بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

(Effect of Dumping Waste Sludge from Mogran Water Treatment Plant (MWTP) on Residual Aluminum in Water and Soil in Blue Nile).

تأثير مخلفات محطة مياه المقرن على تركيز الالمنيوم المتبقي في مياه وتربة النيل الازرق.

A Thesis Submitted in partial fulfillment for the requirements of the degree of M.Sc. in Chemistry.

By :Zakieldin Mohamed Abduelmajeed Abuelgasim

Supervisor: Dr. Mutasim Maknoon Hassan

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بسم الله الرحمن الرحيم

الآية

قال تعالى : (وترى الارض هامدة فإذا أنزلنا عليها الماء اهتزت وربت و أنبتت من كل زوج بهيج).

صدق الله العظيم

الحج الاية(5).

Abstract

This study aims to determine the residual aluminum in water and soil resulting from dumping the waste and sludge disposal from MWTP to the Blue Nile. This plant uses Poly Aluminum Chloride(PAC) as a coagulant in water treatment plant. This research reflects the impact of disposed waste on the quality of Nile water and produced water.

Aluminum was measured at different stages of water treatment including raw water, after adding poly aluminum chloride, after sedimentation, after filtration, after chlorination and treated water. The results were found to be as follows:

0.013, 2.263, 0.044, 0.029, 0.027 and 0.027 ppm respectively. Aluminum concentration was measured in Blue Nile water at the dumping area at which Mogran Treatment Plant (MWTP) drains the waste. Aluminum concentration at the dumping point, at distances 50, 100, 200, 500 and 1000m at the direction of the water current were found to be 8.296, 0.015, 0.014, 0.009, 0.011 and 0.014 ppm respectively. Opposite to direction of the water current at distances 100, 200, 500 and 1000m the concentration of aluminum were found to be 0.013, 0.013, 0.012 and 0.012ppm respectively.

Aluminum concentration in other shore at Toti Island at distances 100m at the direction and opposite direction of the water current from the

point corresponding to the west reject were found to be 0.013 and 0.012ppm respectively.

Aluminum was also measured in soil at the dumping point (where the waste is rejected) and at distances 50m, 100m, 200m, 500m and 1000m at the direction of the current water from the point of dumping the waste. The concentrations were found to be 203.643, 273.472, 213.446, 206.658, 308.5 and 185.5ppm respectively.

The concentration of aluminum in the soil at distance 100, 200 and 1000 m from the dumping point at the opposite direction of the water current were found to be 234.565, 184.634 and 180 ppm respectively.

المستخلص

في هذا البحث تم دراسة متبقي الالمنيوم في الماء والتربة الناتج من صرف محطة المقرن لمعالجة المياه. هذه المحطة تستخدام مادة البولي المنيوم كلورايد كمادة مروبة .هذا البحث يعكس تأثير هذه المخلفات على جودة مياه النيل والمياه المنتجة.

تم قياس الالمنيوم في الماء الخام وبعد اضافة البوليمر وبعد عملية الترسيب وبعد الفلتر وبعد عملية الكلورة ومن الصنبور مباشرة من الماء المعالج، ورصدت النتائج كالاتي:

0.013، 2.263، 0.044، 0.029، 0.027 و 0.027 جزء من المليون على التوالي.

تم تقدير الالمنيوم في مياه النيل الازرق عند منطقة مصب صرف محطة المقرن المحتوي علي كمية عالية من الالمنيوم وحول هذه المنطقةعلى مسافة 50، 100، 200، 500 و 1000 مترفي اتجاه تيار الماء وقد وجد تركيز الالمنيوم 8.296، 0.015، 0.014، 0.009 ، 0.011 و 0.014 جزء من المليون على التوالي. تركيز الالمنيوم على بعد 100، 200 و1000 متر عكس اتجاه تيار الماء هو 0.013، 0.013 و0.012 جزء من المليون علي التوالي. أما تركيز الالمنيوم في الضفة الاخرى عند جزيرة توتي عند النقطة المقابلة لنقطة المصب وحولها على بعد 100 متر في اتجاه التيار وعكس اتجاه التيار هو 0.013 و 0.012 جزء من المليون علي التوالي.

تركيز الالمنيوم في التربة عند منطقة مصب الصرف وحولها على مسافة 50, 100, 200, 500, 1000 متر من منطقة المصب في اتجاه تيار الماء ورصدت النتائج كالاتي:

203.643, 273.472, 213.446, 206.658, 308.5 و 185.5 جزء من المليون علي التوالي.

تركيز الالمنيوم على مسافة 100، 200 و 1000متر عكس اتجاه تيار الماء هو234.565، 184.643 و 180.5 جزء من المليون علي التوالي .

Dedication

I dedicate this effort to the spirit of my father who moved quickly to the hereafter, I ask God his mercy and forgiveness.

To my mother happen and I ask allah to give her health and happiness.

To my brothers and sisters.

Acknowledgment

In the beginning I would like to thank God who help me to complete this research.

Thanks to all Sudan University staff, and I would like to extend my sincere thanks to Dr. Mutasim Maknoon, who provided me with the valuable information that enabled me to accomplish this work.

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List of abbreviations

WHO: World Health Organization

MWTP: Mogran Water Treatment Plant

PAC: Poly Aluminum Chloride

DOC: Direction of water Current

AD: Alzheimer Disease

ALS: Amyotrophic Leteral Sclerosis

PD: Perkinson Dementia

NTU: Niephlometric Turbidity Unit

USFDA: United State Food and Drug Administration

USEPA: United State Environmental Protection Agency

UK: United Kingdom

HAAs: Halo Acetic Acids

THMs: Tri Halo Methanes

JAWWA: Journal of American Water Work Association

JE Chem. Eng : Journal of Environmental Chemical Engineering.

Chapter one:

Introduction

1.0 Introduction

Aluminum (Al) is one of the trace inorganic metals present in drinking water. Aluminum based coagulants especially aluminum sulfate (better known as alum) or poly aluminum chloride (PAC) are commonly used in drinking water treatment to enhance the removal of particulates, colloids and to some extent the dissolved substance via coagulation process. The treatment of surface water with aluminum sulfate has been in operation for over a hundred years all over the world. The use of alum as a coagulant in water treatment often leads to higher concentration of aluminum in the treated water than the raw water itself if the treatment process is not efficient. This because the added alum to the raw water is not removed during treatment and remains as a residual aluminum in the treated water. The occurrence of aluminum in treated water has been considered for many years to be undesirable aspect of treatment practice. There is a considerable concern throughout the world over the level of aluminum found in drinking water source (raw water) and treated water. This has arisen mainly for two reasons. Firstly, acid rain has caused the aluminum level in many fresh water sources to increase. A high concentration of aluminum in treated water give rise to turbidity, reduces disinfection efficiency, and may be precipitated as $Al(OH)_3\downarrow$ during the course of distribution. Secondly, the possibility of association between aluminum and neuropathological diseases including presenile dementia and Alzheimer disease is frequently hypothesized **(Driscoll C. T, et. al 1987, Pattman** A 1992).

1.1 **Residual aluminum**

This study deals with the residual aluminum (aluminum left in treated water and entering into distribution system) and the factors influencing its distribution. Residual aluminum consists of dissolved and particulate species. Particulate aluminum can be easily removed by efficient operation of solid liquid separation facilitate such as clarifiers and filters. Dissolve aluminum species are found in complex form, and can include complexes with natural organic matter, fluoride, phosphate, sulfate and hydroxide ion. At acidic pH (pH= 5.8) and high fluoride concentration, complexation reaction between aluminum and fluoride are quite efficient. Al-F complex is soluble which increases the residual aluminum concentration in water. At alkaline pH, hydroxide ion competes fluoride and form aluminum hydroxide theoretically this will minimize the impact of fluoride on residual aluminum. Natural organic matter is also known to form strong complex with aluminum, but may affects residual aluminum in treated water, depending on the level of organic matter and percentage removal of it from water. Temperature, pH, turbidity of water are important factors in determining aluminum solubility and consequently residual aluminum. Aluminum is an amphoteric element, it is soluble at extremely acidic and alkaline pH conditions, but is insoluble at near neutral pH value (7 → 7.5). **(Van J. E and Edzwald J. K 1990, Nilson R** 1992**).**

Chapter two:

Literature review

Literature review

2.0 Background of the River Nile

The Nile probably gets its name form "nahal" which means "river valley" in Semitic, later "neilos" in Greek and "nilus" in Latin. It is the world's longest river, stretching 95 4,187 miles from its source in the mountains of Burundi. The source of the river is so far from the Mediterranean that it took man until the middle of the 20th century to find it. For centuries, the most accurate source of knowledge on the location of this source were the writings of Herodotus (Greek Historian, 460 BC), who wrote that the Nile's source was a deep spring between two tall mountains. When Nero ordered his centurions to follow the flow of the river in order to find its source, they got no further than the impenetrable valley of the Sudan. John Henning Speke thought that he had finally found the source when he reached Lake Victoria in 1862, only to be later proven wrong and forgotten by history. In 1937, the source was finally stumbled upon by the little known German explorer Bruckhart Waldekker(**Wikipedia, 2005**).

The Nile is formed by three tributaries, the Blue Nile, the White Nile, and the Atbara. The White Nile rises from its source in Burundi, passes through Lake Victoria, and flows into southern Sudan. There, near the capital city of Khartoum, the White Nile meets up with the Blue Nile which has its source in the Ethiopian highlands, near Lake Tana. Over

53% of the Nile's waters come from the Blue Nile. The two flow together to just north of Khartoum, where they are joined by the waters of the Atbara, whose source is also located in the Ethiopian highlands. The river then flows north through Lake Nasser, the second largest man-made lake in the world, and the Aswan Dam before splitting into two major distributaries just north of Cairo. The two distributaries are the Rosetta branch to the west and the Dameita to the east. In ancient times, the number of distributaries was much greater, but slow water flow, human interference, and the accumulation of silt had led to the disappearance of all the other major distributaries. This has effectively led to the desertification of large stretches of Egyptian land **(Wikipedia**, **2010)**.

2.1 Tributaries and distributions

The drainage basin of the Nile covers 3,254,555 square kilo meters (1,256,591 sq miles), about 10% of the area of Africa. There are two great tributaries of the Nile, joining at Khartoum: the White Nile, starting in equatorial East Africa, and the Blue Nile, beginning in Ethiopia. Both branches are on the western flanks of the East African Rift, the southern part of the Great Rift Valley. Below the Blue and White Nile confluence the only remaining major tributary is the Atbara River, which originates in Ethiopia north of Lake Tana, and is around 800 kilometers (500 miles) long. It flows only while there is rain in

Ethiopia and dries very fast. It joins the Nile approximately 300 kilometers (200 miles) north of Khartoum **(wikipedia, 2005).**

2.1.1 White Nile

The source of the Nile is sometimes considered to be Lake Victoria, but the lake itself has feeder rivers of considerable size. The most distant stream and thus the ultimate source of the Nile emerges from Nyungwe Forest in Rwanda, via the Rukarara, Mwogo, Nyabarongo and Kagera rivers, before flowing into Lake Victoria in Tanzania near the town of Bukoba. The Nile leaves Lake Victoria at Ripon Falls near Jinja, Uganda, as the Victoria Nile. It flows for approximately 500 kilometers (300 miles) farther, through Lake Kyoga, until it reaches Lake Albert. After leaving Lake Albert, the river is known as the Albert Nile. It then flows into south Sudan, where it becomes known as the Bahr al Jabal ("River of the Mountain"). The Bahr al Ghazal, itself 716 kilometers (445 miles) long, joins the Bahr al Jabal at a small lagoon called Lake No, after which the Nile becomes known as the Bahr al Abyad, or the White Nile, from the whitish clay suspended in its waters. When the Nile flooded it left this rich material named silt. The Ancient Egyptians used this soil to farm. From Lake No, the river flows to Khartoum. An another branch river called Bahr el Zeraf flows out of the Nile's Bahr al Jabal section and rejoins the White Nile.

The term "White Nile" is used in both; a general sense referring to the entire river above Khartoum and a limited sense, the section between Lake Aswan and Khartoum **(wikipedia, 2010).**

2.1.2 Blue Nile

The Blue Nile springs from Lake Tana in the Ethiopian Highlands. The Blue Nile flows about 1,400 kilometers (870 miles) to Khartoum, where the Blue Nile and White Nile join to form the "Nile proper". 90% of the water and 96% of the transported sediment carried by the Nile originates in Ethiopia, with 59% of the water from the Blue Nile alone (the rest being from the Atbarah, Sobat, and small tributaries). The erosion and transportation of silt only occurs during the Ethiopian rainy season in the summer, however, when rainfall is especially high on the Ethiopian Plateau, the rest of the year, the great rivers draining Ethiopia into the Nile (Sobat, Blue Nile, and Atbarah) flow weakly **(wikipedia, 2005).**

2.1.3- Water sources

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. The majority of human uses require fresh water.

97 percent of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly as groundwater with only a small fraction present above ground or in the air. Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. The framework for allocating water resources to water users (where such a framework exists) is known as water rights **(Lyman J.W and Rosenblatt D. H1988).**

2.1.3.1 Surface water

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss. Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing stream flow **(Wikipedia, 2005).**

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed **(C. W. Wood and A. K. Holliday 1967).**

Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

Brazil is the country estimated to have the largest supply of fresh water in the world, followed by Russia and Canada **(C. W. Wood and A. K. Holliday 1967)**

Throughout the course of a river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through rocks and sediments that underlie the river and its floodplain called the hyporheic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hyporheic zone often forms a dynamic interface between surface water and groundwater from aquifers, exchanging flow between rivers and aquifers that may be fully charged or depleted. This is especially significant in karst areas where pot-holes and underground rivers are common **(Clayton D. B 1994).**

2.1.3.2 Groundwater

.Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer (sometimes called "fossil water").

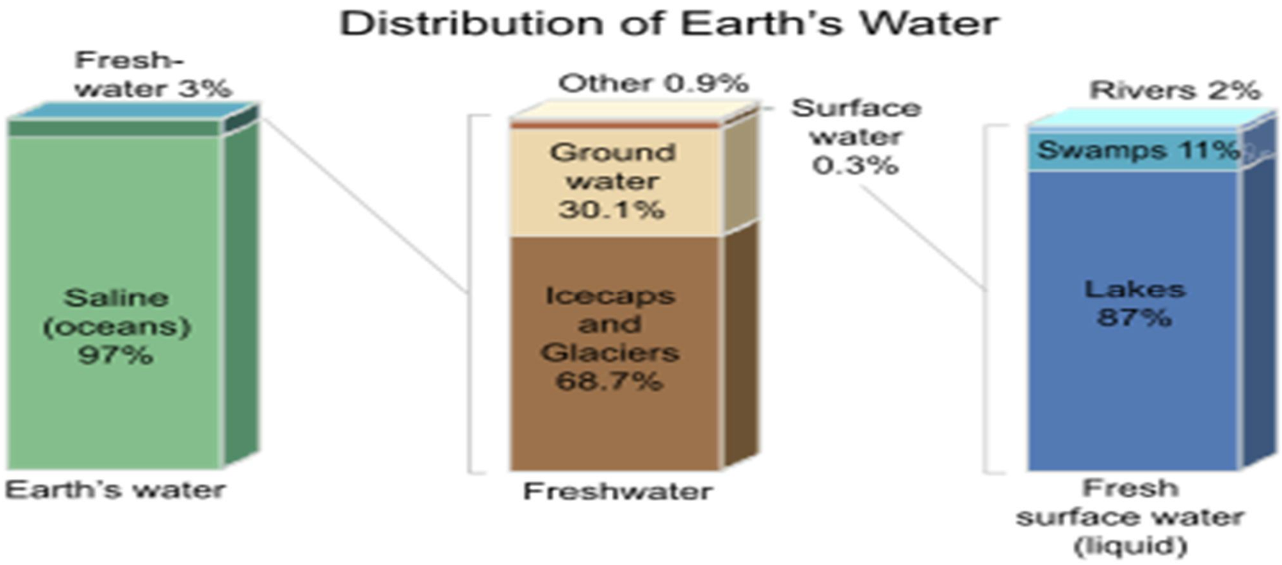
Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source.

The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans.

If the surface water source is also subject to substantial evaporation, a groundwater source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a groundwater source may cause the direction of seepage to ocean to reverse which can also cause soil salinization. Humans can also cause groundwater to be "lost" (become unusable) through pollution. Humans can increase the input to a groundwater source by building reservoirs or detention ponds **(wikipedia, 2010)**

Figure (1):

shows the distribution of earths water



2.1.4 Water treatment

The aims of water treatment are to remove unwanted constituents in the water and to make it safe for drinking or fit for a specific purpose in industry or medical applications. Widely varied techniques are used to remove contaminants like fine solids, micro-organisms and some dissolved inorganic and organic materials, or environmental persistent pharmaceutical pollutants. The choice of method will depend on the quality of the water being treated, the cost of the treatment process and the quality standards expected of the processed water.

The processes below commonly used in water purification plants. Some or most may not be used depending on the scale of the plant and quality of the raw (source) water and the final use **(Gary W. Vanloon and Stephen J. Duffy).**

2.1.4.1 Treatment process

2.1.4.1.1 Pre-treatment.

1. Screening is the first step in purifying surface water is to remove large debris such as sticks, leaves, rubbish and other large particles which may interfere with subsequent purification steps. Most deep groundwater does not need screening before other purification steps.
2. Pre-chlorination – In many plants the incoming water was chlorinated to minimize the growth of fouling organisms on the pipe-work and tanks. Because of the potential adverse quality effects (see chlorine below), this has largely been discontinued (**Lyman J.W and Rosenblatt D. H 1988**).

2.1.4.1.2 Coagulation and flocculation

One of the first steps in a conventional water purification process is the addition of chemicals to assist in the removal of particles suspended in water. Particles can be inorganic such as clay and silt or organic such as algae, bacteria, viruses, protozoa and natural organic matter. Inorganic and organic particles contribute to the turbidity and color of water.

The addition of inorganic coagulants such as aluminum sulfate (or alum) or iron (III) salts such as iron (III) chloride cause several simultaneous chemical and physical interactions on and among the particles. Within seconds, negative charges on the particles are neutralized by inorganic coagulants. Also within seconds, metal hydroxide precipitates of the aluminum and iron (III) ions begin to form. These precipitates combine into larger particles under natural processes such as Brownian motion and through induced mixing which is sometimes referred to as flocculation. The term most often used for the amorphous metal hydroxides is "flocs." large, amorphous aluminum and iron (III) hydroxides adsorb and enmesh particles in suspension and facilitate the removal of particles by subsequent processes of sedimentation and filtration **(Lyman J.W and Rosenblatt D. H 1988)**.

Aluminum hydroxides are formed within a fairly narrow pH range, typically: 5.5 to about 7.7. Iron (III) hydroxides can form over a larger pH range for alum, typically: 5.0 to 8.5.

In the literature, there is much debate and confusion over the usage of the terms coagulation and flocculation where does coagulation end and flocculation begin. In water purification plants, there is usually a high energy, rapid mix unit process (detention time in seconds) where the coagulant chemicals are added followed by flocculation basins (detention times range from 15 to 45 minutes) where low energy inputs turn large paddles or other gentle mixing devices to enhance the formation of flocs. In fact, coagulation and flocculation processes are ongoing once the metal salt coagulants are added **(Jekel M. R. 1991).**

2.1.4.1.3 Sedimentation

Waters exiting the flocculation basin may enter the sedimentation basin, also called a clarifier or settling basin. It is a large tank with low water velocities, allowing flocs to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between the two processes does not permit settlement or flocss break up. Sedimentation basins may be rectangular, where water flows from end to end, or circular where flow is from the center outward. Sedimentation basin outflow is typically over a weir so only a thin top layer of water that furthest from the sludge exits.

In 1904, Allen Hazen showed that the efficiency of a sedimentation process was a function of the particle settling velocity, the flow through the tank and the surface area of tank. Sedimentation tanks are typically designed within a range of overflow rates of 0.5 to 1.0 gallons per minute per square foot (or 1.25 to 2.5 meters per hour). In general, sedimentation basin efficiency is not a function of detention time or depth of the basin. Although, basin depth must be sufficient so that water currents do not disturb the sludge and settled particle interactions are promoted. As particle concentrations in the settled water increase near the sludge surface on the bottom of the tank, settling velocities can increase due to collisions and agglomeration of particles. Typical detention times for sedimentation vary from 1.5 to 4 hours and basin depths vary from 10 to 15 feet (3 to 4.5 meters).

Inclined flat plates or tubes can be added to traditional sedimentation basins to improve particle removal performance. Inclined plates and tubes drastically increase the surface area available for particles to be removed in concert with Hazen's original theory. The amount of ground surface area occupied by a sedimentation basin with inclined plates or tubes can be far smaller than a conventional sedimentation basin **(Kukull W and Lee P. S 1995).**

2.1.4.1.4 Filtration

After separating most flocs, the water is filtered as the final step to remove remaining suspended particles and unsettled flocs.

The most common type of filter is a rapid sand filter. Water moves vertically through sand which often has a layer of activated carbon or anthracite coal above the sand. The top layer removes organic compounds, which contribute to taste and odor. The space between sand particles is larger than the smallest suspended particles, so simple filtration is not enough. Most particles pass through surface layers but are trapped in pore spaces or adhere to sand particles. Effective filtration extends into the depth of the filter. This property of the filter is key to its operation: if the top layer of sand were to block all the particles, the filter would quickly clog.

To clean the filter, water is passed quickly upward through the filter, opposite the normal direction (called back flushing or backwashing) to remove embedded particles. Prior to this step, compressed air may be blown up through the bottom of the filter to break up the compacted filter media to aid the backwashing process; this is known as air scouring. This contaminated water can be disposed of, along with the sludge from the sedimentation basin, or it can be recycled by mixing with the raw water entering the plant although this is often considered poor practice since it re-introduces an elevated concentration of bacteria into the raw water. Some water treatment plants employ pressure filters. These work on the same principle as rapid gravity filters, differing in that the filter medium is enclosed in a steel vessel and the water is forced through it under pressure **(wikipedia, 2012).**

Advantages:

- Filters out much smaller particles than paper and sand filters can.
- Filters out virtually all particles larger than their specified pore sizes.
- They are quite thin and so liquids flow through them fairly rapidly.
- They are reasonably strong and so can withstand pressure differences across them of typically 2–5 atmospheres.
- They can be cleaned (back flushed) and reused

2.1.4.1.5 Disinfection

Pumps used to add required amount of chemicals to the clear water at the water purification plant before the distribution. From left to right: sodium hypochlorite for disinfection, zinc orthophosphate as a corrosion inhibitor, sodium hydroxide for pH adjustment, and fluoride for tooth decay prevention. Disinfection is accomplished both by filtering out harmful micro-organisms and also by adding disinfectant chemicals. Water is disinfected to kill any pathogens which pass through the filters and to provide a residual dose of disinfectant to kill or inactivate potentially harmful micro-organisms in the storage and distribution systems. Possible pathogens include viruses, bacteria, including Salmonella, Cholera, Campylobacter and Shigella, and protozoa, including Giardia, lamblia and other cryptosporidia. Following the introduction of any chemical disinfecting agent, the water is usually held in temporary storage often called a contact tank or clear well to allow the disinfecting action to complete **(Lazerte B. D 1984).**

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Chlorine disinfection

The most common disinfection method involves addition of chlorine or its compounds such as chloramine or chlorine dioxide. Chlorine is a strong oxidant that rapidly kills many harmful micro-organisms. Because chlorine is a toxic gas, there is a danger of a release associated with its use. This problem is avoided by the use of sodium hypochlorite, which is a relatively inexpensive solution that releases free chlorine when dissolved in water. Chlorine solutions can be generated on site by electrolyzing common salt solutions. A solid form, calcium hypochlorite, releases chlorine on contact with water. Handling the solid, however, requires greater routine human contact through opening bags and pouring than the use of gas cylinders or bleach which are more easily automated. The generation of liquid sodium hypochlorite is both inexpensive and safer than the use of gas or solid chlorine. All forms of chlorine are widely used, despite their respective drawbacks. One drawback is that chlorine from any source reacts with natural organic compounds in the water to form potentially harmful chemical by-products. These by-products are known as Tri Halo Methanes (THMs) and Halo Acetic Acids (HAAs). Both carcinogenic in large quantities and are regulated by the United States Environmental Protection Agency (USEPA) and the Drinking Water Inspectorate in the UK. The formation of THMs and Halo Acetic acids may be minimized by effective removal of as many organics from the water as possible prior to chlorine addition. Although chlorine is effective in killing bacteria, it has limited effectiveness against protozoa that form cysts in water **(Lazerte B. D 1984).**

2.1.5 Aluminum compound in water treatment

2.1.5.1 Aluminum sulfate (Alum): is a chemical compound with the formula $Al_2(SO_4)_3$. It is soluble in water and is mainly used as a flocculating agent in the purification of drinking water and waste water treatment plants, and also in paper manufacturing.

Aluminum sulfate is sometimes referred to as a type of alum. Alums are double sulfate salts, with the formula $AM(SO4)_2 \cdot 12H_2O$, where A is a monovalent cation such as potassium or ammonium and M is a trivalent metal ion such as aluminum. The anhydrous form occurs **(Lazerte B. D 1984).**

Preparation

Aluminum sulfate made by adding aluminum hydroxide, $Al(OH)_3$, to sulfuric acid, H_2SO_4:

$2\ Al(OH)_3 + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3+6H_2O$

or by heating aluminum metal in a sulfuric acid solution:

$2\ Al_{(s)} + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\ H_{2\ (g)}$

Types of alum

Potash alum

Aluminum potassium sulfate, potash alum, $KAl(SO_4)_2{\cdot}12H_2O$ is used as an astringent and antiseptic in various food preparation processes such as pickling and fermentation and as a flocculant for water purification, among other things. A common method of producing potash alum is leaching of alumina from bauxite, which is then reacted with potassium sulfate. As a naturally occurring mineral, potash alum is known as alum-(K).

Soda alum

Soda alum, ${\cdot}12H_2O$, mainly occurs in nature as the mineral mendozite. It is very soluble in water, and is extremely difficult to purify. In the preparation of this salt, $NaAl(SO_4)_2$ it is preferable to mix the component solutions in the cold, and to evaporate them at a temperature not exceeding 60 °C. 100 parts of water dissolve 110 parts of sodium alum at 0 °C, and 51 parts at 16 °C. Soda alum is used in the acidulent of food as well as in the manufacture of baking powder (**Barclay A**. and **Peters D**. **1976).**

Ammonium alum

Ammonium alum, $NH_4Al(SO_4)_2 \cdot 12H_2O$, awhite crystalline double sulfate of aluminum is used in water purification, in vegetable glues, in porcelain cements, in deodorants (though potassium alum is more commonly used), in tanning, dyeing and in fireproofing textiles (**Barclay A**. and **Peters D, 1976).**

2.1.5.2 Poly Aluminum Chloride (PAC) compounds were developed to provide better performance than alum could offer. While they accomplished this goal, they also provide additional cost benefits when compared to alum. PAC has a minimal impact on pH and therefore minimized the need to feed adjustment chemicals. And it is able to do a better job while using 30-60% less aluminum on average. This translates roughly to a similar percent reduction in the amount of sludge produced.

The growth rate of PAC has been very impressive. In many areas where PAC has been marketed for a reasonable time period it has replaced over

75% of the total alum demand. Around the same time the PAC was developed, organic polymers, which aided the coagulation process, were also introduced to the water treatment industry. These polymers were generally not effective as primary coagulants but when used in conjunction with aluminum, helped to improve overall performance (**Barclay A**. and **Peters D**. **1976).**

2.1.5.3 Iron (III) chloride also called ferric chloride, is an industrial scale commodity chemical compound, with the formula $FeCl_3$ and with iron in the +3 oxidation state. The color of iron(III) chloride crystals depends on the viewing angle: by reflected light the crystals appear dark green, but by transmitted light they appear purple-red. Anhydrous iron(III) chloride is deliquescent, forming hydrated hydrogen chloride mists in moist air. It is rarely observed in its natural form, mineral molysite, known mainly from some fumaroles.

When dissolved in water, iron(III) chloride undergoes hydrolysis and gives off heat in an exothermic reaction. The resulting brown, acidic, and corrosive solution is used as a flocculant in water treatment **(Lazerte B. D 1984).**

2.1.6 Coagulation mechanism

- Salts of Al(III) and Fe(III) are commonly used as coagulants in water and wastewater treatment.
- When a salt of Al(III) and Fe(III) is added to water, it dissociates to yield trivalent ions, which hydrate to form aqua-metal complexes $Al(H_2O)_6^{3+}$ and $Fe(H_2O)_6^{3+}$. These complexes then pass through a series of hydrolytic reactions in which H_2O molecules in the hydration shell are replaced by OH^- ions to form a variety of soluble species such as $Al(OH)^{2+}$ and $Al(OH)^{2+}$. These products are quite effective as coagulants as they adsorb very strongly onto the surface of most negative colloids **(Lide D. R (1993).**

Destabilization using Al(III)

- Al(III) and Fe(III) accomplish destabilization by two mechanisms: (1) Adsorption and charge neutralization.
  (2) Enmeshment in a sweep flocs.
- Interrelations between pH, coagulant dosage, and colloid concentration determine mechanism responsible for coagulation.
- Charge on hydrolysis products and precipitation of metal hydroxides are both controlled by pH. The hydrolysis products possess a positive charge at pH values below iso-electric point of

the metal hydroxide. Negatively charged species which predominate above iso-electric point, are ineffective for the destabilization of negatively charged colloids.

- Precipitation of amorphous metal hydroxide is necessary for sweep-floc coagulation.
- The solubility of $Al(OH)_3(s)$ and $Fe(OH)_3(s)$ is minimal at a particular pH and increases as the pH increases or decreases from that value. Thus, pH must be controlled to establish optimum conditions for coagulation (Roberson C. E and Hem J. D 1969).
- Alum and ferric chloride reacts with natural alkalinity in water as follows:

- $Al_2(SO_4)_3.14H_2O + 6\ HCO^{3-} \longrightarrow 2\ Al(OH)_{3\downarrow} + 6CO_2 + 14H_2O + 3SO_4^{2-}$

- $FeCl_3 + 3\ HCO^{3-} \longrightarrow Fe(OH)_{3\downarrow} + 3\ CO_2 + 3\ Cl^-$

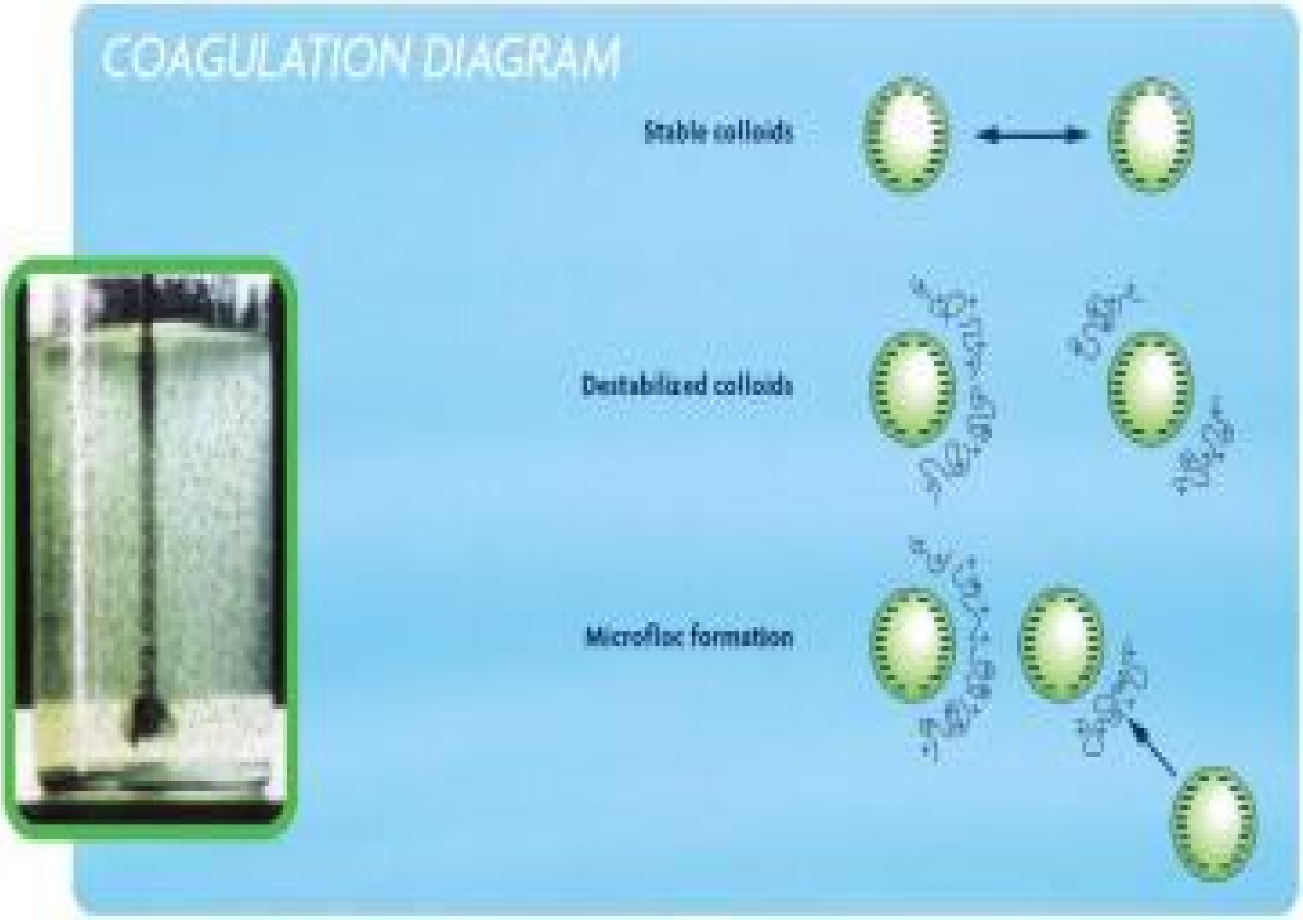

Figure (2):

shows the coagulation mechanism

2.1.7 Study of site (Mogran Water Treatment Plan)

The station is located in Mogran area in Khartoum at the distance of approximately 2km east of the old bridge of the White Nile. The station was established at several stages, first stage being in year (1961), the station operation was started in (1964). During the flood the station takes the turbid water from the Blue Nile whereas in the rest of the days it takes water from the White Nile. The overall productivity of the plant (90000) cubic meter /day.

2.1.7.1 Component of Mogran Water Treatment Plant

The intakes

Mogran water treatment plant intakes are located on the Blue Nile on a platform inside the Nile that moves hydraulically according to the level of the river it ranges between 9-12 meters.

Pipelines

These convey water from intakes to distribution basins where required chemical are added.

Flocculation and sedimentation basins

They are five basins in the station that are used to get rid of colloid material that contaminates the water and to remove the small particles, turbidity causing substance and bacteria.

Filtration basins

Are used for water filtration to separate the impurities of water via passing it in a filtration media. Mogran water treatment used 18 rapid sand filter.

Chlorination room

Is a room where chlorine is added to treated water.

Storage

The capacity of storage amount up to 18000 cubic meters of clean water.

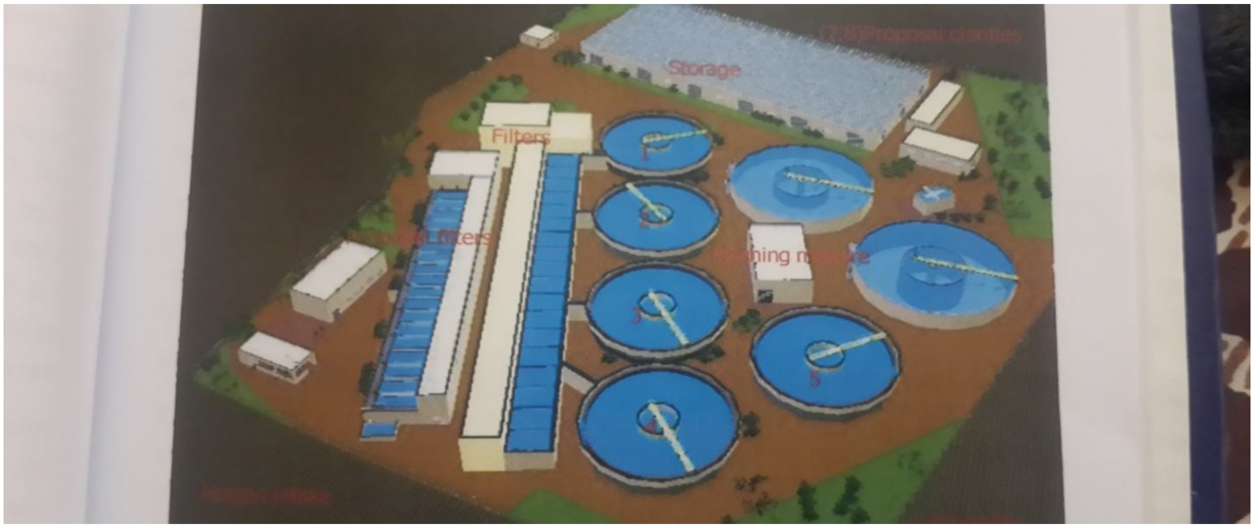

Figure (3):

Shows the component of Mogran Water Treatment Plant

Figure (4): Shows Flocculation and sedimentation basins

2.1.8 Water quality

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water **(Water quality and treatment, 1999).**

2.1.8.1 Standards

In the setting of standards, agencies make political and technical scientific decisions about how the water will be used. In the case of natural water bodies, they also make some reasonable estimate of present conditions. Different uses raise different concerns and therefore different standards are considered. Natural water bodies will vary in response to environmental conditions. Environmental scientists work to understand how these systems function, which in turn helps to identify the sources and fates of contaminants. Environmental lawyers and policymakers work to define legislation with the intention that water is maintained at an appropriate quality for its identified use.

The vast majority of surface water on the planet is neither potable nor toxic. This remains true when seawater in the oceans (which is too salty to drink) is not counted. Another general perception of water quality is that of a simple property that tells whether water is polluted or not. In fact, water quality is a complex subject, in part because water is a complex medium intrinsically tied to the ecology of the Earth. Industrial and commercial activities (e.g. manufacturing, mining, construction, transport) are a major cause of water pollution as are runoff from agricultural areas, urban runoff and discharge of treated and untreated sewage **(Water quality and treatment 1990, WHO guideline, 2008).**

2.1.8.2 Categories

The parameters for water quality are determined by the intended use. Work in the area of water quality tends to be focused on water that is treated for human consumption, industrial use, or in the environment.

2.1.8.2.1 Human consumption

Contaminants present in untreated water include microorganisms such as viruses, protozoa and bacteria; inorganic contaminants such as salts and metals; organic chemical contaminants from industrial processes and petroleum use; pesticides and herbicides; and radioactive contaminants.

Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, use of water bodies as a heat sink, and overuse (which may lower the level of the water).The United States Environmental Protection Agency (EPA) limits the amounts of certain contaminants in tap water provided by US public water systems. The Safe Drinking Water Act authorizes EPA to issue two types of standards primary standards regulate substances that potentially affect human health, and secondary standards prescribe aesthetic qualities, those that affect taste, odor, or appearance. The U.S. Food and Drug Administration (FDA) regulations establish limits for contaminants in bottled water that must provide the same protection for public health. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of these contaminants does not necessarily indicate that the water poses a health risk. In urbanized areas around the world, water purification technology is used in municipal water systems to remove contaminants from the source water (surface water or groundwater) before it is distributed to homes, businesses, schools and other recipients. Water drawn directly from a stream, lake, or aquifer and that has no treatment will be of uncertain quality **(WHO guideline 2010).**

2.1.8.2.2 Industrial uses

Dissolved minerals may affect suitability of water for a range of industrial and domestic purposes. The most familiar of these is probably the presence of ions of calcium and magnesium which interfere with the cleaning action of soap, and can form hard sulfate and soft carbonate deposits in water heaters or boilers. Hard water may be softened to remove these ions. The softening process often substitutes sodium cations. Hard water may be preferable to soft water for human consumption, since health problems have been associated with excess sodium and with calcium and magnesium deficiencies. Softening decreases nutrition and may increase cleaning effectiveness **(WHO 1997).**

2.1.9 Aluminum

2.1.9.1 Sources and uses

Aluminum is the most abundant metal on Earth, comprising about 8.23% of the Earth's crust. It is found in a variety of minerals, such as feldspars and micas, which, with time, weather to clays. Aluminum is chiefly mined as bauxite, a mineral containing 40-60% aluminum oxide (alumina). Aluminum is also found as a normal constituent of soil, plants and animal tissues.

Canada is the world's third largest producer of aluminum; in 1988 the production was estimated at 1.5 million tones. The metal is used for the production of a wide variety of articles, including building and construction materials, cans and packaging materials, vehicle parts and aircraft frames.[1] Salts of aluminum are used by the pharmaceutical industry as major ingredients of anti-acids and anti-diarrhoeals. Aluminum is also used extensively as a food additive and as a component of food packaging materials. In addition, substantial amounts of aluminum salts (alum) are commonly added as flocculants during the treatment of drinking water **(Rezania S 1985).**

2.1.9.2 Aluminum in water treatment

During water purification or treatment processes, aluminum salts (most commonly alum or aluminum sulfate) are frequently used as coagulants to remove color and turbidity. This results in the reduction of both pathogenic micro-organisms and the particles that protect pathogens from chemical disinfection. Removal of humic substances and other naturally occurring organic matter also reduces the formation of disinfection by-products, including carcinogenic chlorine compounds. The removal of organics that impart color to water improves the appearance of the water. This is a significant benefit, as appearance is an important factor in maintaining public confidence in the water supply. In addition, removal of color will promote more efficient chlorination and longer-lasting chlorine residuals. The most common treatment train using alum is conventional surface water treatment, which involves chemical addition, flocculation, coagulation, sedimentation and filtration. This treatment train and its efficiency in removing contaminants and attaining low levels of residual aluminum are discussed in detail below. There are, however, other processes used in Canada -- for example, chemical mixing, coagulation, flocculation and filtration (direct filtration) and chemical mixing, coagulation and filtration (in-line filtration) that also employ alum as the principal coagulant. The design and operation of each of these processes influence the aluminum concentration in the finished drinking water, which may vary significantly from about 30 µg/L to 200 µg/L or higher. Additional treatment processes, such as lime softening, also influence aluminum levels in finished drinking water. As a consequence of alum treatment, levels of aluminum in treated water are often higher than those in raw water. However, with proper treatment practices in a conventional plant, aluminum levels can be reduced in finished water. Most of the alum used as a coagulant is changed to insoluble aluminum hydroxide, which either settles out or is removed by filtration. Residual aluminum concentrations in finished waters are a function of the aluminum levels in the source water, the dosing of aluminum-based coagulant, the pH of the water, temperature levels and the efficiency of filtration. Under optimal conditions, the conventional treatment train is capable of achieving a minimum aluminum concentration in the treated water of around 0.03 mg/L. Higher concentrations may occur in drinking water if the raw water is particularly dirty or if there is inadequate control over pH during treatment. high particulate aluminum residuals may also occur if an insufficient alum dosage has been used. Levels of aluminum in the finished water above 0.3 mg/L usually reflect a lack of optimization in the coagulation, sedimentation or filtration stages of conventional treatment. High residual concentrations of aluminum (above 0.4 mg/l) in some water may result in the deposition of gelatinous aluminum-containing substances in the distribution system, which in turn may result in reductions in flow rate through the system and deterioration of water quality. High residual aluminum levels in the distribution system may also interfere with the disinfection process, by enmeshing and protecting micro-organisms **(Davidson A. M and Walker G. S 1982).**

Very high concentrations of residual aluminum can be minimized by effective removal of particulate matter, particularly when raw water contains high concentrations of total aluminum. The best way to control aluminum is optimization of the coagulation and filtration processes. To achieve optimal coagulation, one should control the coagulant dosage and coagulation pH. Optimizing coagulant dosage may entail increasing or decreasing the amount of alum added, depending on the specific conditions of the water treatment process. Adjustment of the coagulation pH to 6.0-7.0 provides the best results, as this is the range of minimum solubility of aluminum hydroxide. However, high-alkalinity waters with pH >8 can require significant chemical dosages to reach the optimum pH. Temperature also influences the outcome, because the pH of minimum solubility increases at lower temperatures. Alum coagulation at lower temperatures has been observed to result in slightly higher residual turbidities and may therefore result in higher residual aluminum. Several investigators have found that low turbidity in filtered water (<0.1-0.15 NTU) results in a very low aluminum residual, but one should note that this applies only if the pH is in the correct zone. Optimization of coagulation should be accompanied by good mixing, good clarification and good filtration of the treated water. A shortfall in any of these can result in increased aluminum residuals as well as other harmful effects. Practicable, large-scale water treatment technology is not available at every water system for reducing aluminum levels in finished water. Alternative coagulants, such as iron chloride, poly aluminum chloride and poly aluminum sulfate, may be useful as replacements for aluminum sulfate and will result in lower aluminum residuals. Alternative coagulants should be used only following a thorough on site evaluation of their performance **(Driscoll C. T. and Letterman R. D 1987).**

2.1.9.3 Aluminum in drinking water

There is no consistent, convincing evidence that aluminum in drinking water causes adverse health effects in humans and aluminum does not affect the acceptance of drinking water by consumers or interfere with practices for supplying good water. Therefore, a health-based guideline or aesthetic objective has not been established for aluminum in drinking water. In recognition of advancing research into the health effects of aluminum and in an exercise of the precautionary principle, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible. For plants using aluminum-based coagulants, operational guidance values of less than 0.1 mg/L (100 µg/L) total aluminum for conventional treatment plants and less than 0.2 mg/L

(200 µg/L) total aluminum for other types of treatment systems (e.g direct or in-line filtration plants, lime softening plants) are recommended. These values are based on a 12-month running average of monthly samples.

Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes (i.e., microbiological quality) or interfere with the removal of disinfection by-product precursors **(Jekel M. R 1991) .**

2.1.9.4 Chemistry of aluminum in water

The chemical speciation of aluminum in drinking water is of particular interest, as the form of aluminum regulates its solubility, bioavailability and toxicity. One factor determining the form of aluminum in water is pH. In raw water with low concentrations of dissolved organic compounds such as humic and fulvic acids, the dependence of dissolved aluminum concentration on pH resembles a parabola with a sharp solubility minimum at around pH 6.5. The solubility of aluminum increases at lower pH values owing to the formation of $Al(OH_2^{+)}$, $Al(OH^{2+)}$ and $Al(H_2O_2^{3+}$ often abbreviated as Al_3 and sometimes referred to in the literature as free aluminum. The solid $Al(OH)_3$ is the predominant species between pH 5.2 and 8.8, whereas the soluble $Al(OH)_4^-$ predominates above pH 9.

The form in which aluminum is present in drinking water is also dependent on whether the water is fluoridated as fluoride has a strong affinity for aluminum particularly under acidic conditions. In un fluoridated water at pH values above 6.5 and with an aluminum concentration of 100 µg/L, the predominant species is $Al\ (OH)_4^-$. In fluoridated water (typically 53 µmol/L), AlF_2^+ and AlF_3 species are among those that can be found below pH 6.5; above pH 6.5, mixed OH^-/F^- complexes or $Al(OH)_4^-$ may occur.

When alum is added to raw water for treatment, the form of aluminum changes along a number of pathways, depending on the quantity of alum added, the temperature, the pH, the types and concentrations of dissolved materials present as well as the types and surface area of particulate matter present **(Driscoll C. T and Letterman R. D 1988).**

2.1.9.5 Toxicity of aluminum in Humans

On acute exposure, aluminum is of low toxicity. In humans, oral doses up to 7200 mg/d (100 mg/kg per day) are routinely tolerated without any signs of harmful short-term effects. However, two healthy individuals who drank water accidentally contaminated with an aluminum sulfate solution (aluminum concentrations ranged from 30 to 620 mg/L) experienced ulceration of the lips and mouth **(ATSDR 1992).**

Intake of large amounts of aluminum can lead to a wide range of toxic effects, including microcytic anaemia, osteomalacia, glucose intolerance of uraemia and cardiac arrest. Elderly persons with elevated serum aluminum levels exhibit impaired complex visual-motor co-ordination and poor long term memory. In addition, aluminum has been shown to inhibit a number of enzyme activities, including those of key enzymes involved in catecholamine synthesis, such as dihydropteridine reductase **(Davidson A. M and Walker G. S 1982).**

2.1.9.5.1 Dialysis Encephalopathy

There is extensive literature on the impairment of various aspects of central nervous system function in humans following inadvertent parenteral exposure to aluminum. The most studied aluminum-related syndrome is dialysis encephalopathy, chronic symptoms of which include speech disorders, neuropsychiatric abnormalities and multifocal myoclonus. More subtle symptoms of the condition include disturbances to tetra-hydrobiopterin metabolism and abnormalities in a number of psycho-motor functions (e.g., visual spatial recognition memory), all occurring at mildly elevated serum aluminum levels (59 µg/L) and in the absence of chronic dementia. Patients with dialysis dementia were shown to have markedly elevated serum aluminum levels with increased concentrations in many tissues, including the cerebral cortex.’ Investigators reported a correlation between the aluminum concentration in water used to prepare the dialysate fluid and the incidence of dialysis dementia. The mechanism of neurotoxicity in dialysis dementia has not been established. However, mild cases have been reported to respond to chelation therapy with desferrioxamine to lower serum aluminum **(Hicks J. S and Hackett D. S 1987).**

2.1.9.5.2 Amyotrophic Lateral Sclerosis (ALS) and Parkinson's Dementia (PD)

It has been postulated that aluminum plays a role in the aetiology of two severe neurodegenerative diseases, amyotrophic lateral sclerosis (ALS) and Parkinson's dementia (PD). ALS and PD, which are observed at very high incidence among the Chamorro people on Guam, are both characterized by the loss of motor neuron function and the presence of neurofibrillary tangles in the brain. A high incidence of ALS is also found in two other areas, western New Guinea and the Kii Peninsula of Japan. The soils and drinking water of Guam and the two other affected areas are very low in calcium and magnesium but very high in aluminum, iron and silicon. Intraneuronal deposition of calcium and aluminum in post-mortem brains of patients with ALS has been reported. Garruto and Yase suggested that chronic nutritional deficiencies of calcium and magnesium may lead to increased absorption of aluminum (and other metals), resulting in the deposition of aluminum in neurons. These deposits could interfere with the structure of neurons and eventually result in neurofibril-lary tangles. The dramatic decrease in the incidence of ALS and PD on Guam with a change in dietary habits and local water supplies has given support to this theory. However, as the diet of the Guam population is known to include the seeds of the false sago palm, which contain the toxic amino acid beta-*n*-methylamino-L-alanine an amino acid that caused a degenerative disease with similarities to ALS when given repeatedly by mouth to two cynomolgus monkeys the contribution of these seeds to Guam's high incidence of neurological disorders should be examined more closely. As well, non-native persons who had lived for long periods on Guam did not exhibit an increased incidence of dementia, which suggests the dementia may have a genetic rather than an environmental cause **(Davidson A. M and Walker G. S 1982).**

2.1.9.5.3 Alzheimer's Disease (AD)

Aluminum has also been suggested as having a causal role in the onset of AD. Memory lapses, disorientation, confusion and frequent depression are the first recognizable symptoms that mark the beginning of progressive mental deterioration in patients with AD. Numerous other causes have been suggested for AD, including genetic and environmental factors, but none of them has been proven **(Michel P 1991).**

2.2 Previous Studies

Many studies about residual aluminum in raw water and drinking water (tap water) resulting from the use of aluminum salt for drinking water treatment plant were coducted. All the studies reviewed were conducted in Canada, Germany, and United State. In Sudan Dr. Mutasim Maknon (ph.D.) Studied the residual aluminum in water after removing the turbidity by using PAC. Below is a brief description of previous studies regarding the objective and result of this research.

Wilhelm & Idel (1995) Aluminum level in drinking water. The objective of his study was to determine the concentration of residual aluminum in public water supplies, by analyzing aluminum parameter .The result of this analysis are 0.01mg/l as average value of aluminum level in public water supplies in western Germany.

Letterman & Driscoll (2008) Aluminum in drinking water. The aim of this paper reviews the presence of aluminum in drinking water with an emphasis on speciation, removal, health problem, and regulation.

Water sample analysis results gave concentration of aluminum in raw water in range (0.001 – 0.009) and (0.004 -0.009) for treated water(water treatment plant at Oswego , New York).

Gender & Gunn (2012) Residual aluminum in drinking water.

The aim of this paper to determine residual aluminum concentration in drinking water and tested their aluminum speciation methodology in three water treatment plants.

In one treatment plant, the raw water total aluminum concentration of 0.004mg/l was reduced to 0.001mg/l after treatment.(Canada).

A.A.AL-Zahrani and M.H.Abdul–Majid (2009) Extraction of Aluminum from Local Clay by Hydrochloric Acid Process.

The aim of this paper is to investigate the extraction of aluminum from local clay by calcination and hydrochloric acid leaching of clay.

Environmental Canada & Health Canada (2010) Determination of residual aluminum level in water treatment process.

The aim of this paper to determine of residual aluminum concentration in finished drinking water . The mean total aluminum concentration was estimated to be 101µg/l (approx. 0.001mg/l).

Chapter three:

Materials & Methods

Materials & Methods

3.1 Materials:

3.1.1 Water Samples:

All water samples were collected from the shore of Blue Nile at the dumping area where the water plant of Almogran drains the waste. The samples were collected from different distances from the dumping point in the direction and opposite to direction of the water current.

3.1.2 Clay Samples:

All clay samples were collected from the shore of Blue Nile at the dumping area where the water plant of Almogran drains the waste. The samples were collected from different distance from the dumping point in the direction and opposite to direction of the follow of water current.

3.1.3Chemicals

* Hydrochloric acid (3M), UK.

* Ascorbic acid, powder pillows, USA.

* Aluminum reagent, powder pillows, USA(as Alu-Ver).

*Bleaching Reagent (powder pillows, USA).

* Deionized Water.

3.1.4 Instruments:

* Spectrophotometer model (HACH) 500 DR – Sample cell

* Water Distiller

* Hot plat with stirrer

3.1.5 Glassware:

* Two cells of (HACH) made from quartz.

* Conical flask 50ml.

* Volumetric flask 50ml, 100ml.

* Buchner funnel.

3.1.6 Preparation of reagent solution used :

3.1.6.1 Preparation of hydrochloric acid (3M)

66.25ml of concentrated hydrochloric acid (35%) were transferred into 250ml volumetric flask and the volume was completed with deionized water to mark.

3.2 **Methods:-**

3.2.1 Determination of aluminum in water by photometric method:

50ml of water sample were placed in graduated cylinder. Ascorbic acid content in a pillow was added and dissolved by shaking several time. Aluminum reagent was added to the mixture and dissolved by shaking. 10ml of this mixture were placed in a sample cell and the content of one bleaching 3 reagent powder pillow was added and shaken vigorously to dissolve. After 15 minute reaction time the concentration of aluminum in ppm was determined using Uv-vis Spectrophotometer. The results were recorded in table (4.1) in chapter four (Standard Method for Examination of Water and Waste Water 2015).

3.2.2 Extraction of Aluminum from Clay:

The clay sample was grinded using a ball mill, then sieved using mechanical shaker for 5 min. The oversize clay was further grinded and sieved using the same sieve .The procedure was repeated till the entire clay sample passed through the sieve.

Grinded clay sample passing 100 mesh was subjected to calcination in a muffle furnace at 600^0C for one hour. Five grams of calcined clay sample were leached in boiling hydrochloric acid (3M) under reflux for one hour. The ratio is 10:1 liquid to solid weight ratio, at fixed shaking rate of 160cycle/min. By the end of leaching, the resulting slurry was filtered, washed three times with 10ml portion of deionized water. The filtrate and washings were collected in 250 volumetric flask and diluted to the mark. Aluminum was Analyzed using Uv- vis – Spectrophotometer, DR 5000. The results were recorded in table (4.2) in chapter four (Tilley G. S, et. al 1997).

Chapter four:

Results & Discussions

Results & Discussions

Table (4.1)

The concentration of aluminum at different stages in Mogran Water Treatment Plant (MWTP).

NO.	Symbol	Sample stage	Concentration of Al (ppm)
1	**A**	Raw water sample	0.013
2	**B**	Raw water after adding coagulant (PAC)	2.263
3	**C**	Water after sedimentation	0.044
4	**D**	Water after filtration	0.029
5	**E**	Water after disinfection	0.027
6	**F**	Final treatment water (tap water)	0.027

PAC : Poly Aluminum Chloride.

Note: poly aluminum chloride (PAC) is used as a coagulant in this plant.

A	0.013
B	2.263
C	0.044
D	0.029
E	0.027
F	0.027

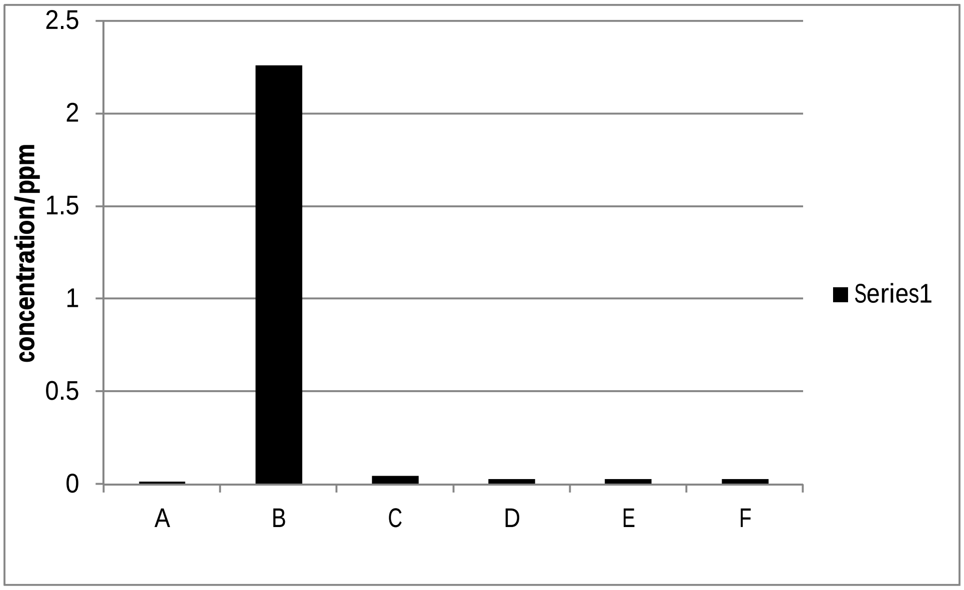

Figure (5):

The aluminum concentration at different stages of treatment plant as in table (4.1).

Table (4.2):

The concentrations of aluminum in raw water collected from Blue Nile in the dumping area where the Mogran Water Treatment Plant (MWTP) drains the waste**.**

NO	**Symbol**	**Location of sample taken and stage**	**Concentration of Al(ppm)**
1	Aw	rejected water at the (drain) point	8.296
2	Bw	water at 50m distance from reject at the DOC	0.015
3	Cw	water at 100m distance from reject at the DOC	0.014
4	Dw	water at 200m distance from reject at the DOC	0.014
5	Ew	water at 100m distance from reject at the opposite DOC	0.014
6	Fw	water at 200m distance from reject at the opposite DOC	0.013
7	Gw	water at 1000m distance from reject at the DOC	0.009
8	Hw	water at 500m distance from reject at the DOC	0.011
9	Iw	water from reject at the other site of the Nile	0.013
10	Jw	water 100m D FROM reject at the other site at the DOC	0.012
11	Kw	water 1000m D FROM reject at the other site at the opposite DOC	0.012

MWTP :Mogran Water Treatment Plant

DOC : Direction Of the water Current

Aw	**8.296**
Bw	0.015
Cw	0.014
Dw	0.014
Ew	0.014
Fw	0.013
Gw	0.009
Hw	0.011
Iw	0.013
Jw	0.012
Kw	0.012

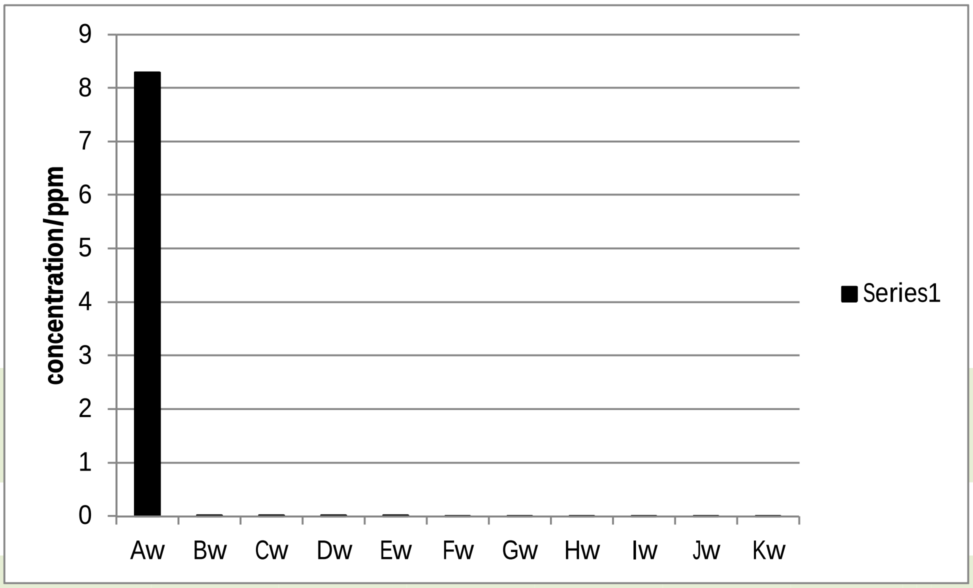

Figure (6) :

The aluminum concentration in water at the dumping area as in the table (4.2).

Table (4.3):

The concentration of aluminum in soil samples taken from different distances from the dumping area (drain).

No.	**Parameter**	**Comment**	**Concentration of Al(ppm)**
1	As	Soil at the reject region (drain)	203.643
2	Bs	soil at 50m distance from reject point at the DOC	273.472
3	Cs	Soil at 100m distance from reject point at the DOC	213.446
4	Ds	Soil at 200m distance from reject at the DOC	206.658
5	Es	Soil at 500m distance from reject point at the DOC	308.5
6	Fs	Soil at 1000m distance from reject point at the DOC	185.5
7	Gs	Soil at 100m distance from reject point at the opposite DOC	234.565
8	Hs	Soil at 200m distance from reject point at the opposite DOC	184.643
9	Is	Soil at 1000m distance from reject at the opposite DOC	180.0

As	**203.643**
Bs	**273.472**
Cs	**213.446**
Ds	**206.658**
Es	**234.565**
Fs	**184.643**
Gs	**185.5**
Hs	**308.5**
Is	**180**

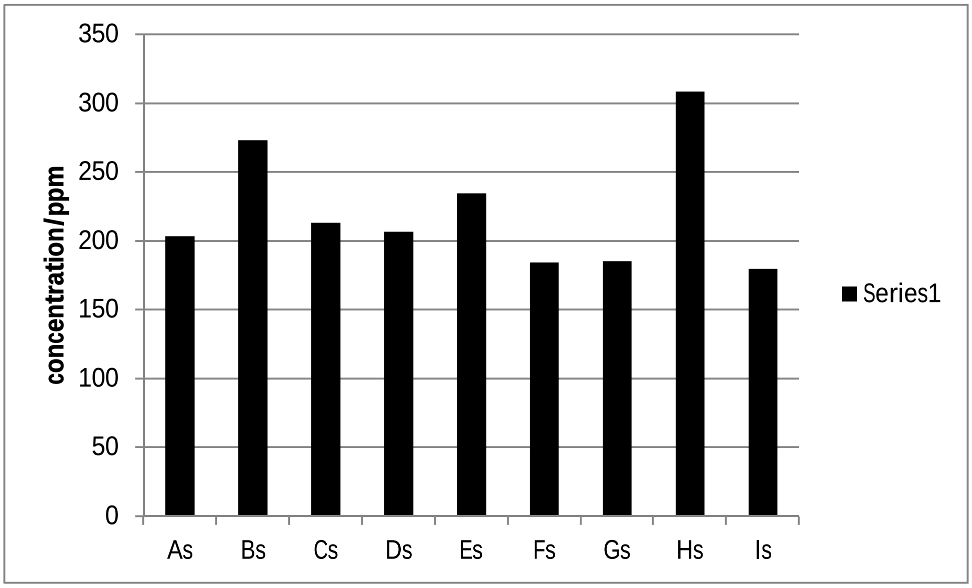

Figure (7):

The aluminum concentration in soil at the dumping area as in table (4.3)

Table (4.4):

The actual aluminum concentration in soil contributed by drain waste.

Parameter	Result/ppm natural aluminum +contributed from drain	Result/ppm average natural aluminum	Result/ppm AL.CFD
As	203.643	182.73	20.913
Bs	273.472		90.742
Cs	213.446		30.716
Ds	206.658		23.928
Es	234.565		51.835
Fs	184.643		1.913
Hs	308.5		125.770

As	20.913
Bs	90.742
Cs	30.716
Ds	23.928
Es	51.835
Fs	1.913
Hs	125.77

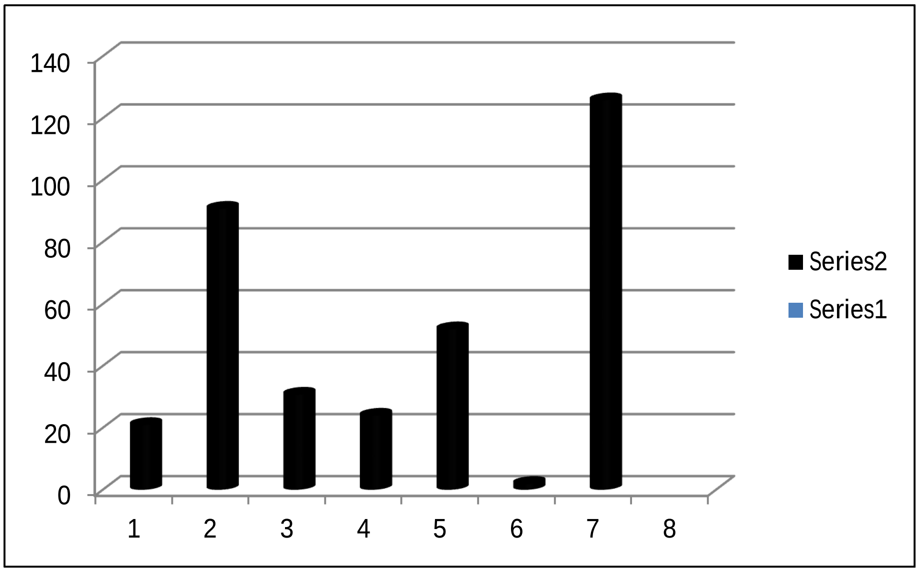

Figure (8):

The actual aluminum concentration in soil contributed by drain waste as in table (4.4).

4.2-Discussion

Table (4.1) shows the concentration of aluminum at different stages of treatment process. The concentration of aluminum in raw water is low and found to be 0.013ppm. The concentration rised to 2.263ppm after adding the coagulant (PAC). Then decreased at settling & filtration stages. These two stages reduce the amount of aluminum in water. This is attributed to the settlement of most added aluminum in a form of insoluble aluminum hydroxide or due to the adsorption of aluminum ions on the surface of sludge and clays.

After the stage of disinfection the concentration of aluminum remains constant without change and found to be 0.027 ppm as the concentration in the final treated water.

Table (4.2) shows the concentration of aluminum in the Nile water at the dumping area at which MWTP drains the waste. The results show high concentration of aluminum at the dumping area (drain region) which gave 8.296 ppm. This is because the waste (sludge) containing high concentration of aluminum is dumped at this point.

The concentration of aluminum at different distances 50m, 100m, 200m, 500m, and 1000m at the direction of water current from the point of dumping the waste and mud coming from the MWTP were found to be 0.015, 0.014, 0.014, 0.011and 0.009 ppm respectively. All these results fall in the permissible range for aluminum in drinking water according to

WHO and Sudanese standards. This proves that, there is no risk of aluminum concentration in the current condition.

At the opposite direction of water current and distances 100m and 200m from the dumping point, the concentration of aluminum was found to be 0.014 and 0.013ppm respectively. This is the same concentration of aluminum in raw water. This also proves that dumping of this waste containing high concentration of aluminum does not contribute in contaminating the river water with aluminum.

Table(4.3) shows the concentration of aluminum in soil resulting from natural content of aluminum in clays plus the aluminum mixed with the mud in the waste (drain). Because the drain contains high amount of aluminum hydroxide produced in the plant.

The concentration of aluminum in the soil at the dumping point (where the waste is rejected) and at distances 50m, 100m, 200m, 500m and 1000m at the direction of the current water from the point of dumping the waste were found to be 203.643, 273.472, 213.446, 206.658, 308.5 and 185.5ppm respectively. Unlike the result of aluminum concentration in water, there is no regular decrease in concentration of aluminum in the soil as we move far from the dumping point. This is because the distribution of aluminum is not homogenous in the solid waste as in liquid water. The concentration of aluminum in the solid at distances 100, 200 and 1000m from the dumping point located at the opposite direction of the water current were found to be 234.565, 184.643 and 180.00ppm respectively. These results show low concentration of aluminum at 200m and 1000m distances as that given in 1000m far in the direction of the water current. These results may prove that, there is a possibility of contamination of soil with aluminum within 500m in all direction from the dumping point.

Chapter five:

Conclusion & Recommendation

Conclusion & Recommendation

5.1- Conclusion

This study included the following:

Determination of residual aluminum in drinking water during water treatment processes and in treated water. All results were found to be within the permissible level limit of drinking water according to Sudanese specification 2007, and WHO guidelines.

Aluminum content in raw water, and in soil at the dumping area, at different distances from the drain waste at the direction of flow and opposite to direction of flow, found that the aluminum in raw water is very low around dumping area of drain waste, and this due to the most aluminum species is aluminum hydroxide (precipitated). There are a few amount of aluminum were found as complex form, this case clearly appeared in region A (drain region), because all aluminum complex is soluble in water. The aluminum in soil was found that the concentration of aluminum varying from one to another region and irregular manner resulting due to effect of flow in distribution of precipitated aluminum hydroxide. No risk of dumping the waste back to the river it present condition were controlled, as there is no aluminum detected in river water due to dumping waste which contain high aluminum content

5.2-Recommendation

1- Dumping of waste and mud coming from the plant should be avoided as it increases the aluminum content in the soil at the dumping point and area around it.

2- The management of MWTP and the local authorities have to seek for a method for recovering aluminum from this waste to be used again. If this is not feasible or costing at least it will decrease the aluminum content in the soil.

3- To avoid high concentration of aluminum in treated water :

    a- Excessive coagulant (PAC) should not be added

    b- Good mixing at flash mixer where the coagulant is added is necessary.

    c- Use optimum mixing speed for flocculation.

    d- Efficient flocculation is a key process controlling residual aluminum.

    e- Efficient filtration of aluminum flocs.

    f- Use optimum pH in coagulation process.

    g- Use of multimedia filtration to produce water in turbidity below 5 NTU minimize the amount of aluminum flocs particle in finish water.

    h- Use of activated carbon filter will be minimize the amount of residual aluminum in treated water.

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