Sudan University of Science and Technology
College of Graduate Studies

Complementary research to obtain a master′s degree in Environmental Engineering:

Evaluation and Design of the water treatment plant of Rabak City and the quality of it′s productive water.

(تقويم وتصميم محطة تنقية مياه مدينة ربك وجودة مياهها المنتجة)

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Dedication

I dedicate this study with my love to my parents ,brothers ,sisters ,teachers and all my friends for their continuous direct and indirect support ,patience and encouragement throughout the different stages of this work.

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Abstract

This research dealt with the problem of water in the city of Rabak, where the design of the drinking water purification plant was evaluated as well as the quality of drinking water produced

Subject study had been divided into five major chapters, the first chapter of which included an introductory which in brief highlighted the importance of water in general, and the subject of study ,the study handled the main and the sub target.

The second chapter discussed the parameters of drinking water (physical, chemical, biological) ,and discussed the stages of its purification and water unites purification ,also discussed the material used in water purification.

The third chapter is composed of study district and the station site, the steps measures.

Fourth chapter we approached an evaluation of the water , its design, the outcome of evaluation , design and its performance.

The last chapter was the conclusion of the study and the important future recommendations.

المستخلص

تناول هذا البحث مشكلة المياه في مدينة ربك ، حيث تم تقييم تصميم محطة تنقية مياه الشرب وكذلك جودة مياه الشرب المنتجة منها.

تم تقسيم هذه الدراسة إلى خمسة فصول رئيسية ، تضمن الفصل الأول منها تمهيدًا أبرز باختصار أهمية المياه بشكل عام ، وموضوع الدراسة ، حيث تناولت الدراسة الهدف الرئيسي والاهداف الفرعية.

وناقش الفصل الثاني معايير مياه الشرب (الفيزيائية والكيميائية والبيولوجية) ، وناقش مراحل تنقية المياه ، كما ناقش المواد الكيميائية المستخدمة في تنقية المياه.

يتكون الفصل الثالث من منطقة الدراسة وموقع المحطة ،وخطوات ومراحل اجراء هذه الدراسة.

اما في الفصل الرابع تناولنا تقييم جودة المياه وتصميم المحطة ، ونتائج التقييم والتصميم والاختبارات المعملية.

وكان الفصل الأخير هو إنهاء الدراسة ووضع التوصيات المستقبلية الهامة.

The Index:

Tables index:

Abbreviations

U V	Ultra violet.
BOD	Biological oxygen demand
COD	chemical oxygen demand
PH	Power of hydrogen.
TDS	Total dissolved solids.
TSS	Total suspended solids
MPN	Most probable number

CHAPYER ONE

INTRODUCTION

INTRODUCTION

1 – 1 Background:

Water is one of the most important elements necessary for life and its continuation on the planet.

There is no biological process except in the presence of a percentage of water, and the industrial processes of large and small require the presence of water and cannot do without.

Although water is one of the most abundant natural resources, there is a problem with the distribution of these resources. There are some densely populated areas with scarce water resources, for example in North Africa and the Arabian Peninsula.

On the other hand, there are areas where water resources are much in need, as in Europe. This inequitable distribution has led to the scarcity of potable water in a number of countries.

The increase in population density, the high standard of living of the world's people, the steadily expanding cities and the large industrial expansion in the world exacerbate this problem, and many governments are seeking techniques that allow the use of wastewater after treatment.

The production of drinking water from fresh surface water involves several processes, energy consumption and chemical dosing, all having global environmental impacts. These should be considered in the choice of water treatment processes.

Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids, and gases from water. The goal is to produce water fit for specific purposes. Most water is purified and disinfected for human consumption (drinking water), but water purification may also be carried out for a variety of other purposes, including medical, pharmacological, chemical, and industrial applications. The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination; and the use of electromagnetic radiation such as ultraviolet light.

Water purification may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, and fungi as well as reduce the concentration of a range of dissolved and particulate matter.

The standards for drinking water quality are typically set by governments or by international standards, These standards usually include minimum and maximum concentrations of contaminants, depending on the intended use of the water.

1 – 2 Statement of research problem:

The city of rabak suffers from a number of water problems, including water scarcity in the summer as a result of the decline of the Nile and the water in the network is weak and may be zero. Also, the water is turbid with high units especially in the flood season. Failure to carry out periodic maintenance of water pipes and to keep up to date on the developments.

Sometimes the color of the water changes to red and black in addition to that population and Distant areas do not reach the required quantity.

1 – 3 Research objective:

►To evaluate and design of drinking water stations and treatment stages

Conduct physical, chemical and biological tests of the water of the city of Rabak.

►To evaluate water quality.

►To Identify water problems on the network and suggest solutions to address these problems.

►To Ensure the highest quality water.

►To ensure the conformity of water to the Sudanese standards of drinking water.

1 – 4 Study area:

Rabak is the capital of white Nile state, The White Nile State is located in the southern part of Sudan with its new map between latitudes 12-13, 30 degrees north and longitudes 31-33.30 degrees east.

North Kordofan State, South-South Kordofan State, Upper Nile State in South Sudan from the South, and Al Jazeera and Sennar States to the east. The state has a total area of 39,701 square kilometers.

The city of Rabak is the capital of the state and the second largest city in terms of area and economic importance after the city of Kosti and the second largest commercial center of the White Nile State.

The population of the state is about 215,794,5 people, according to 2007 estimates.

Study area:

CHAPTER TWO

LITERATURE REVIEW

LITERATURE REVIEW

2.1 Introduction

Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water. That is why the aim of this chapter is to provide an overview of water quality characteristics - Physical, Chemical, Microbiological, and Biological characteristics.(Mark j.Hummer,2005)

2.2 Physical Characteristics of Water

Physical characteristics of water (temperature, colour, taste, odour and etc.) are determined by senses of touch, sight, smell and taste. For example temperature by touch, colour, floating debris, turbidity and suspended solids by sight, and taste and odour by smell.(Mark j.Hummer,2005).

2.2.1 Temperature

The temperature of water affects some of the important physical properties and characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity and solubility of dissolved gases and etc. Chemical and biological reaction rates increase with increasing temperature. Reaction rates usually assumed to double for an increase in temperature of 10 °C. The temperature of water in streams and rivers throughout the world varies from 0 to 35 °C.

2.2.2 Colour

Colour in water is primarily a concern of water quality for aesthetic reason. Coloured water give the appearance of being unfit to drink, even though the water may be perfectly safe for public use. On the other hand, colour can indicate the presence of organic substances, such as algae or humic compounds. More recently, colour has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water.

2.2.3 Taste and Odour

Taste and odour are human perceptions of water quality. Human perception of taste includes sour (hydrochloric acid), salty (sodium chloride), sweet (sucrose) and bitter (caffeine). Relatively simple compounds produce sour and salty tastes. However sweet and bitter tastes are produced by more complex organic compounds. Human detect many more tips of odour than tastes. Organic materials discharged directly to water, such as falling leaves, runoff, etc., are sources of tastes and odour-producing compounds released during biodegradation.

2.2.4 Turbidity

Turbidity is a measure of the light-transmitting properties of water and is comprised of suspended and colloidal material. It is important for health and aesthetic reasons.

2.2.5. Solids

The total solids content of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight at 103 °C to 105 °C. The organic fraction (or volatile solidscontent) is considered to be related to the loss of weight of the residue remaining after evaporation of the water and after ignition of the residue at a temperature of 500 °C. The volatile solids will oxidize at this temperature and will be driven off as gas. The inorganic (or fixed solids) remind as inert ash. Solids are classified as settleable solids, suspended solids and filterable solids. Settleable solids (silt and heavy organic solids) are the one that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass-fibre filters.

2.3 Chemical Characteristics of Water

The chemical characteristics of natural water are a reflection of the soils and rocks with which the water has been in contact. In addition, agricultural and urban runoff and municipal and industrial treated wastewater impact the water quality. Microbial and chemical transformations also affect the chemical characteristics of water(Mark j.Hummer,2005).

2.3.1 Inorganic Minerals

Runoff causes erosion and weathering of geological formation, rocks and soils as the runoff travels to the surface-water bodies. During this period of contact with rocks and soils the water dissolves inorganic minerals, which enter the natural waters. Inorganic compounds may dissociate to varying degrees, to cations and anions.

(A)Major Cations

Major cations found in natural water include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}). Calcium (Ca^{2+}), is the most prevalent cation in water and the second inorganic ion is bicarbonate in most surface water.($HCO3^{-}$)

The principal concern about calcium is related to the fact that calcium is the primary constituent of water hardness. Calcium precipitates as $CaCO_3$ in iron and steel pipes. A thin layer of $CaCO_3$ can help inhibit corrosion of the metal. However, excessive accumulation of $CaCO_3$ in boilers, hot water heaters, heat exchangers, and associated piping affects heat transfer and could lead to plugging of the piping. Calcium concentration up to 300 mg/L or higher have been reported. However, calcium concentrations of 40 to 120 mg/L are more common.

Magnesium is not abundant in rocks as calcium. Therefore, although magnesium salts are more soluble than calcium, less magnesium is found in surface water. Sodium and potassium are commonly found as free ions. The concentration of these cations in natural water usually are low.

Other constituents in natural water in concentration of 1 mg/L or higher include aluminium, boron, iron, manganese, phosphorus and etc.

(A) Major Anions

Major anions include chloride, sulfate, carbonate, bicarbonate, fluoride and nitrate. Bicarbonate (HCO_3^{-}) is the principal anion found in natural water. These ions are very important in the carbonate system, which provides a buffer capacity to natural water and is responsible in a great measure for the alkalinity of water.

One source of **bicarbonate** ions (HCO_3^-) in natural water is the dissociation of carbonic acid (H_2CO_3) that is formed when carbon dioxide (CO_2) from the atmosphere, or from animal (e.g. fish) and bacterial respiration, dissolves in water.

In addition to bicarbonates (HCO_3^-) anions such as chlorides (Cl^-), sulfates (SO_4^{2-}), and nitrates (NO_3^-) are commonly found in natural water. These anions are released during the dissolution and dissociation of common salt deposits in geologic formations.

The concentration of the **chlorides** anions (Cl^-) determines the water quality because the quality of water get worse after increasing in the concentration of this anions which limit possibilities of using of natural water for different purposes (household, agriculture, industry and etc.). Principal source of the chlorides anions (Cl^-) in natural water are magmatic rock formations that include chlorine-content minerals. The second source of this anions is Ward Ocean from where a considerably amount of chlorides anions (Cl^-) enter in the atmosphere. From atmosphere chlorides anions (Cl^-) enter in the natural water in result of interaction between precipitation and soil.

The **sulfates** anions (SO_4^{2-}) are frequently found in natural water as the result of the chemical dissolution, dissolve sulfur-content minerals and oxidize sulfates and sulfur:

$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O+CO_2$;

$2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$;

$2S + 3O_2+ 2\ H_2O = 2\ H_2SO_4$.

The sulfates anions (SO_4^{2-}) enter in natural water as the result of the oxidation of the substances from plant and animal origin. The increase concentration of the sulfates anions (SO_4^{2-}), at one hand brings about change for the worse of some physical characteristics of water (taste, smell and etc.) and on the other hand has destructive influence upon human consumption. The concentration of the sulfates anions (SO_4^{2-}) fluctuates in a wide range in surface water - from 5 mg/l to 60 mg/l.

Nitrate anions (NO_3) are found in natural water as the result of the bacteriological oxidation of nitrogenous materials in soil. That is why the concentration of these anions rapidly increases in summer when the process of the nitrification takes place very intensively. Another important source for dressing of the surface water with Nitrate anions (NO_3) are precipitations, which absorb nitric oxides and convert them into nitric acid. A great deal of nitrate anions (NO_3) enter in surface water together with domestic water and water from industry, agriculture and etc. Nitrate anions (NO_3) are one of the indicators for the degree of the pollution with organic nitrate-content substances.

Other anions found in water include **fluorides** (F^-), **carbonates** (CO_3^{2-}) and **phosphates** (PO_4^{3-}). Typical concentrations of major ions in the classic "word average" river are presented in Table 2.1.

Table 2.1 Typical concentrations of Major Ions in the Classic "Word Average"

Constituent	Concentration mg/L	Cations meg/L	Anionsmeg/L

Cations			
Ca^{2+}	15	0.750	-
Mg^{2+}	4.1	0.342	-
Na^{+}	6.3	0.274	-
K^{+}	2.3	0.059	-
Anions			
HCO_3^-	58.4	-	0.958
SO_4^{2-}	11.2	-	0.233
Cl^-	7.8	-	0.220
NO_3^-	1	-	0.017
Sum	106.1	1.425	1.428

2.3.2. Carbonate Equilibrium

The carbonate - bicarbonate system is presumably the most important chemical system in natural waters. The carbonate system provides the buffering capacity essential for maintaining the pH of natural water systems in the range required by bacteria and other aquatic species.

The carbonate system includes the following species: CO_2, H_2CO_3, HCO_3^- , CO_3^{2-}, OH^- and H^+. The total content (mol/dm^3) of its components is as follows:

$$\sum CO_2 = [CO_2] + [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$$

Frequently Ca^{2+} and $CaCO_3$ are included in the carbonate system, since Ca^{2+} is second in abundance to HCO_3^- in natural waters. The solution of carbon dioxide

(CO_2) into natural water causes the formation of carbonic acid (H_2CO_3) (1). The H_2CO_3 dissociates to bicarbonate (HCO) and hydrogen (H^+) ions (2). In its turn HCO_3^- can dissociate and produce carbonate (CO) and hydrogen (H^+) ions (3).

(1) $CO_2 + H_2O \rightleftarrows H_2CO_3$;

(2) $H_2CO_3 \rightleftarrows H^+ + HCO$;

(3) $HCO_3 \rightleftarrows H^+ + CO$.

The hydrogen ion (H^+) concentrations $[H^+] = 10^{-pH}$ in water controls the pH of the solution. The pH of water is defined as the negative logarithm of the $[H^+]$, where $[H^+]$ is the hydrogen ion concentration expressed in moles per litre (mol/L).

$$pH = -\log[H^+] = \log\frac{1}{[H^+]}$$;

$$pOH = -\log[OH^-] = \log\frac{1}{[OH^-]}$$

The pH is the negative power to which 10 must be raised to equal the hydrogen ion concentration or $[H^+] = 10^{-pH}$. In a neutral solution $[H^+]$ is 10^{-7} or pH = 7. At greater hydrogen ion concentrations the pH is lower and for greater hydroxide ion concentrations the pH increases. The pH range is from 0 (extremely acidic) to 14 (extremely basic).

Therefore, the pH of the water controls which species is predominant. Water molecules HOH (commonly written as H_2O) dissociate or ionize to H^+ and OH^- ions.

$2H_2O \rightleftarrows H_3O^+ + OH^-$

or written in a simple form:

$H_2O \leftrightarrows H^+ + OH^-$.

The product of $[H^+]$ and $[OH^-]$, in mol/L, is constant:

$[H^+]\ [OH^-] = K = 1 \times 10^{-14}$

where K is the ion-product constant of water.

If the hydrogen ion concentration is 10^{-4} mol/L the hydroxide ions (OH^-) concentration must be $10^{-14}/10^{-4} = 10^{-10}$ mol/L. Since the 10^{-10} is smaller than 10^{-4}, the solution is acidic. A large amount of hydrogen ions (H^+) in water makes the water acidic and lack of hydrogen ions makes the water basic. A basic solution has predominance of hydroxide ions (OH^-). The dissociation reactions of carbonic acid (H_2CO_3) and of the bicarbonate ion (HCO) can be written as the following equations:

$H_2CO_3 \leftrightarrows HCO + H^+$ and $k_1 = 10^{-6.35}$ at 25 °C;

$H_2CO_3 \leftrightarrows CO + H^+$ and $k_2 = 10^{-10.3}$ at 25 °C.

These equations can be used to define the relative distribution of carbonate species as a function of pH. Changes in pH can have drastic effects on the species present in the carbonate system. Therefore the fraction of carbonic acid $[H_2CO_3]$ may be expressed as α_0 and written as the fraction:

$$\alpha_0 = \frac{[H_2CO_3]}{[H_2CO_3]+[HCO_3^-]+[CO_3^{2-}]}$$

Similarly the fraction of bicarbonate ion $[HCO_3^-]$ and carbonate ions $[CO_3^{2-}]$ may be expressed as α_1 and α_2, respectively, and written as the following fractions:

;$$\alpha_1 = \frac{[HCO_3^-]}{[H_2CO_3]+[HCO_3^-]+[CO_3^{2-}]}$$

$$\alpha_2 = \frac{[CO_3^{2-}]}{[H_2CO_3]+[HCO_3^-]+[CO_3^{2-}]}$$

2.3.3 pH and Alkalinity

Alkalinity is defined as the capacity of natural water to neutralize acid added to it. Total alkalinity is the amount of acid required to reach a specific pH (pH = 4,3 to 4,8). Total alkalinity can be approximated by alkalinity as the following expression:

Total alkalinity = $[HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$

Total alkalinity includes Hydroxide alkalinity $[OH^-]$, Bicarbonate alkalinity $[HCO_3^-]$ and Carbonate alkalinity $[CO_3^{2-}]$. If the pH and total alkalinity are measured, the concentration of the various components of alkalinity can be calculated using the values of α_1 and α_2 determined for the pH of the water. These values can be used to calculate the:

Hydroxide alkalinity = $\frac{K_w}{[H^+]}$

Bicarbonate alkalinity = $\alpha_1 C_t$

Carbonate alkalinity = 2 $\alpha_2 C_t$

where C_t is total carbonate and C_t= [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}].

The amount of strong acid (in eq/L) required to change colour of the water from pink to clear (colourless) when a small amount of phenolphthalein reagent is put into the water sample is phenolphthalein alkalinity. This colour change occurs at approximately pH = 8.3. Continuing the titration to pH = 4.3, which is the H_2CO_3 endpoint, yields the total alkalinity. The values of each three forms of alkalinity can be determined using the relative values of the phenolphthalein alkalinity and the total alkalinity, expressed as either eq/L or mg/L $CaCO_3$.

2.3.4 Acidity

Acidity is the "quantitative capacity of aqueous media to react with hydroxyl ions". Titration with a strong base (NaOH) to define end points (pH = 4,3 and pH = 8,3). Acidity indicates the corrosiveness of acidic water on steel, concrete and other materials.

2 – 4 Components of drinking water purification plant:

●Water source

●intake

●Low lift station

●Quick Mixing Bins

●Primary sedimentation ponds

●Material Preparation Unit

●Slow Mixing Bins

●Secondary sedimentation ponds

●Filters

●Filtration water tanks

●High lift units

2-4-1 intake

Is the site chosen by the Engineer to take away the turbidity of water and take the necessary construction work to protect the bottom of the watercourse and its aspects in a way to ensure access to the current and future water levels.

2 -4 – 2 Screening:

Water from lakes, rivers or the ground passes through a screen as it enters the water treatment plant. When the water source is a lake or river, the screen serves an important function, keeping out large natural contaminants such as plants and wood, or fish. If ground water is used, screening may not be necessary since the water has passed through layers of the earth in what is essentially a natural screening function.

2 -4 -3 Sedimentation:

The water and floc flow into a sedimentation basin. As the water sits there, the heavy floc settle to the bottom, where they remain until removal.

Sedimentation is divided into two parts:

(A)Natural sedimentation: The purpose of this process is to remove the largest possible percentage of suspended substances in water in private ponds without adding substances to help this sedimentation.

(A)Chemical sedimentation: The purpose of this process is to deposit the largest proportion of suspended materials by providing different engineering factors and operation of the ponds. These factors include:

●Horizontal velocity of water in basins.

●Surface area of ponds.

●Sediment extraction method.

●Water temperature and temperature.

●Duration of water in the basin.

●Volume and density of outstanding water.

●**Coagulation:**

Treatment plant workers add alum and other chemicals to the water, which cause tiny sticky particles, or floc, to form. These floc attract dirt particles, making them eventually heavy enough to sink to the bottom of the water storage tank.

●**Coagulants:**

There is a global agreement materials for drinking water purification stations purification:

- Solid aluminum sulphate.
- PAC.
- Ferric sulphate.
- Chloride Chloride.
- SODUIM hydroxide.
- Calcium Sulphate.
- Chloride aldehyde.

▪ Sodium aluminate.

▪Magnesium oxide.

•Flash mixing :

is the process by which a coagulant is rapidly and uniformly dispersed through the mass of water. This process usually occurs in a small basin immediately preceding or at the head of the coagulation basin. Generally, the detention period is 30 to 60 seconds and the head loss is 20 to 60 cms of water. Here colloids are destabilised and the nucleus for the floc is formed.

●**The slow mixing:** The purpose is to complete the interaction between the additives in the previous phase and the suspended materials in water and impurities and in a period of 20/40 minutes and during this period the small suspended materials are collected in the form of larger granules that can then be deposited in the sedimentation ponds and the slow blending process The following methods:

▪ Baskets with water or vertical barriers.

▪ Ponds where mechanical mixing is performed.

●**Sedimentation tanks:**

The percentage of precipitation from the suspended materials in the settling ponds is 90% and the ratio of deposition of the suspended materials depend on:

▪Foundations of sedimentation pond design.

▪Water quality.

●**Foundations of sedimentation pond design:**

▪Surface loading rate is between 20-40 cubic meters / m2 / day.

▪Duration of water in the basin (2_4) hours.

▪The depth of the basin (3-6) meters.

▪The horizontal velocity of the water is not more than 15 cm / min.

▪The ratio of length to width is within 1: 4.

▪For circular tubing, it is recommended that the diameter should not exceed 40 m.

▪The water exit rate on the output of the pipe is 450 cubic meters / day.

▪When using the form of V, the depth is 5 cm and the distances between them (8-15) cm.

2 – 4 – 4 Filtration:

Water passes through layers of gravel, sand and perhaps charcoal, which serve to filter out any remaining particles. The gravel layer is often about 1 foot deep and the sand layer about 2½ feet deep.

●Backwash:

The amount of water to be washed can be calculated on the basis that it is equal to (1-5) % of the filtered water intake during the nomination period and takes 15 minutes.

CHAPTER THREE

RESEARCH METHODOLOGY

RESEARCH METHODOLOGY

3-1 Introduction:

The Nile Water Authority plan aims to provide water supply of quality and quantity to the citizens of the state and to promote social, economic and environmental development. To achieve this objective, the Commission has embarked on the construction of a number of modern Nile water purification plants with advanced specifications and techniques including precision equipment for measuring, monitoring and controlling all purification processes. Stations Establish and establish a modern distribution network that is compatible with the environment and producing healthy drinking water conforming to international standards to deliver it to all consumers in a safe manner.

3 – 2 Study area:

Located on the eastern bank of the White Nile west of the city of Rabak in an area of 50 acres, this plant was designed in 1995 to produce 300.000 cubic meters per day and is now in service.

Lines attached to the station

●The water carrier line of 800 mm diameter is 6.5 kilometers long to feed the eastern side of the city which is 27 square, 29 square, 21 square, 36 square, square 53 box.

●The water carrier line is 800 mm to the south and center of the city, which is: square 6, square 8, square 9, square 13, square 14, square 17, square 33, box 56, plus the ancient lord (market).

●The water carrier line is 400 mm diameter to feed the western side of Rabak city.

●A 400 mm water carrier line to feed the northern part of the city, namely: Hilla Al-Jadida, Al-Zuhour, Al-Rawashdeh, And squares 2,3,4,5

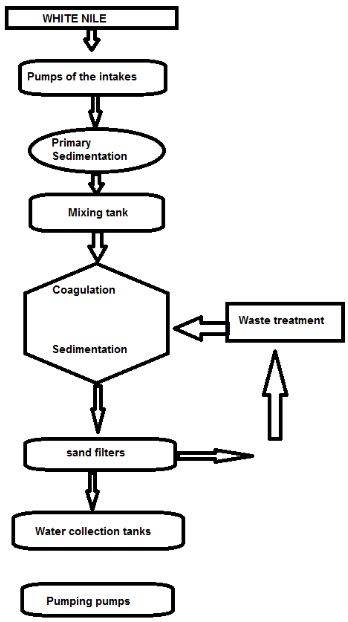
Areas served by the station:

The Rabak Drinking Water Station serves as a residential square

Residential boxes 1,2,3,4,5,6, 7,8,9,10,13,14,17,23,27,and 29.

Al hella aljadeeda ,alrawashda,and hai alzuhoor.

•Treatment steps diagram:



3 - 3Water purification steps:

Water purification and treatment is divided into two main parts:

1 / Dispose of turbidity which is particles of clay and suspended materials.

2 / Elimination of microbes

3 – 3 - 1 disposal of turbidity:

and is in the following stages:

•screening phase:

It is a square mesh around the pump to protect it from any impurities (large or lumpy animal residues) that can cause pump failure or reduce productivity.

•primary sedimentation basins: This phase depends on the roughness of the raw water where the efficiency of this stage increases by increasing the turbidity of raw water and vice versa and ranges, and its efficiency ranges from 60% to 80%

•Phase of adding chemicals: chemicals are added in the rapid mixing basin, in which the three chemicals are added by a specific dose (L / h) according to the laboratory results. In this step, the contact process

•Sand filters:

The sand filter consists of layers (asphalt, coarse sand, fine sand) with specific depths and diameters.

At this stage, the small particles that have not been deposited in the previous phase are blocked. There are 10 filters in the station, 8 of which are in the case of two pumps, 4 in the case of one pump and the rest is reserve. The water is filtered into the filter tanks, including the main tanks, including pump pumps in the network.

3 -3 – 2 Disposal of microbes:

The chlorine gas is used to purify the water from the microbes where it is prepared in a complete system and the chlorine is injected into three stages in the plant:

Primary injection: Between the stage of the primary sedimentation ponds and the rapid mixing basin. The injection is done only in the case of the reduction of the raw water turbidity below 50 TCU.

Intermediate injection: after sedimentation ponds.

Final injection before the ground tanks and it is assumed that the ratio of chlorine free water treated between 0.2 - 0.8 mg per liter.

The plant has a chemical laboratory and a microbiology laboratory to ensure the water produced.

3–4 Safety and Security:

Security and safety equipment available at the station:

●Buoys by the take

●Fire extinguishers in all buildings

●Oxygen pans and cylinders in the chlorine cylinders chamber

●A water jet line connected with the service station water line

●The security and safety instructions shown in the administrative building.

3 - 5 Research Plan:

● The title of the project was the evaluation and design of the drinking water station in Rabak City.

● The introduction of the research, which explains the field of research and its significance, and the importance of the deficiency resulting from this research..

● A plan was developed to collect and obtain information as well as a timeline for the progress of the project.

● All design factors have been studied and compared with standard design and better solutions proposed for this plant.

● The information was collected from the station and the data were taken by field visits from the point of view of the water to the network.

●The research is divided into two parts : water quality assessment and design factors assessment.

The plan that collected the information was developed as follows:

3 – 6 Collection of information and studies related to the plant:

The information was collected based on research research and hypotheses and was collected from the library of the college, which is a theory and scientific equations.

3 - 6 – 1 Field visits:

The Rabak water station was visited several times and data and information were collected in the field accompanied by the competent engineer.

3 – 6 -2 Interview with specialists:

We have several interviews with the station manager, engineers and a number of senior workers.

3 – 6 – 3 Visit related institutions:

We have made several visits to the Rabak Water Authority to obtain permission to enter the station and conduct the study, as well as a visit to the statistics department in the Authority.

3 – 6 -4 world Wide Web:

A number of information has been obtained from the Web.

Water quality assessment:

3-7 Physical parameters analysis:

3 -7-1 Turbidity:

The turbidity of sample is the reduction of transparency due to the presence of particulate matter such as clay or slit, finely divided organic matter, plankton or other microscopic organisms. These cause light to be scattered and absorbed rather than transmitted in straight lines through the sample. The values are expressed in nephelometric turbidity units (NTU). The method is applicable to drinking, surface and saline waters in the range of turbidity 0-40 NTU. Higher values may be obtained by dilution of the sample.

3-7-2 Total Dissolve solids:

The following two methods are applicable for TDS measurement
Gravimetric Method

Determination of TDS based on conductivity

• Determination of TDS based on conductivity

This method involves two steps:
•Determination of Conductivity

•Calculation of TDS by conductivity

3-7-3 Conductivity

Specific conductance is determined by using a Wheatstone bridge in which a variable resistance is adjusted so that it is equal to the resistance of the unknown solution between platinized electrodes of a standard conductivity cell.

Temperature affects conductivity, which varies by about 2% per degree Celsius. The temperature of 25:C is taken as standard. It is desirable to observe the conductivity at 25:C or as near to this temperature as possible, although compensation for variations from it can be made. In some instruments, this is made automatically.

• Calculation of TDS by conductivity:

The ability of a solution to conduct an electric current is the functioning of the concentration and charge of ions in the solution and also depends on ionic mobility. Ionic mobility decreases with increase in number of ions per unit volume of solution due to interionic effect and other factors. Broadly, the relationship between conductivity and dissolved solids and conductivity and soluble cations is given by the following equations:

$$A\,K = S \text{ and,}$$

$$K = 100\,C$$

Where

A = multiplication factor for converting conductivity values to total dissolved solids;

K = conductivity in µs/cm,

S = total dissolved solids in mg/L, and

C = total soluble cations in meq/L.

the value of A varies from 0.54 to 0.96 depending on the nature of ion present in water, and is usually taken as 0.65.

TDS = 0.65*118 = 76.7 mg/l .

3-8 Chemical parameters:

3-8-1 PH:

pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect pH value of water. The overall pH value range of natural water is generally between 6 and 8. In case of alkaline thermal spring waters pH value may be more than 9 while for acidic thermal spring waters, the pH may be 4 or even less than 4. Industrial wastes may be strongly acidic or basic and their effect on pH value of receiving water depends on the buffering capacity of water. The pH value of water obtained in the laboratory may not be the same as that the time of collection of water samples, due to loss or absorption of gases, reactions with sediments, hydrolysis and oxidation or reduction taking place within the same sample bottle. pH value should preferably be determined at the time of collection of sample.

The value of pH is = 6.55

3-8-2 Nitrate :

Determination of nitrate (NO3) is difficult because of the relatively complex procedures required, the high probability that interfering constituents will be present and the limited concentration ranges of the various techniques. Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters. Significant sources of nitrate are chemical fertilizers, decayed vegetable and animal matter, domestic effluents sewage sludge disposal to land, industrial discharge, leachates from refuse dumps and atmospheric washout.

3-8-3 Chloride:

The presence of chloride in natural waters can be attributed to dissolution of salt deposits, discharges of effluents from chemical industries, oil well operations and seawater intrusion in coastal areas. Each of these sources may result in local contamination of both surface water and groundwater. The salty taste produces by chloride depends on the chemical compositions of the water. A concentration of 250 mg/L may be detected in some waters containing sodium ions. On the other hand, the typical salty taste may be absent in water containing 1000mg/L chloride when calcium and magnesium ions are predominant. High chloride content may harm pipes and structures as well as agricultural plants.

3-8-4 Fluoride:

Fluoride ions have dual significant in water supplies. High concentration of F^- causes dental fluorosis (disfigurement of the teeth). At the same time, a concentration less than

0.8 mg/L results in 'dental caries'. Hence it is essential to maintain the F^- concentration between 0.8 to 1.0 mg/L in drinking water. Among the many methods suggested for the determination fluoride ion in water, the Colorimetric method (SPANDS) and the ion selective electrode method are the most satisfactory and applicable to variety of samples. Because all of the Colorimetric methods are subject to errors due to presence of interfering ions, it may be necessary to distill the sample before making the fluoride estimation.

Table (3-1): Maximum limits for interfering substances:

Chlorides (as CI)	2000 mg/L
Sulphates (as SO_4)	300 mg/L
Alkalinity (as $CaCO_3$)	400 mg/L
Iron (as Fe)	2 mg/L
Aluminium (as Al)	0.5 mg/L
Phosphates (as PO_4)	5 mg/L

3-8-5 Total hardness:

Water hardness is a traditional measure of the capacity of water to precipitate soap. Hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions. It is caused by dissolved polyvalent metallic ions. In fresh water, the principal hardness causing ions are calcium and magnesium which precipitate soap. Other polyvalent cations also may precipitate soap, but often are in complex form, frequently with organic constituents, and their role in water hardness may be minimal and difficult to define. Total hardness is defined as the sum of the calcium and magnesium concentration both expressed as $CaCO_3$ in mg/L. The degree of hardness of drinking water has been classified in terms of the equivalent $CaCO_3$ concentration as follows:

0-60 mg/L Soft

60-120 mg/L Medium

120-180 mg/L Hard

>180 mg/L   Very Hard

3-8-6 Alkalinity:

Alkalinity of sample can be estimated by titrating with standard sulphuric acid (0.02N) at room temperature using phenolphthalein and methyl orange indicator. Titration to decolourisation of phenolphthalein indicator will indicate complete neutralization of OH^- and ½ of CO_3^- while sharp change from yellow to orange of methyl orange indicator total alkalinity (complete neutralization of OH^-, CO_3^- , HCO_3)

3-8-7 Sulphate:

Sulphate ions usually occur in natural waters. Many sulphate compounds are readily soluble in water. Most of them originate from the oxidation of sulphate ores, the solution of gypsum and anhydrite, the presence of shales, particularly those rich in organic compounds, and the existence of industrial wastes. Atomospheric sulphur dioxide formed by the combustion of fossil fuels and emitted by the metallurgical roasting processes may also contribute to the sulphate compounds of water. Sulphur trioxide (SO_3) produces by the photolytic oxidation of sulphur dioxide comes with water vapours to form sulphuric acid which is precipitated as acid rainor snow.

3-9 Bacteriological parameters:

3-9-1 Total coliform:

The term "total coliforms" refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources.

3-9-2 faecal streptococci:

The presence of faecal streptococci is evidence of faecal contamination. Faecal streptococci tend to persist longer in the environment than thermotolerant or total coliforms and are highly resistant to drying

Comparison of methods for analysis of coliform bacteria

Table (3-3):

Multiple fermentation tube technique	Membrane filter technique
Slower: requires 48 hours for a positive	More rapid: quantitative results in or presumptive positive about 18 hours
More labour-intensive	Less labour-intensive
Requires more culture medium	Requires less culture medium
Requires more glassware	Requires less glassware
More sensitive	Less sensitive
Result obtained indirectly by statistical approximation (low precision)	Results obtained directly by colony count (high precision)
Not readily adaptable for use in the field	Readily adapted for use in the field
Applicable to all types of water	Not applicable to turbid waters
Consumables readily available in most countries	Cost of consumables is high in many countries
May give better recovery of stressed or damaged organisms in some circumstances	

3-9-3 Multiple fermentation tube analysis:

The technique has been used for the analysis of drinking-water for many years with satisfactory results. It is the only procedure that can be used if water samples are very turbid or if semi-solids such as sediments or sludges are to be analysed. The procedure followed is fundamental to bacteriological analyses and the test is used in many countries.

CHAPTER FOUR

RESULTS

RESULTS AND DISSCUSSION

4 – 1 Intake of plant:

The pump consists of three pumps, two horizontal pumps, each producing 2600 cubic meters per day, and the third is installed with two pumps and the other one.

4-1-1 Evaluating pumps:

•Vertical pump:

By using equation (4 – 1):

$$HP = \frac{\gamma * Q * H}{75\ E}$$

Water density Kg/m³ $\gamma \equiv$

Q ≡ DISCHARGE M³/S

HP ≡ The capacity of the horse pump

H ≡ Press the button (M)

E ≡ Pump efficiency (%)

Q=100000 m³/day $=\frac{100000}{24*60*60}$ =1.16 m³/s

E = 98 %

HP = $\frac{1000*1.16*1000}{75*98} = 15782.3\ HORSE$

• Horizontal pump:

E = 87 %

HP = $\frac{1000*1.16*1000}{75*0.87}$ = 17777.8 $HORSE$

4-1-2 Evaluation of the intake pipe:

In the case of two horizontal pumps

Q = 2600*2 =5200 m^3/hr =1.4 m^3/s .

Pipe diameter:

D = 900mm = 0.9m

Pipe section area:

A = $\pi D^2/4$ = $\frac{3.14*(0.9)^2}{4}$ =0.64m^2

By using Continuity equation

Q = A * V

V = $\frac{Q}{A}$ =$\frac{1.4}{0.64}$ = 2.18 m/s.

This indicates that the intake pipe is not exposed to erosion and corrosion, the standard speed of running water in the pipes lies (0.6 - 4)

In the case of a horizontal pump and another vertical:

Q= 3600+2600 = 6200 m^3/s = 1.72 m^3/s

Q = A*V

$V = Q/A = \mathbf{1.72}/_{\mathbf{0.64}}$ = 2.68 m/s

This indicates that the intake pipe is not exposed to erosion and corrosion, the standard speed of running water in the pipes lies (0.6 - 4) m/s.

4 – 2 Primary sedimentation tanks:

Tank depth = 4 m

Tank diameter = 40 m

There are two tanks :

Volume = A*d = $\pi d^2 * d/4 = \frac{3.14 * 40^2 * 4}{4}$ = 5026 m^3

4-2-1 Detention time:

D.T = Volume/discharge

For one tank Q = 100000/2 = 50000 m^3/day

D.T = 5026/50000 = 0.1 day =2.4 hr, that is okay.

The length of the sediment should be (2 - 4) hours.

4-2-2 Surface area of sedimentation tank:

From equation:

A = Volume/diameter = 5026/4 = 1256.5 m^2

$A = \pi D^2/4$

$D = \sqrt{1256.5 * 4 \frac{1}{3.14}} = 40\ m$ That is ok

In the circular tanks, the diameter of the circular basin should not be more than 40 m

4-2-3 Surface over flow rate:

Surface over flow rate = Q/A

Q = 100000/2 =50000 m^3/day.

Surface over flow rate = 50000/1256.5 = 40 m^3/m^2/day

Surface loading is between 20 – 40 m^3/m^2/day

4- 3 Weir over flow rate (WOR):

WOR = Q/R

R = ΠD

R ≡ The circumference of the circle is equal to the length of the weir.

R = 3.14 * 40 = 125.6 m .

WOR = 50000/125.6 = 398 m^3/m^2/day. It is ok .

From the foundations of the design of sedimentation tank, the water exit rate should not exceed 450 m^3/m^2/day.

4 – 4 Chemical additives for coagulation:

The chemicals are added to the rapid mixing basin with three mixers where the chemical is added by a specific dose according to the results of the laboratory, The water is distributed in three basins.

4-4-1 Flash mixing tank design:

Volume = area * depth

$V = (\pi D^2/4) * d = (\pi * 4^2 * 4)/4 = 50.2\ m^3$

Detention time = volume /discharge = 50.2/1.157 =43.4 sec

Detention time must ranging (20 – 60)

That is ok

4-4-2 Gentle mixing tank design:

$A = \pi D^2/4$

D = 24.8 m

D ≡ diameter of tank

$A = 3.14 * 24.8^2/4 = 482.8\ m^2$

Total volume = 6821 m^3

Number of tanks = total volume of tanks /the volume of one tank

The depth of tank = 4.7 m

Volume of tank = A*D = 482.8 * 4.7 =2269.16 m^3

N = 6821 / 2269.16 = 3

The number of gentle mixing tank is three.

That is ok.

4 – 6 filters:

The number of filters in the station 20 filters, including 16 in the case of two pumps and the use of a pump in the case of one pump, the water filtered into the filters, including the main tanks and finally pump pumping network.

The thickness of the concrete in the filter 30 cm and the fine sand of 50 cm The yield of one filter 250 m3 / day, every 5 water filters are collected through a tube in one tank and then collected all the water in the ground reservoir.

•The number of filters:

$N = 0.044^* \sqrt{Q}$

$N = 0.044 * \sqrt{100000} = 13.9 = 14$

There are backup filters

That’s ok

●Wash filters:

The filters are washed by pumping the air first to pick up the sand and gravel. After that, air and water are pumped to wash. Wash water is pushed to the settling ponds to perform the treatment.

The reverse is repeated at 10 liters per square meter for ten minutes.

4 – 7 Disinfection:

Chlorine gas is used to disinfect water from microbes where it is prepared in an integrated system.

•The chlorine is injected into the plant during phases:

4-7-1 The primary injection is between the primary sedimentation ponds and the rapid mixing basins where the injection is in the case of a drop of raw water turbidity of 50 NTU.

4-7-2 Medium injection in the filtration ponds.

4 – 8 Storage:

The station has a number of ground reservoirs with a capacity of 2500 cubic meters each, and each reservoir has a hole for discharge of water.

4-9 Evaluation of reservoirs:

Calculate the time of water retention in the tank to complete the chlorination process from the equation

D.T = Volume / discharge

D.T = 25000/100000 = 0.25 day = 6 hr

Detention time must ranging (6 – 8) hr.

That is ok.

4 – 10 The result of laboratory tests:

Table (4-1)

Test	Value (Mg/L)	Permissible limits according to (SSMO)
pH	6.55	6.5 - 8.5
Turbidity	24.2(NTU)	5NTU
Chloride	17.8	250Mg/L
fluoride		105 Mg/L
Nitrate		10 Mg/L
Hardness	130	500 Mg/L
Calcium	19	200 Mg/L
Electrical conductivity	118(µ.s)	1250(µ.s)
TDs	77	1000Mg/L
E.coli	Not found	Zero

CHAPTER FIVE

DISSCUSSION

Discussion

From the result that is collected from laboratory analyses we observed:

1/ the vertical pump of the plant is working with 98 % efficiency and the horizontal pump is working with 87% efficiency.

2/ the intake pipes are not exposed to erosion and corrosion, the standard speed of running water in the pipes with in the allowed limits.

3/ Primary sedimentation tanks parameters volume ,surface area of sedimentation ,surface over flow rate ,detention time and weir over flow rate are within the allowed limits.

4/ the flash mixing tanks for chemical additives which use to coagulation is three with total volume of 50.2 M^3 .

5/the genteel mixing tanks are three too with a total volume of 6821 M^3.

6/ The number of filters in the station 20 filters with a capacity of 250 m^3/day.

7/ the physical parameters (pH =6.55) , (TDS = 77),(electrical conductivity =118) with in the allowed limits according to **Sudanese specifications (SSMO), table (2-7)** except the parameter turbidity(24.4) its out of range , I recommended that to check the sedimentation tank and chemical substances use for coagulation.

8/all the chemical parameters such as pH, choride ,floride ,nitrate ,sulphate ,calcium and total hardness are within the allowed limits according to **Sudanese specifications (SSMO) .**

9/the bacteriological analysis of multiple fermentation tube did not shown any bacterial contamination .

CHAPTER SIX

CONCULOSION AND RECOMMENDATIONS

CONCLUSION AND RECOMMENDATION

5 – 1 Conclusion:

After field visits and tours we have found the following:

The plant is designed to produce 300.000 cubic meters / day designed in two phases, the first phase with a design capacity of 50.000 m3 / day And the second phase to produce 300,000 cubic meters per day.

The station works by dewatering system to draw stagnant water and return it to the Nile, thus maintaining the public health inside the station, in addition to the presence of sludge ponds that work on the deposition of impurities.

Since the white Nile is the source of the plant and although it contains a low rate of turbidity compared to blue Nile, the initial deposit basins were made to reduce the percentage of silt entering the plant and then return water to the settling ponds and treat them again, It can be skip but it work to reduce the amount of chemicals added to the raw water which reduce economic cost.

A fixed distance was selected to ensure access to the required water at the low level of the Nile .

The standard velocity of the pipes was calculated in the outlet and found to be resistant to abrasion and corrosion in the work of horizontal pumps or in the case of the work of horizontal pump and other vertical.

The primary sedimentation ponds were designed and found to be circular and found to conform to the specifications of a diameter of 40 meters and a depth of 4 meters.

Slow and rapid blending pools are designed.

The candidate was designed and evaluated and found that there were additional filters with a production capacity of 250 m3 / h per filter.

The study found that the station works well, but there are periods when the plant has some problems, especially during the period of the river's decline and sometimes the lack of chemicals.

Finally, the capacitor time was calculated in the tank which is 6 hours

And the second phase to produce 300,000 cubic meters per day

5 – 2 Recommendations:

We recommend the completion of the second phase of the target to reach 300,000 cubic meters per day in order to provide sufficient water supply.

Samples should be taken from the water to ensure that they meet the specifications and standards at least every two hours.

Attention should be paid to the station's laboratory and equipped with the necessary and advanced equipment.

Care should be taken of periodic maintenance and rehabilitation as this will lead to the sustainability of the service provided to users and its continuity for a long period

It is necessary to have a specialist in the safety and occupational health of the contractor to take over supervision and follow-up workers and follow-up safety purposes at the station.

Conductive chemicals and disinfectants must be regularly available

To make periodic awareness of workers and citizens and to inform them of the high economic cost in order to rationalize the use of water.

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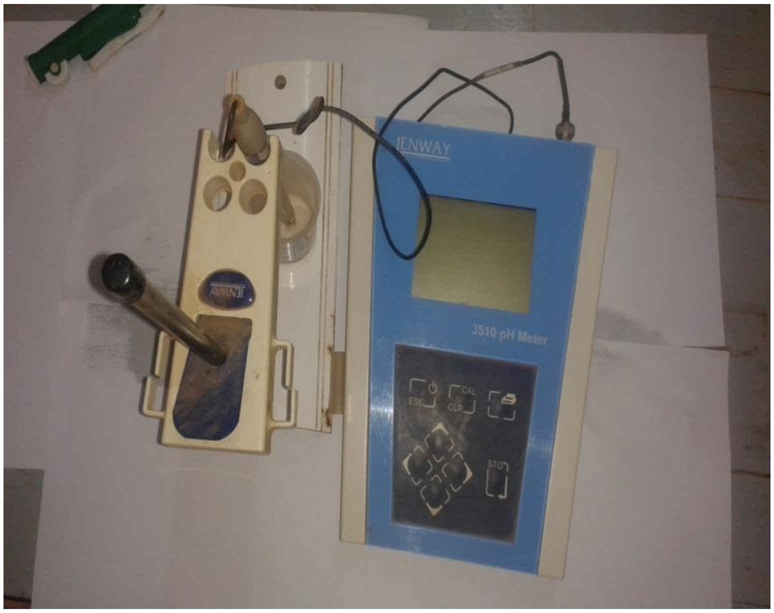

PH meter

discater

Sensitive Balance

cup

Sedimentation tank