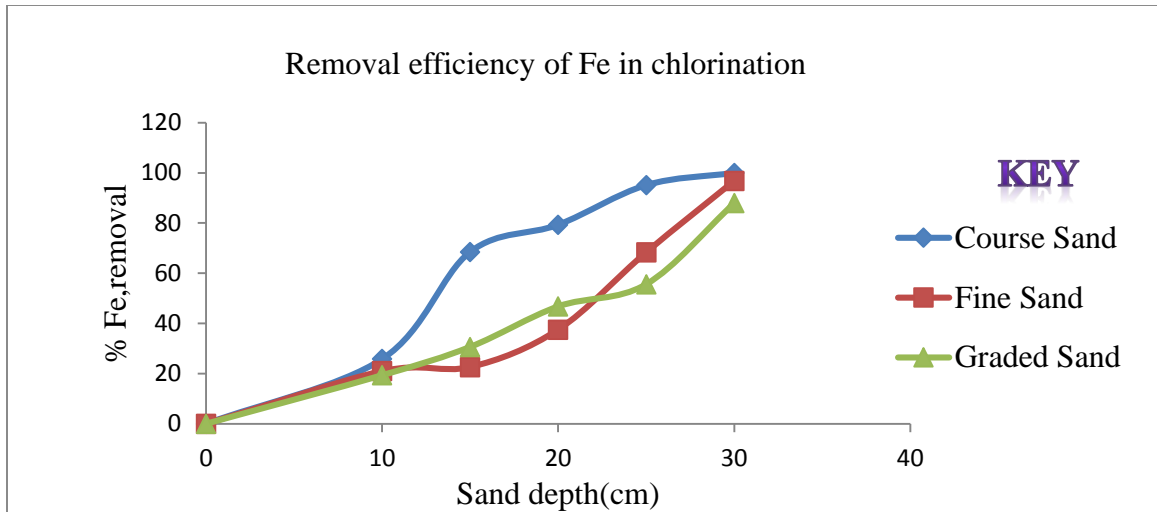
Figure 12: Removal of iron from potable water without aeration process

According to the result were reported that Cho, (2005) and Berbenni, (2000) who recommended that sand bed depth of 0.5 m was capable of consistently reducing concentration of about 7 mg/l to < 0.3 mg/l .such consistent performance is achievable with a sand of 0.4-1.18 mm size. This sand needs 0.05 m deep gravel support layer to ensure that it does not escape through the hacksaw cut slots in the drainage bar ,also it is evident that has the depth increases, the removal percentage of iron also increases.

Table 7: Percentage Removal of Iron from Groundwater in aeration process

	Course sand	Fine sand	Graded sand
Sand depth(cm)	% of removal	% of removal	% of removal
0	0	0	0
10	17.47	21.1	6.8
15	30.09	26.2	21.36
20	41.35	32	32
25	53.39	50	46.6
30	83.49	79.2	64.07

During aeration process course sand is better removal of iron than other sands. This is due to the pore space of course sand is larger than fine and grade sand. The particle size large, have large pore space the by nature sand is negatively charge easily attracted positively charge, the particulate matter and iron can easily adsorbed easily. The water is filter to plate of discharge holder. I hope it is better than chlorination, due to low cost, easily available the material and soon.

Removal efficiency of Fe in aeration

KEY
Fine Sand
Course sand
Graded Sand
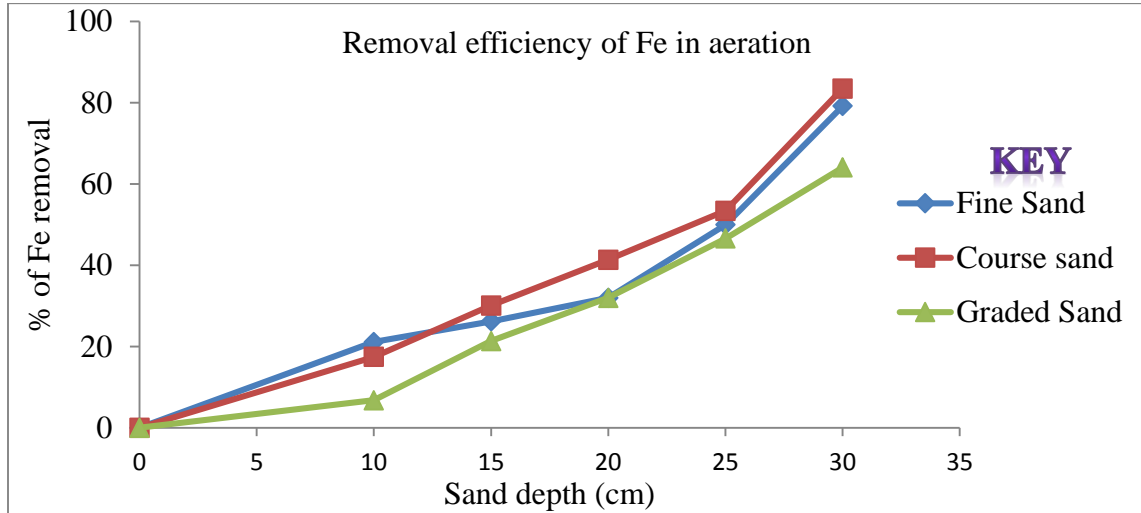
Figure 13: Removal of iron from potable water in aeration process

Course sand was better removal than other fine and graded sand like chlorination, at the depth increase the concentration of Iron decreased, the removal efficiency increased .this due to the oxidation of air in the water Iron (II) changed into Iron (III) form during aeration process.

4.2 Effect of Turbidity on the removal of Iron

The factor that affect iron removal from groundwater turbidity was the main factor that influence the iron concentration, iron concentration depends up on turbidity due to the corrosively and the taste of water can be fluctuated by this physical water quality parameters. If iron concentration decrease, turbidity also decrease.

Table 8: The effect of turbidity on the removal of iron from groundwater

Sand depth(cm)	Without aeration						With aeration					
	Course sand		Fine sand		Graded sand		Fine sand		Course sand		Graded sand	
	Fe (mg/l)	Turbidity(NTU)	Fe (mg/l)	Turbidity(NTU)	Fe (mg/l)	Turbidity(NTU)	Fe (mg/l)	Turbidity(NTU)	Fe (mg/l)	Turbidity(NTU)	Fe (mg/l)	Turbidity(NTU)
0	6.2	8	6.2	8	6.2	8	5.15	8	5.15	8	5.1	8
10	4.60	4	4.9	6	5.0	10	4.06	2	4.2	6	4.80	8
15	1.45	4	4.8	4	4.3	7	3.80	2	3.60	4	4.05	6
20	0.30	2	3.0	3	3.3	6	3.5	3	3.02	3	3.50	6
25	0.2	0	0.95	1	2.75	4	1.75	2	2.40	1	2.75	5
30	0	0	0.2	0	0.75	3	1.07	0	0.85	0	1.85	5

The sand depth increase, concentration of Iron decrease and Turbidity of the sample also decreased in course sand in both case during aeration and without aeration process, but in fine sand turbidity was decreased, sand depth increased. However, in other case fluctuated the concentration in graded sand, this due to smallest pore space and the particle size
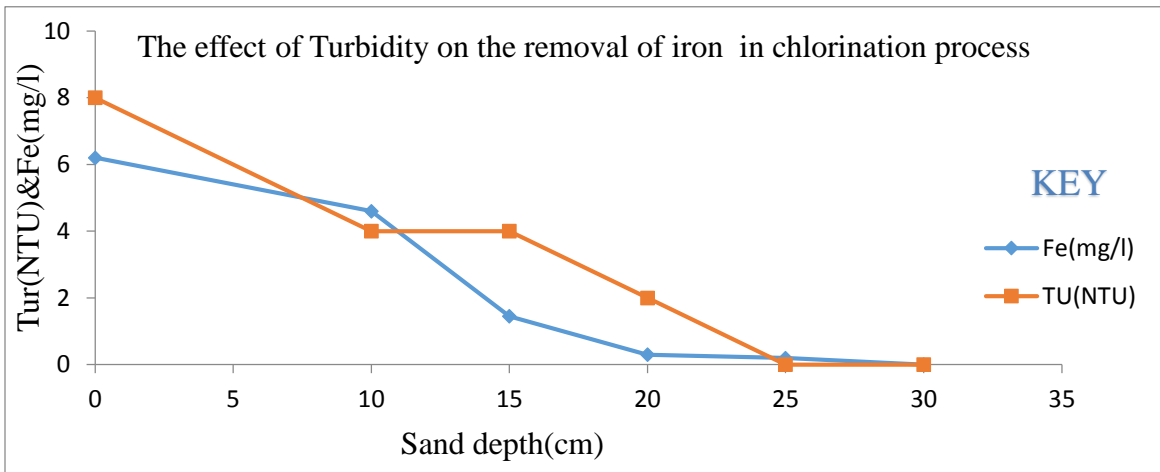
Figure 14: Turbidity on the removal of Iron in without aeration process

In the study the concentration of Iron decreased, turbidity also decreased its concentration and the removal efficiency also increased. Without aeration (chlorination) is better removal efficiency than aeration process. Turbidity is significantly affected the removal of Iron from groundwater. This due to suspended particle, cloudiness suspension of the supernatant water sample.

Turbidity was the main factor that influenced the removal of Iron from the sample water. In the oxidation of chlorine, turbidity decreased as the sand depth increased and filtration rate decreased, the removal of Iron increased.

In India, a study was performed using single pass constructed soil filter (CSF) that has a depth of 30 cm for the removal of iron from drinking water results indicated that an iron level in the effluent was less than 0.3 mg/l (Nemade *et al*.,2009).
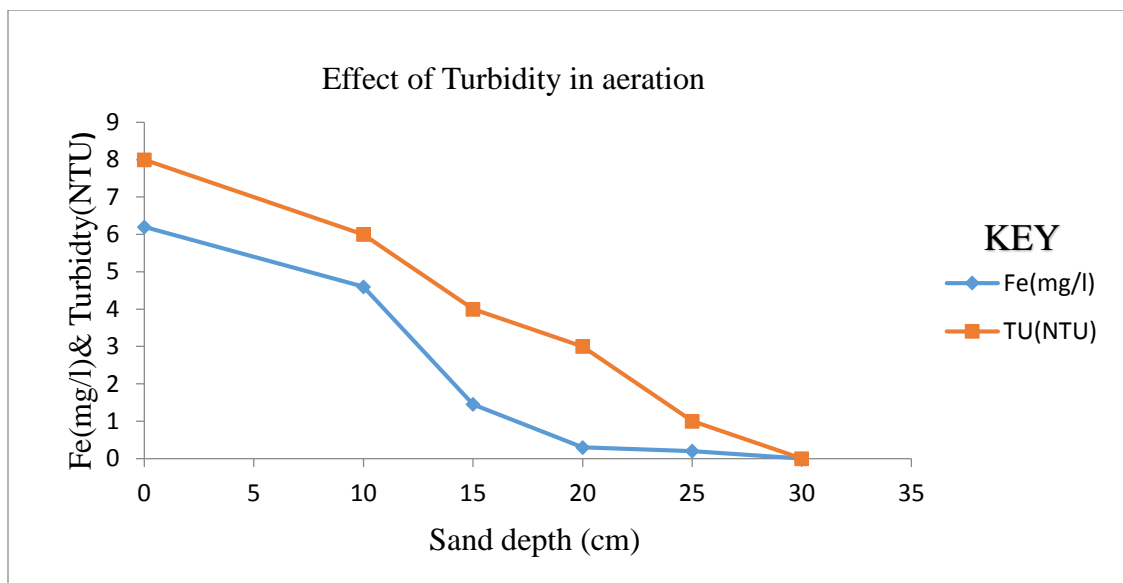
Figure 15: Turbidity on the removal of Iron in aeration process

According to Ahmed *et al*., (2009) states that the ability of removing iron salt from groundwater by using aeration and filtration system without any chemical additions. From his result that may be concluded that

1.The most economical sand depth according to the Egyptian Standard limit for Drinking Water for both, effluent turbidity (1 NTU) and effluent iron concentration (0.3 mg/l) are be summarized as; The best sand depth is more than 70 cm when influent turbidity is < 30 NTU and filtration rate is < 200 m^3 /m^2 / day.

2. After aeration of raw water most of the turbidity is settled during the first time of filtration.

3. Increasing in the filtration rate with constant sand depth increases the influent turbidity In addition, Ahmed *et al*., 2009, explained that the filter is normally clean and the spacing (voids) between sand particles are large enough to pass most of suspended solids. But, with the time running, the individual particles may block the pores. So, as the porosity of the filter media decreases the effluent turbidity decreases until a certain time and the effluent turbidity increases again especially for small sand depths.

4.3 Effect of Color on the removal of Iron

Colorimetric methods are based on measuring the intensity of color of a colored target chemical or reaction product. The optical absorbance is measured using light of a suitable wavelength. The concentration is determined by means of a calibration curve obtained using known concentrations of the determinant. The same as turbidity, color was enhanced the result of Iron from groundwater.

Table 9: The effect of color on the removal of iron from groundwater

Sand depth(cm)	Without aeration						With aeration					
	Course sand		Fine sand		Graded sand		Fine sand		Course sand		Graded sand	
	Fe (mg/l)	Color(TCU)	Fe (mg/l)	color(TCU)	Fe (mg/l)	Color(TCU)	Fe (mg/l)	Color(TCU)	Fe (mg/l)	Color(TCU)	Fe (mg/l)	Color(TCU)
0	6.2	6	6.2	6	6.2	6	5.15	10	5.15	10	5.1	10
10	4.60	5	4.9	4	5.0	13	4.06	5	4.2	10	4.80	15
15	1.45	3	4.8	3	4.3	5	3.80	3	3.60	8	4.05	18
20	0.30	1	3.0	3	3.3	3	3.5	1	3.02	5	3.50	11
25	0.2	0	0.95	2	2.75	0	1.75	0	2.40	3	2.75	9
30	0	0	0.2	1	0.75	2	1.07	0	0.85	0	1.85	3

From the above table (9) indicated that the Iron concentration directly proportional to color of the groundwater. The curve shows that Iron and color determination (analyzed) the concentration of iron decreased when color of water decrease at the sand depth increase.
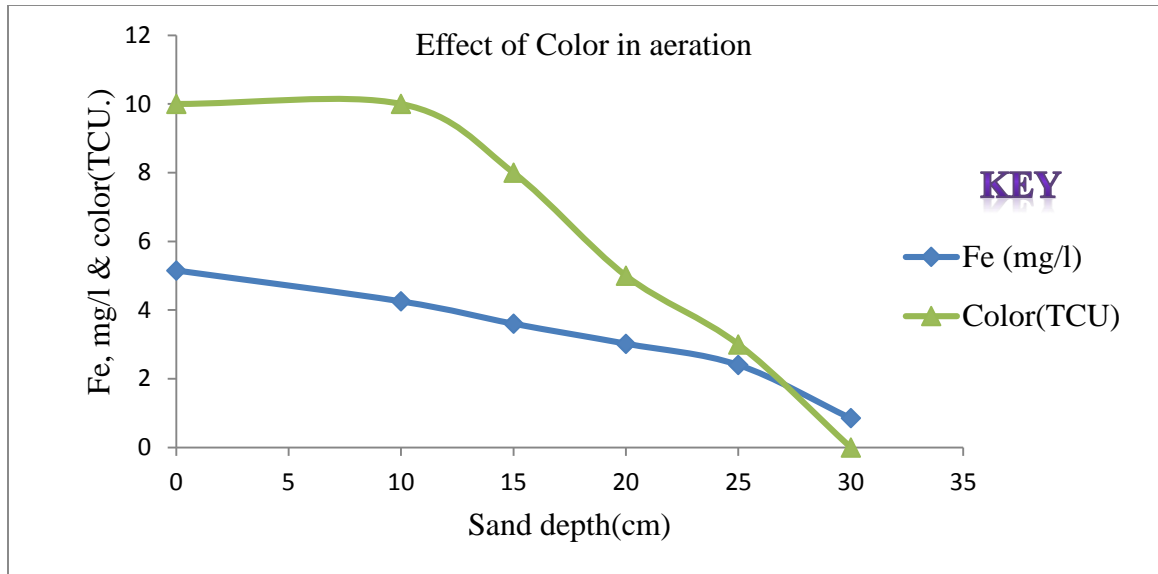
Figure 16: The removal of Iron on the effect color versus sand depth in aeration

From the above graph the sand depth is increase the color parameter decrease, this due water is flocculation, sedimentation and adsorption on the surface of the filtration in particle size.

In comparisons this experimental investigation from different authors innovation similarity: aeration, sedimentation then filtration were powerful adsorbent of the removal of iron from potable water and wastewater contaminant and water purification technology due to low cost, easily available and no need chemical addition. Finally, simple technology to design at community level as well as at household (HH) level. Difference: rock formation, source of natural zeolites, soil type, particle size and porosity of sand and soil formation of groundwater are different from country to country.
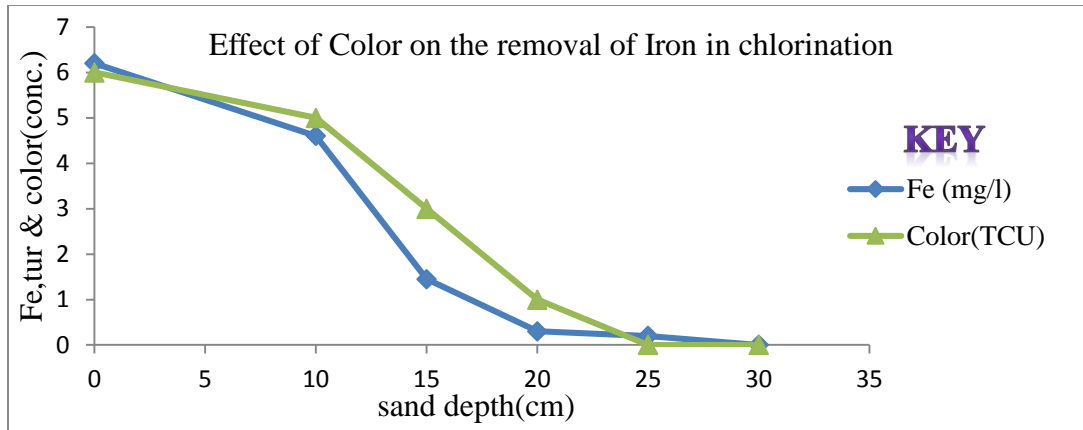
Figure 17: The removal of Iron on the effect color versus sand depth with without aeration

4.4 Effect of pH on the removal of Iron

pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection of public water supply. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower-pH water is likely to be corrosive. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems.

Table 10: The effect of pH on the removal of iron from groundwater

| Sand depth(cm) | Without aeration | | | | | | With aeration | | | | | |
| | Course sand | | Fine sand | | Graded sand | | Fine sand | | Course sand | | Graded sand | |
	Fe (mg/l)	pH	Fe (mg/l)	pH	Fe (mg/l)	pH	Fe (mg/l)	pH	Fe (mg/l)	pH	Fe (mg/l)	pH
0	6.2	7.9	6.2	7.9	6.2	7.9	5.15	8.1	5.15	8.1	5.1	8.1
10	4.60	8.1	4.9	8.05	5.0	8.0	4.06	8.0	4.2	8.2	4.80	8.15
15	1.45	7.95	4.8	7.95	4.3	7.75	3.80	8.05	3.60	8.0	4.05	8.25
20	0.30	7.95	3.0	7.95	3.3	7.85	3.5	7.95	3.02	7.6	3.50	8.10
25	0.2	7.90	0.95	7.12	2.75	7.85	1.75	7.95	2.40	7.6	2.75	8.30
30	0	8.0	0.2	8.0	0.75	7.95	1.07	7.12	0.85	7.2	1.85	7.95
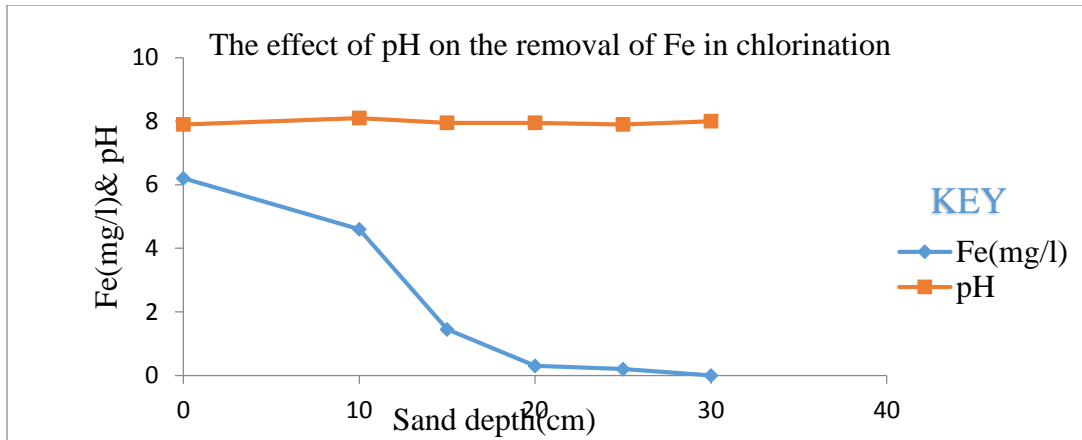
Figure 18: The effect of pH on removal of Iron from without aeration process

As the result of MH, 2011, Ethiopian water quality standard state that the range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in water where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0. In waters with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change), changes in pH induced by external causes may be quite dramatic. Extremes of pH can affect the palatability of a water but the corrosive effect on distribution systems is a more urgent problem. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable.
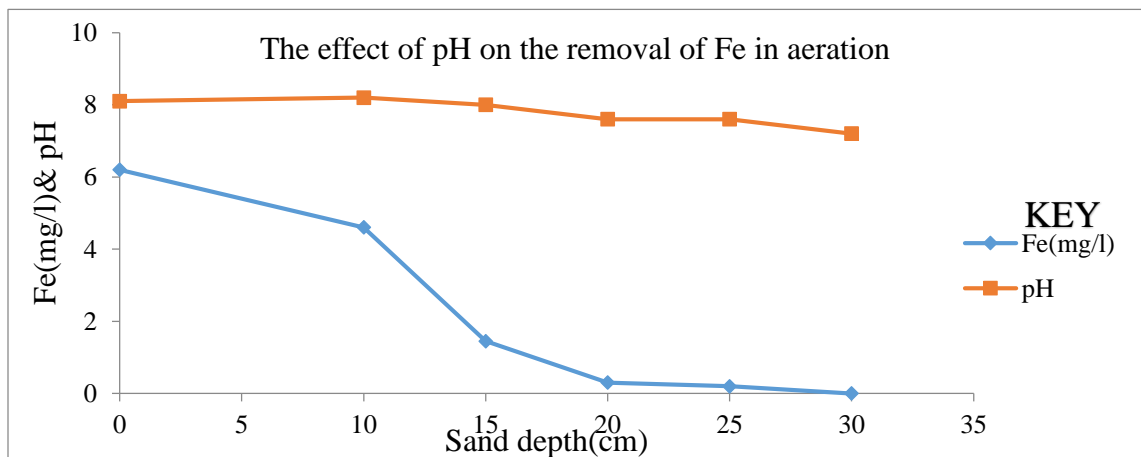
Figure 19: The effect of pH on removal of Iron in aeration process

According to Twort *et al., (*1985) result states that the pH value of most natural waters is in the range of between 4 - 9. Water with low pH levels (acidic water) is said to be soft and is found in peat land areas of a low pH value 4 - 6.9, water that originates in chalky limestone areas are regarded as hard water with high pH values 7.1 - 9. Water with a pH of 7 is neutral (Twort et al., 1985). As the pH of the water rises the levels of carbon dioxide are reduced, so too is the tendency for the water to dissolve the iron in the ground. It is for this reason that the unit processes of precipitation, coagulation-flocculation and chlorination are usually preceded by pH adjustment. It is therefore crucial to ensure that the solution pH is kept within specific limits in order to ensure that the required chemical reaction proceeds as quickly as possible (Twort *et al.,* 1985).

4.5 Effect Manganese on the removal of iron

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is used principally in the manufacture of iron and steel alloys, as an oxidant for cleaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. More recently, it has been used in an organic compound. Manganese greensands are used in some locations for potable water treatment. Manganese is an essential element for humans and other animals and occurs naturally in many food sources (WHO, 2006).

Table 11: The effect of Mn on the removal of iron from groundwater

Sand depth (cm)	Without aeration						With aeration					
	Course sand		Fine sand		Graded sand		Fine sand		Course sand		Graded sand	
	Fe (mg/l)	Mn (mg/l)	Fe (mg/l)	Mn (mg/l)	Fe (mg/l)	Mn (mg/l)	Fe (mg/l)	Mn (mg/l)	Fe (mg/l)	Mn (mg/l)	Fe (mg/l)	Mn (mg/l)
0	6.2	0.02	6.2	0.02	6.2	0.02	5.15	0.02	5.15	0.02	5.1	0.02
10	4.60	0.014	4.9	0.023	5.0	0.019	4.06	0.27	4.2	0.03	4.80	0.01
15	1.45	0.013	4.8	0.022	4.3	0.014	3.80	0.18	3.60	0.01	4.05	0.017
20	0.30	0.012	3.0	0.02	3.3	0.014	3.5	0.16	3.02	0.01	3.50	0.003
25	0.2	0.01	0.95	0.018	2.75	0.012	1.75	0.01	2.40	0.03	2.75	0.1
30	0	0.001	0.2	0.001	0.75	0.01	1.07	0.01	0.85	0.02	1.85	0.05

During the removal of iron from ground water by filtration using natural zeolites, manganese and iron mostly found in ground water, in my study manganese also not found largely like iron at higher concentration way. The statistical sketching of course sand in aeration and without aeration process like this.
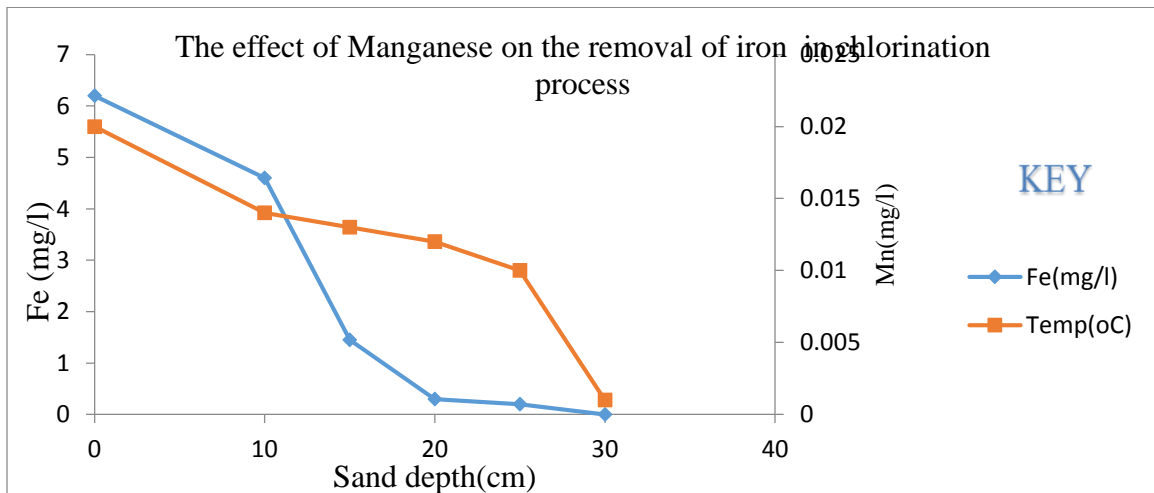
Figure 20: The effect of Mn on the removal of Iron from without aeration process

At the sand depth increase, Manganese concentration decrease, iron concentration decreased during the sand depth increase, without aeration (chlorination) not highly affected iron concentration manganese water quality parameters.

Mn was a factor for the removal of Iron, not significantly influenced Iron concentration like color, odor and turbidity parameter. This due to soil type of the Town mostly clay soil it interfere excess of Iron concentration of the environment. This excess concentration of Iron percolation the soil during rainy season mostly. So, the groundwater could be affected by Iron concentration.

According to Michael, 2009 explained that two contaminants in water supplies, iron is the most common .Manganese is typically found in iron-bearing water. In the ferrous state, (Fe^{2+}) iron is soluble in water and is oxidized in the presence of air into the insoluble form of (Fe^{3+}) ferric form. These metals are not harmful to health in general, but their effects are aesthetically unpleasant as they impart a cloudy appearance, odor and a bitter taste to water which are detectable at very low concentrations. Although ferruginous water is perfectly safe to the majority of people, it can pose a health risk to a minority of people who suffer a condition of heredity hemochromatosis.

The symptoms of hemochromatosis vary and can include: chronic fatigue, arthritis, heart disease, cirrhosis, cancer, diabetes, thyroid disease, impotence, and sterility. In the United States iron overload is primarily due to a genetic disorder known as hereditary hemochromatosis. It is characterized by lifelong excessive absorption of iron accumulating in body organs, from, for example ferruginous drinking water (Michael, 2009).
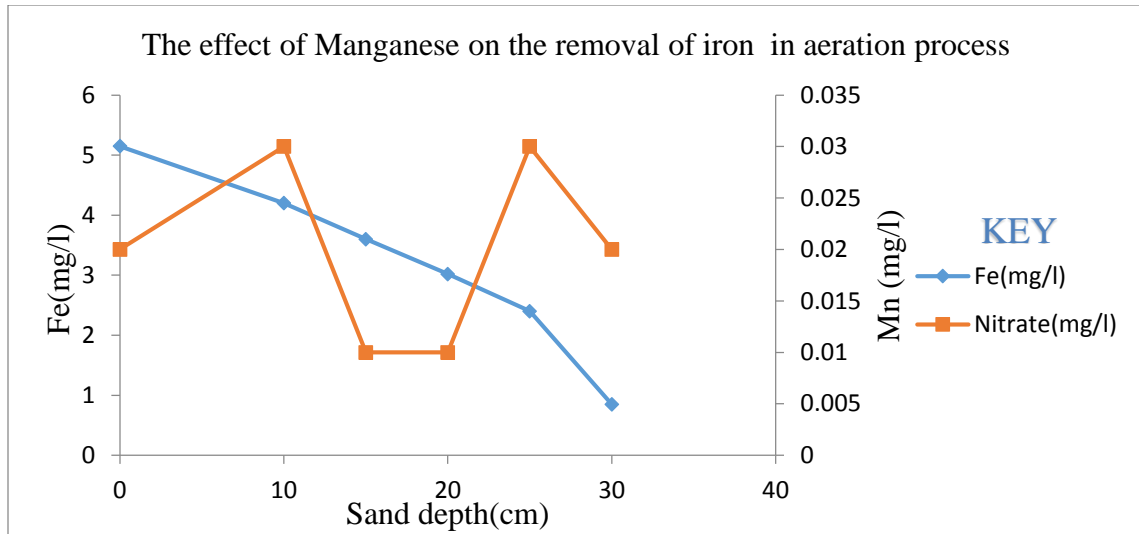
Figure 21: The effect of Mn on the removal of Iron in aeration process

The above graph determined that Iron concentration decreased, sand depth increased, Manganese concentration, increased after aeration from sand depth (0-10)cm, from (10-15)cm Mn concentration decreased, from (15-20)cm, remain constant, from (20-25)cm, increased Mn concentration, from (25-30)cm, decreased Mn concentration. Finally, Mn during aeration process variable concentration, this might be the drawback of aeration process.

4.6 Effect Nitrate on the removal of iron

Chemicals are used in agriculture on crops and in animal husbandry. Nitrate may be present as a consequence of tillage when there is no growth to take up nitrate released from decomposing plants, from the application of excess inorganic or organic fertilizer and in slurry from animal production.

This form of pollutant in drinking water is as a direct result of farming. The nitrates leach into the aquifers affecting groundwater or as farm run-off running into rivers, streams and lakes, affecting surface water supplies. The main health concern of nitrate pollution is "blue baby" syndrome or methaemglobinaemina

Table 12: The effect of Nitrate on the removal of iron from groundwater

| Sand depth(cm) | Without aeration | | | | | | With aeration | | | | | |
| | Course sand | | Fine sand | | Graded sand | | Fine sand | | Course sand | | Graded sand | |
	Fe (mg/l)	NO_3(mg/l)	Fe (mg/l)	NO_3(mg/l)	Fe (mg/l)	NO_3 (mg/l)	Fe (mg/l)	NO_3(mg/l)	Fe (mg/l)	NO_3(mg/l)	Fe (mg/l)	NO_3(mg/l)
0	6.2	0.25	6.2	0.25	6.2	0.25	5.15	0.25	5.15	0.25	5.1	0.25
10	4.60	0.385	4.9	0.32	5.0	0.32	4.06	0.45	4.2	0.23	4.80	0.35
15	1.45	0.35	4.8	0.2	4.3	0.31	3.80	0.41	3.60	0.25	4.05	0.3
20	0.30	0.3	3.0	0.2	3.3	0.3	3.5	0.31	3.02	0.35	3.50	0.2
25	0.2	0.3	0.95	0.2	2.75	0.29	1.75	0.38	2.40	0.20	2.75	0.1
30	0	0.2	0.2	0.2	0.75	0.25	1.07	0.25	0.85	0.19	1.85	0.25

In this study, nitrate was not significantly affected the removal of iron due to the pollution of groundwater not contaminated the source nitrates like urea, fixing bacteria and so on.

In the beginning suggested that the borehole, digging at local farm land, I had checked that the concentration of nitrate in the groundwater very low. So, the water supply was not suffer the problems of nitrate in this study.
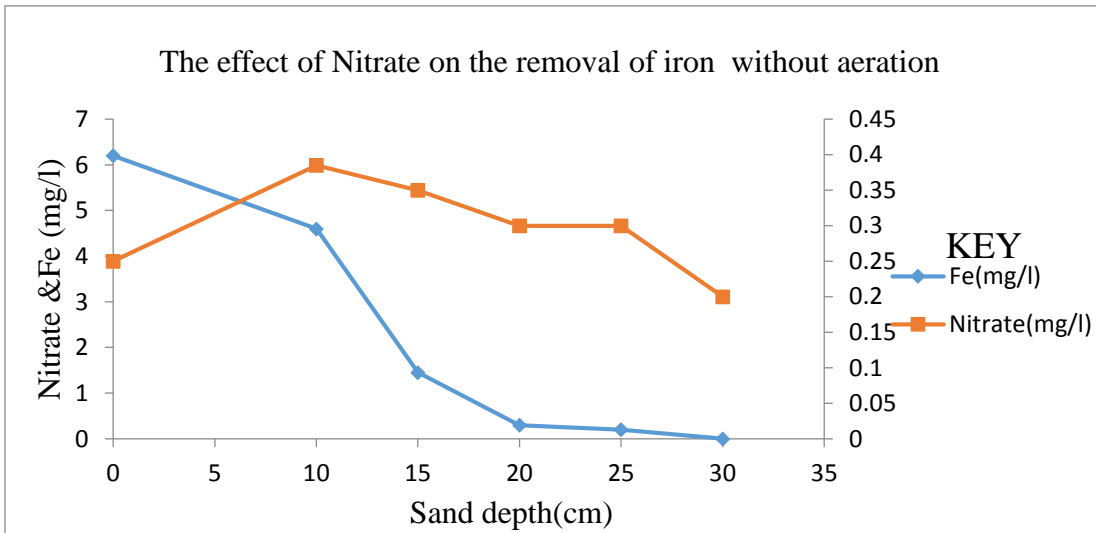
Figure 22: The effect of Nitrate on removal of Iron from without aeration process

In the result of the study nitrate was enhanced during the removal of Iron from groundwater ,nitrate mostly based on cultivation of crop and fixation of bacteria in farming occupational status, however ,in the Town low agricultural cultivation so nitrate was not significantly affected the removal of Iron. Even though, in chlorination process nitrate decreased its concentration before than raw sample.

During aeration process not enhanced like chlorination, once increased and decreased significantly not alter the efficiency of Iron concentration figure .22 can be illustrated the nitrate concentration on the removal of Iron from groundwater
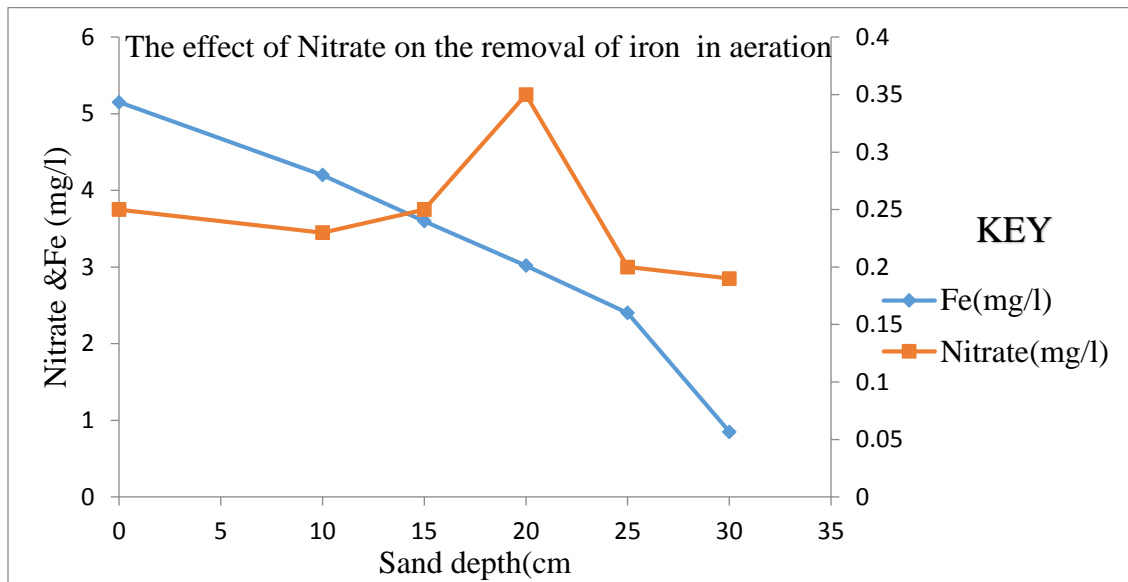
Figure 23: The effect of Nitrate on removal of Iron in aeration process

4.7 Effect temperature on the removal of iron

Table 13: The effect of temperature on the removal of iron from groundwater

| Sand depth(cm) | Without aeration | | | | | | With aeration | | | | | |
| | Course sand | | Fine sand | | Graded sand | | Fine sand | | Course sand | | Graded sand | |
	Fe (mg/l)	Tem(°C)	Fe (mg/l)	Tem(°C)	Fe (mg/l)	Tem(°C)	Fe (mg/l)	Tem(°C)	Fe (mg/l)	Tem(°C)	Fe (mg/l)	Tem(°C)
0	6.2	24.1	6.2	24.1	6.2	24.1	5.15	24.1	5.15	24.1	5.1	24.1
10	4.60	22.1	4.9	23.4	5.0	22.5	4.06	23.4	4.2	22.2	4.80	21.7
15	1.45	22	4.8	23.3	4.3	22.1	3.80	23.5	3.60	23.1	4.05	22.6
20	0.30	21.6	3.0	22.9	3.3	22.9	3.5	22.1	3.02	21.7	3.50	23.5
25	0.2	22.8	0.95	22.5	2.75	21.6	1.75	23.6	2.40	21.9	2.75	22.4
30	0	21.1	0.2	22,1	0.75	22.1	1.07	24	0.85	22.1	1.85	21.3

In this study, temperature significantly not altered the removal of iron, simply once up and down not proportionally increased its concentration of the sample.
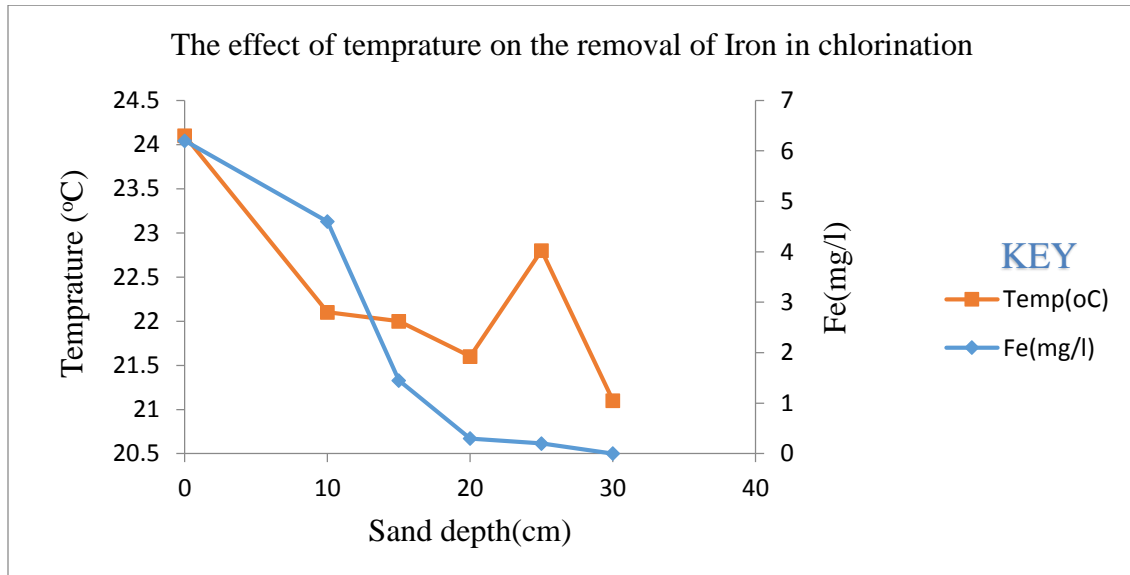
Figure 24: The effect of temperature on removal of Iron from without aeration process

High temperature may enhance growth of microorganisms & may increase test. Odor, color & corrosion the groundwater supply. Temperature is the physical parameter that involved during groundwater analysis.
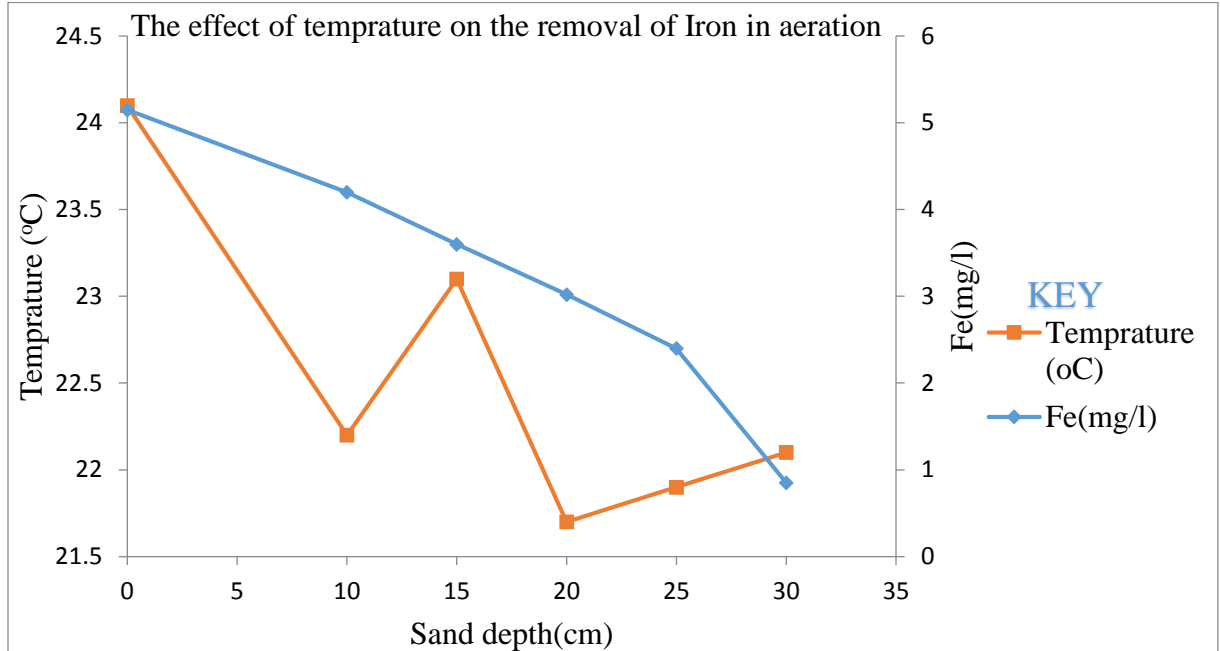
Figure 25: The effect of temperature on removal of Iron in aeration process

4.8 Effect conductivity on the removal of iron

According to the result of Hassanien, 2004 reported that the current passing in water resulted in evolution of heat energy and consequently temperature rise. The conductivity of a material depends on several factors including temperature and the presence of impurities. It was usually related to the total dissolved solids. The low removal of total dissolved solids and small decrease of conductivity with increasing residence current time was a concern (table). The conductivity of distilled water is normally about 1 uS whereas rain water may have conductivity in the range of (20-40 µS/cm), as it contains dissolved ions. The decrease of both conductivity and TDS removal confirm (Barkley *et al*., 1993) the electrocoagulation theory that the electric current neutralizes the electrostatic charges on suspended materials and prompts the precipitation of certain soluble ionic species, and thereby facilitate their removal.

Table 14: The effect of conductivity on the removal of iron from groundwater

Sand depth(cm)	Without aeration						With aeration					
	Course sand		Fine sand		Graded sand		Fine sand		Course sand		Graded sand	
	Fe (mg/l)	Conductivity (µS/cm)	Fe (mg/l)	Conductivity (µS/c)	Fe (mg/l)	Conductivity (µS/cm)	Fe (mg/l)	Conductivity (µS/cm)	Fe (mg/l)	Conductivity (µS/cm)	Fe (mg/l)	Conductivity (µS/cm
0	6.2	173.5	6.2	173.5	6.2	173.5	5.15	173.5	5.15	173.5	5.1	173.5
10	4.60	168.7	4.9	171	5.0	168	4.06	163	4.2	171	4.80	169
15	1.45	168	4.8	171	4.3	168.5	3.80	161	3.60	168	4.05	166
20	0.30	158.8	3.0	171.3	3.3	166.5	3.5	161	3.02	171	3.50	172
25	0.2	157.7	0.95	171.3	2.75	166.3	1.75	161	2.40	170	2.75	165
30	0	157	0.2	171.6	0.75	167	1.07	165	0.85	180	1.85	171
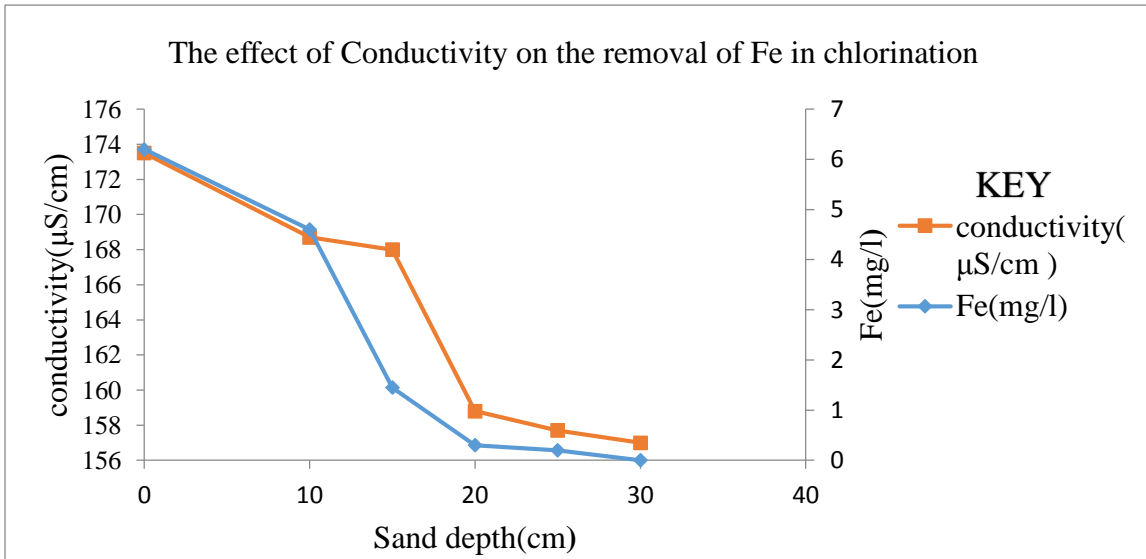
Figure 26: The effect of conductivity on removal of Iron from without aeration process

The proper development of monitoring wells is essential to the ultimate collection of "representative" water samples. During the drilling process, fines are forced through the sides of the bore hole into the formation, forming a mud cake that reduces the hydraulic conductivity of the materials in the immediate area of the well bore. To allow water from the formation being monitored to freely enter into the monitoring well, this mud cake must be broken down opposite the screened portion of the well and the fines removed from the well. This process also enhances the yield potential of the monitoring well, a critical factor when constructing monitoring wells in low-yielding geologic materials

In the study conductivity is one physical factor during chlorination (without aeration) conductivity somehow increased and other case decreased as Iron concentration decreased.
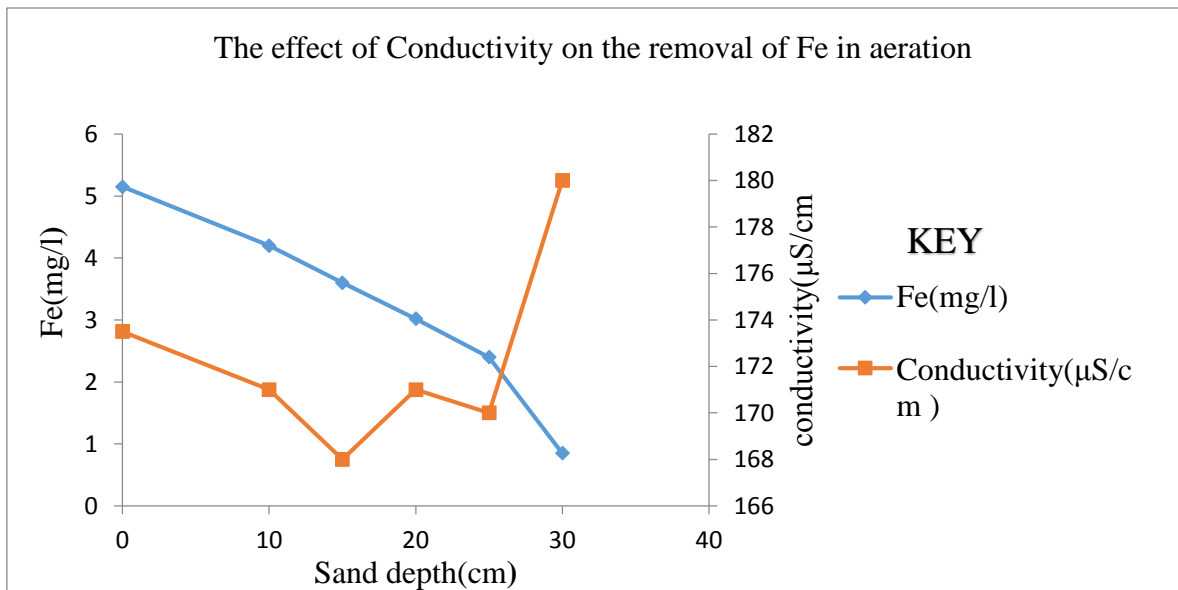
Figure 27: The effect of conductivity on removal of Iron in aeration process

Determination of filtration rate:

The flow rate for each type of sand filter was determined using a graduated cylinder of known volume (one liter) in a certain time according to the following equation:

Flow rate = (Volume of cylinder (liter))/(Time (sec.)) = liter / sec or m^3/hr   (1)

Filtration rate = (Flow rate) / (area of the filter) = m^3/m^2/hr   (2)

Design of an ideal sand filter:

The course sand was the best type of sand since it had the best percentage of removal of iron at 30 cm depths of sand.

The course sand filtered of 30 cm depth yield the permissible limit specified in WHO guideline. Such values were reached after approximately 30 hr continuous time of filtration without deterioration of filtered water quality. Assuming a filtration rate of 2.4 $m^3/m^2/hr$, a filter diameter (D) meter, sand depth of 30 cm, and filter run time of 30 hrs.

Filtration rate =flow rate/area of the filter $\quad = \quad m^3/m^2/hr$

2.4 = flow rate/$3.14*(D)^2/4$

Flow rate =$1.884 (D)^2$

Flow rate=volume of cylinder/time=$1.884(D)^2$= V/30hr

$D^2 = V/56.52$ (3)

For example, for design of an actual house filter for a family consisting of 5 persons with an average water consumption of 7 liters per person/day (for drinking, food preparation and cleanup). This leads to a total consumption of 35 liters per day and a total water consumption of almost one cubic meter per month. After three months representing the period of the filter run, the volume required for 3 months
= Average water consumption *No. of persons*30 days*3 months

$$= 7 \text{ (liters) } *5 \text{ (persons) } *30 \text{ (days)}*3 \text{ (months)}$$

$$= 3150 \text{ liters} = 3.15 \text{ m}^3$$

$$D^2 = V/56.52$$

$$= 3.15/56.52$$

$$= 0.055732$$

$$D = 0.236077m= 23.6 \text{ cm}=24 \text{ cm the diameter of the circular tank}$$

Therefore, The diameter of the circular tank filter = 24cm and total height = 30 cm
This design for household (HH) level as community level done the same as it is.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1 Conclusions

A natural zeolite showed better results for iron removal as adsorptive, however the percentage of iron removal declined along with the rise of its initial concentration in solution. Natural zeolite did not cause an increase in pH values in solution, moreover a slight fall was observed.

At 30 cm sand depth filtration is the most effective way of the removal of Fe in aeration and without filtration process, with removal percentage of 83.49 % and 100 % respectively by course sand from sample of groundwater.

Iron concentration was recorded to drop below the permissible limits specified in WHO Guideline and Ethiopian Standard for drinking water quality from an initial concentration to final concentration 6.20 to 0 mg/L respectively.

Sand depth, turbidity, color are the major factor that affect the removal of iron from public groundwater in the Town.

In the removal of iron using filtration sand washing, drying, washed drain gravel from 4mm to 12mm size incorporated under the filtration material before sand media immersed. The retention time for flocculation of iron oxide (II) in the laboratory more than 28 hour were used for better yield iron concentration and other parameter analysis.

Natural Zeolites were effective adsorbent based on effective size, particle size and porosity the sand and also the nature of the sand highly influenced the removal of Iron from groundwater.

Finally, aeration then sand filtration better removal of Iron, Advantage of such treatment were simplicity, easily available the natural zeolites, low cost design as house hold and a community level, and without the need of chemical addition. Moreover, periodic washing for sand filter or replacement of sand by other sand was needed in order to get sufficient flow rate.

5.2 Recommendations

1. I recommended that course sand and Fine sand remove iron in both case in the aeration and without aeration for Asossa Town were effective. For the time being in the Town there is no aeration material and other facility to design this technology. For future time this technology better modification for treatment way of the Town in the case of heavy metal removal as well as wastewater treatment.

2. Sand filtration was better than chlorination, it was reduced chemical cost, low cost, it needs small labor cost and also it used for a long period of time with a care of sanitation.

3. Therefore, Natural Zeolites were effective for removal of iron in groundwater and also better treatment of water quality parameter like physical, biological and chemical.

4. Sand being the cheapest adsorbing surface is very effective in removal of dissolved iron from drinking water and the rate of filtration is also very high. The only demerit is subsequent development of bacterial layer due to rigorous use. Again back washing is needed from time to time.

5. Natural zeolites for future another alternative for treatment plant substitute chlorination disinfection process.

6. At household (HH) level and community level the base for practical application in water purification technology.

7. For university and other researcher, I recommended to address the effects of different source of natural zeolites availability in relation to environmental friendly, economic improvement and cost reduction in rapid sand filter and slow sand filter for future studies.

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Annex 1

Table 15: The physical and chemical parameter of raw water sample before aeration

Parameter	Unit	3:20 Am 11/07/2016	4:15 Am 1/08/2016	8: 30 Pm 5/9/2016	Mean	Standard Deviation (SD)
Turbidity	NTU	0	8	4	4	4
Color	TCU	0	10	5	5	5
pH	-	7.78	7.90	7.72	7.75	0.09
Chloride	mg/l	0.2	0.1	0	0.1	0.1
Temperature	ºC	22.8	24.15	25.5	24.15	1.35
Iron	mg/l	6.20	5.60	5.90	5.90	0.3
Manganese	mg/l	0.007	0.15	0.30	0.153	0.146
Nitrate	mg/l	0.208	0.302	0.25	0.255	0.047
Conductivity	µs/cm	175.1	172.1	173	173.55	1.539

Table 16: The physical and chemical parameter of raw water sample after aeration

Parameter	Unit	3:20 Am 11/07/2016	4:15 Am 1/08/2016	8: 30 Pm 5/9/2016	Mean	Standard Deviation (SD)
Turbidity	NTU	0	6	3	3	3
Color	TCU	8	7	3	6	2.645
pH	-	7.90	8.0	8.30	8.10	0.208
Chloride	mg/l	0.8	0.9	0.6	0.7	0.152
Temperature	^oC	23.3	24.15	26.5	24.65	1.657
Iron	mg/l	4.85	5.60	4.87	5.15	0.427
Manganese	mg/l	0.19	0.17	0.30	0.22	0.07
Nitrate	mg/l	0.16	0.208	0.33	0.23	0.087
Conductivity	µs/cm	170	166.7	168.6	168.43	1.656

Table 17: The physical and chemical parameter of raw water sample in chlorination

Parameter	Unit	3:20 Am 11/07/2016	4:15 Am 1/08/2016	8:30 Pm 5/9/2016	Mean	Standard Deviation (SD)
Turbidity	NTU	0	0	0	0	0
Color	TCU	6	2	1	3	2.645
pH	-	8.20	7.90	7.60	7.90	0.3
Chloride	mg/l	0.2	0.4	0.1	0.3	0.152
Temperature	ºC	22.5	23.4	26.5	24.13	2.098
Iron	mg/l	6.50	4.90	7.20	6.20	1.179
Manganese	mg/l	0.02	0.01	0.03	0.02	0.01
Nitrate	mg/l	0.1	0.306	0.2	0.202	0.103
Conductivity	µs/cm	170.8	171.8	168.1	170.23	1.914

Table 18: Physical and Chemical analysis after filtration in aeration process

	Sand types														
	Course sand					Fine sand					Grain sand				
	Sand depth(cm)					Sand depth(cm)					Sand depth(cm)				
Parameter	*10*	*15*	*20*	*25*	*30*	*10*	*15*	*20*	*25*	*30*	*10*	*15*	*20*	*25*	*30*
Turbidity	6	4	3	0	0	2	2	2	0	0	8	6	6	5	5
Color	10	8	5	0	1	5	1	0	0	0	15	18	11	9	3
pH	8.2	8.05	7.2	7.6	7.6	8	8.05	7.95	7.95	7.12	8.15	8.25	8.10	8.30	7.95
Chloride	12.7	3.1	2.9	0.3	0.5	0.7	0.01	0	0	0	11.5	1.5	0.2	0.18	0.25
Temperature	23.4	23.5	22.1	23.6	24	22.2	23.1	21.7	21.9	22.1	21.7	22.6	23.5	22.4	21.3
Iron	4.25	3.60	3.02	2.4	0.85	4.06	3.80	3.50	1.75	1.07	4.80	4.05	3.50	2.75	1.85
Manganese	0.03	0.01	0.01	0.0003	0.02	0.27	0.18	0.16	0.016	0.012	0.011	0.017	0.003	0.1	0.05
Nitrate	0.45	0.41	0.308	0.38	0.25	0.2332	0.25	0.35	0.2	0.19	0.35	0.3	0.2	0.1	0.25
Conductivity	172	168	171	170	180	163	161	161	161	165	169	166	172	165	171

Table 19: Physical and Chemical analysis after filtration without aeration process

Parameter	Course sand					Fine sand					Grain sand				
	Sand depth(cm)					Sand depth(cm)					Sand depth(cm)				
	10	*15*	*20*	*25*	*30*	*10*	*15*	*20*	*25*	*30*	*10*	*15*	*20*	*25*	*30*
Turbidity	4	4	1	0	0	2	0	0	0	0	10	7	6	4	3
Color	5	8	5	0	0	5	2	0	0	0	13	5	3	2	0
pH	8.1	7.95	7.95	7.95	7.90	8	8.05	7.95	7.95	7.12	8.0	7.75	7.85	7.85	7.95
Chloride	5	0.4	0.1	0	0	2.4	1.5	0.5	0.3	0.21	1.2	0.82	0.72	0.32	0.24
Temperature	22.1	22	21.6	22.8	21.1	23.4	23.3	22.9	22.5	22.1	22.9	23.6	22.7	21.6	22.1
Iron	4.60	1.15	0.3	0.2	0	4.90	4.80	3.0	0.95	0.2	5.0	4.30	3.30	2.75	0.75
Manganese	0.014	0.013	0.012	0.001	0	0.023	0.022	0.02	0.018	0.014	0.019	0.014	0.014	0.012	0.001
Nitrate	0.385	0.35	0.3	0.3	0.2	0.32	0.2	0.2	0.2	0.2	0.32	0.31	0.3	0.29	0.25
Conductivity	168.7	168	155.8	157.7	157	171	171	171.3	171.3	171.6	168	168.5	166.5	166.3	167

Annex 2

Procedural steps of laboratory analysis

Annex 3

A. Material (Equipment)

1. Photometer (Model, wagtech 7100)
2. Conductivity meter
3. Mesh (sieve analysis) (size 0.25, 0.5, and 1.0 mm)
4. Acid-washed glassware eye glass
5. Test-tube (10 and 20 ml)
6. Cylindrical jack
7. Graughted cylinder (50,100, and 200ml)
8. Stiller
9. Washing bath
10. Jar (5, 20 liters)
11. Sprayer
12. Computer, laptop

B. Chemicals and Reagents

a. Concentrated hydrochloric acid (HCl)
b. Phenol red tablet for pH determination
c. Nitrate powder and tablet 1 and 2
d. Reagent of iron in tablet form (HR)
e. Manganese No 1 and 2
f. Chlorine powder
g. Distilled water
h. Chlorine tablet 1 and 3

Annex 4

Some of laboratorial photo during Experimental analysis