

الإهداء

بدأنا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات وهانحن اليوم والحمد لله نطوي سهر الليالي وتعب الأيام

وخلاصة مشوارنا بين دفتي هذا العمل المتواضع.

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Abstract

The main objective of this project is to find a suitable technique for advanced wastewater treatment. Purification of water effluent from Nablus western treatment plant is considered for reuse it.

To achieve this objective, the plant was visited. It was found that the amount of treated wastewater is around 12000 m³/day. Economic advanced treatment process can be used to improve the quality of water. However, the water outflows from the plant is pumped for expensive disposal in Israel.

Therefore the research team studied and designed a pilot system for advanced treatment. It consists of a sequence treatment processes: sand filtration, microfiltration and chlorination.. purification was done with and without nitrification. Multiple experiments were conducted to study the properties of water system prior and post. From these experiments, it has been noticed that the best system consists of sand filter and chlorination with nitrification. from this system the colonies of fecal were changed from 68 to 0 and colonies of coliform were changed from ∞ to 0 respectively and the conductivity didn't change .

Based on the pilot study, a detailed design of the sand filter systems was made for the treatment plant. The plant needs 4 filters (3 filters and 1 standby) the dimensions of each filter is 4m x 3m x 3.25m and each filter include two cells. As a conclusion the designed system was found to be feasible and water quality confirms with standards set for agricultural water in Palestine.

Chapter One: Introduction

Water is crucial for all life on earth. It plays an essential role in our health, economy, food production, and environment. Despite its importance, water is a finite natural resource and cannot be created. The fact that our supply is finite has dire implications on our world population of nearly 7 billion people and growing. The global water consumption rate doubles every twenty years, a pace that is double the rate of population growth if population and consumption trends persist, it is estimated that the demand for water will surpass its availability by 56% and 1.8 billion people will be living in regions of water scarcity by 2025. (W1)

As a result of increasing in water consumption there is increasing in the production of wastewater and this leads to two major problems facing the world which are, Finding new sources of water and disposal of wastewater .

Wastewater is one of the most important problems that threaten the Palestinian environment, In order to face this problem many wastewater treatment plants were established to treat the water which come from two Resources, domestic and industrial resources.

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal. However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant or aquaculture system. In the case of irrigation, the required quality of effluent will depend on the crop or crops to be irrigated, the soil conditions and the system of effluent distribution adopted. Through crop restriction and selection of irrigation systems which minimize health risk, the degree of pre-

application wastewater treatment can be reduced. A similar approach is not feasible in aquaculture systems and more reliance will have to be placed on control through wastewater treatment

Wastewater quality may be defined by its physical, chemical, and biological characteristics. Physical parameters include color, odor, temperature and turbidity. Chemical parameters associated with the organic content of waste-water include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulfate, sulfide, nitrates and phosphates. Bacteriological parameters include coliforms, fecal coliforms, specific pathogens and viruses. (Hammer,2003)

Nablus western wastewater treatment plant one of the plant that was established recently This plant is treated the water resulting from the western area of the Nablus city and the villages of DeirSharaf, Beit Iba, Beit wazan , Qusin and Zawata. This plant consists of pipes line of sewage along the 10 km stretching from Tunis Street in west of the Nablus city and even in the treatment plant in Wade Alzumr, and Tank with a capacity of 4,000 cubic meters for the collection and treatment of rainwater, And establish a wastewater plant serving 150 000 citizen until 2020. (PI 1)

Water resulting from the plant is not being used because the quality of Resulting water is Less than the standards of any fields (drinking, industry and agriculture), the water outflows from the station go by pipes to occupied territories and are paid a lot of money to the Israeli Government to dispose of water . (PI 1)

Lack of water resources and disposal of wastewater is a real problem. In this project, the process and technology which are used in Nablus Western wastewater treatment plant was studied to find the best advanced treatment which is useable and have economic feasibility to improve the characteristic of water resulting from treatment plant to reuse it. The main objectives of this project are:

- Investigate the existing plant including treatment methods, sizes and parameters.
- investigate the possible advanced treatment processes.
- analyze the treated water properties and find a proper use filed.
- design the necessary advanced treatment equipment.

Chapter Two:-Quality Of Water

The water quality defined by its physical, chemical, and biological characteristics, an understanding of the nature of water is essential because the use of water in the different fields depends on the nature of it.

2.1 physical characteristics:

The physical characteristic are colour, turbidity and odour which are called organoleptic parameters because sensed by human organs of eye, nose, and throat. The other physical characteristics are temperature and total solids and pH. (Metcalf & Eddy, 1979)

2.1.1 Colour:

Clear water is colourless but the colour of water is caused by several reasons such as dissolved minerals, dyes of humic acid from plants which causes a brown-yellow colour, and when organic compounds are broken down by bacteria, the dissolved oxygen in the water is reduced to zero and its colour changes to black. (Metcalf & Eddy, 1979)

Colour is measured in units of mg/L on the platinum cobalt (pt/Co) scale. Raw water is of a very good colour quality at values of less than 10 mg/L, is acceptable at 100 mg/L and is unacceptable at levels higher than 200 mg/L. (Kiely, 1996)

2.1.2 Odour:

Odour in water are caused by the presence of the by-products of plant and animal microorganisms, especially hydrogen sulphide which produced by anaerobic microorganisms that reduce sulphates to sulphides. (Kiely, 1996)

2.1.3 Turbidity:

Turbidity is caused by the presence of very fine suspended and clay particles and is a measure of the ability of water to scatter light. Turbidity is measured on nephelometric turbidity units, Water of very good turbidity quality is less than 1 NTU and considered unacceptable if the value is greater than 5 NTU.(Kiely, 1996)

2.1.4 Temperature:

The temperature of water is a very important parameter because its effect on aquatic life, thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity and solubility of dissolved gases .oxygen is less soluble in warm water than in cold water.(Bica, et. al, 2000)

Abnormally high temperature can foster the growth of undesirable water plants and wastewater fungus. (Bica, et. al, 2000)

2.1.5 Total solid

Total solid content of a water is defined as all the matter that remains as residue upon evaporation at 103°C to 105°C. Total solid include both the suspended solids and the filterable solid.(Metcalf & Eddy, 1979)

Suspended solids are divide into two typed (1) settleable solids which are defined as the solids that settle in an undisturbed sample of liquid after a specific time period and the particle size of it is greater than 10µm, (2) non-settleabel solids which are don't settle in a undisturbed sample and have a size particles in the range from 1µm to 10µm. (Metcalf & Eddy, 1979)

Filterable solids are divided into two types (1) colloidal solids which are defined as the solids that can't be removed by settling, its removed by biological oxidation or coagulation, followed by sedimentation and the particle size of it in the range from $10^{-3}\mu\text{m}$ to $1\mu\text{m}$. (2) dissolved solid which consist of both organic and inorganic molecules and ions that are present in true solution in water and it has a particles size less than $10^{-3}\mu\text{m}$. (Metcalf & Eddy, 1979)

2.1.6 pH:

pH is one of the most common water quality tests performed. pH indicates the sample's acidity, but is actually a measurement of the potential activity of hydrogen ions (H^+) in the sample. pH measurements run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids. Solutions with a pH above 7.0, up to 14.0 are considered bases. All organisms are subject to the amount of acidity of stream water and function best within a given range. (Bica, et. al, 2000)

The pH scale is logarithmic, so every-unit change in pH actually represents a ten-fold change in acidity. In other words, pH 6.0 is ten times more acidic than pH 7.0; pH 5 is one hundred times more acidic than pH 7.0.(Bica, et. al, 2000)

Changes in the pH value of water are important to many organisms. Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly. This is especially true of aquatic macro invertebrates and fish eggs and fry. (Kiely, 1996)

2.2 chemical characteristic

The chemical characteristics of water are come from of the soils and rocks which the water has been in contact with it. In addition, agricultural, urban runoff, municipal, industrial treated wastewater, Microbial and chemical transformations affect the chemical characteristics of water.

The chemical characteristic is presented in two (1) organic matter (2) inorganic matter

2.2.1 Organic matter

Organic chemicals are made up of carbon (C), hydrogen (H) as well as nitrogen (N) and oxygen (O) also may contain sulfur (S), phosphorus (P), fluorine (F), chlorine (Cl), bromine (Br), and iodine (I). (Giurma, et. al, 2000)

Organic matter in water affects the quality of water, its cause disagreeable tastes and odors in drinking water. Vinyl chloride, benzene and other organic contaminants are known carcinogenic agents, while chloroform is a cancer-suspect agent. (Giurma, et. al, 2000)

2.2.1.1 Types of organic matter

Organic matter divides into two parts which are:

1- Natural Organic Matter

Organic materials are found in natural water as a result of the interaction between soils and precipitation. Organic materials in soils originate from plant and animal degradation products. These degradation products condense and polymerise into fulvic and humic acids to kerogen and finally coal. (Giurma, et. al, 2000)

2- Man-made Organics

Synthetic organic compounds include a broad variety of aliphatic and aromatic compounds. (Giurma, et. al, 2000)

2.2.1.2 Measurement of Organics in Water - Organic Carbon

Organics in water can be expressed in terms

✚ Total organic carbon (TOC):

TOC is the difference between total carbon (TC) and inorganic carbon (IC).(Giurma, et. al, 2000)

✚ Biological Oxygen Demand (BOD):

- BOD5 is the amount of dissolved oxygen used up from the water sample by microorganisms as they breakdown organic material at 20°C over a 5 day period. (Kiely, 1996).
- BOD ultimate: is the amount of dissolved oxygen used up from the water sample by microorganisms as they breakdown organic material at 20°C over 20 day period
- $BOD_u = \text{twice } BOD_5$.(Kiely, 1996)

✚ Chemical Oxygen Demand(COD):

COD, Chemical oxygen demand: the COD test measures the total organic compound. The test determine the amount of oxygen needed to be chemically oxidise the organics in water and wastewater (it takes about 2 hours). (Kiely, 1996)

$$BOD_5 = 0.6 \text{ COD}$$

$$BOD_u = 0.92 \text{ COD}$$

2.2.2 Inorganic matter

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 anion, The major cations are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+). Calcium (Ca^{2+}) and the major anions are chloride, sulfate, carbonate, bicarbonate, fluoride and nitrate. (Kiely, 1996)

2.2.2.1 Inorganic Indicators of Water Quality

Some of the inorganic parameters include hardness, total dissolved solids, and conductivity.

Hardness

Is express principally by the sum of the divalent metallic cations, Ca and Mg. Two types of hardness are found (1) Carbonate (2) non-carbonate hardness.

Hardness expressed as mg/L CaCO_3 is used to classify waters from "soft" to "very hard". This classification is summarized in Table 1 (Kiely, 1996)

Table 1: Classification of water according to hardness

Hardness as mg/L CaCO_3	Classification
0 – 60	Soft
61 – 120	Moderately hard
121 – 180	Hard
>180	Very hard

Total Dissolved Solids

Total dissolved solids (TDS) is a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water. (Giurma, et. al, 2000)

Conductivity

Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current, The electric current is conducted in the solution by the movements of ions so the higher of the numbers of ions the higher of the ionic mobility and so the higher of the magnitude of conductivity. (Kiely, 1996)

2.3 Microbiological Characteristics

The main group of microorganisms that concern in natural water are: protists ,plant, and animals , each group that includes a number of members as shown in figure 1.(Kiely, 1996).

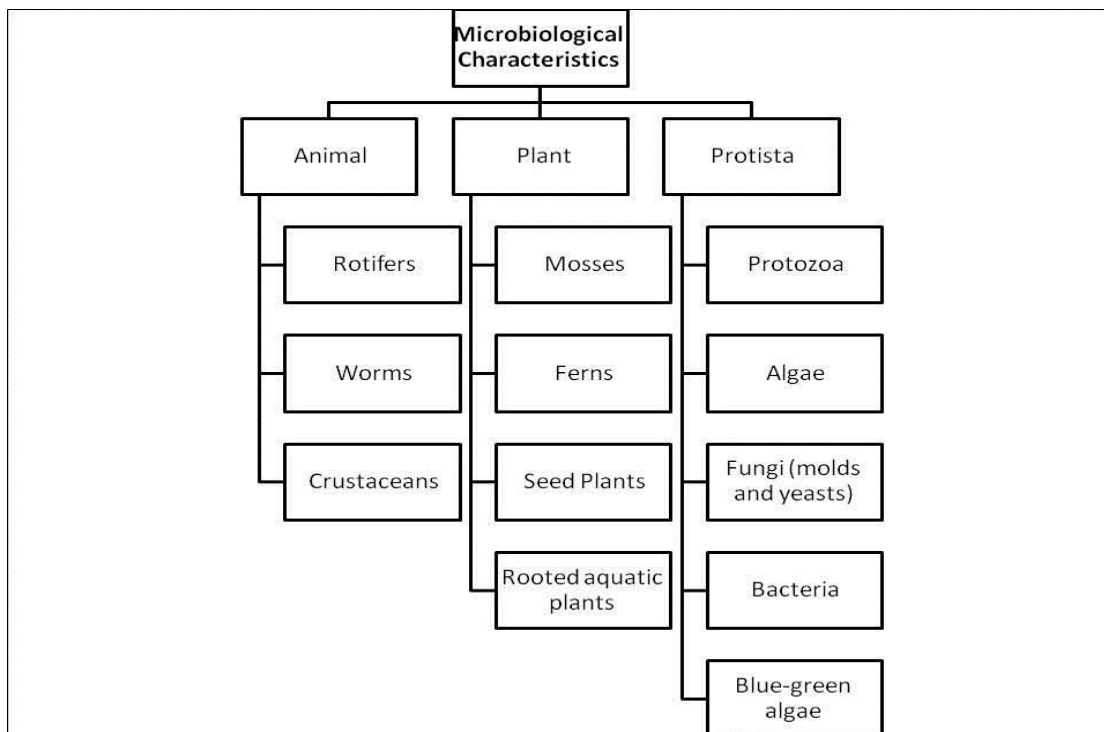


Figure 1: Simplified Classification of Microorganisms in Water

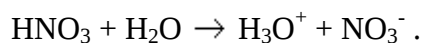
Many protozoa, bacteria and viruses that cause diseases transmitted to humans directly through the water.(Kiely, 1996)

Coliform organisms have been used to determine the microbiological characteristics of waters, The coliform group of aerobic bacteria and facultative bacteria that ferment lactose to gas, Coli is commonly used as an organism indicator this organism is present in the warm-blooded animals intestine, including humans, Therefore the presence of coli in water indicates the presence of pathogenic organisms of human origin ,The concentration of organisms indicator is reported in CFU/100 mL (CFU = colony forming units) or in MPN/100 mL (MPN = most probable number). (Kiely, 1996)

2.4 Biological characteristics

Aquatic ecosystem plant and animal materials are composed of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur. These elements are building for carbohydrates, lipids, proteins, phospholipids and nucleic acid. (Kiely, 1996)

- ✚ Protein and nucleic acids consist of nitrogen ,are important nitrogen-containing compounds in aquatic systems, NO₂ reacts with OH⁻ in the air to form nitric acid, nitric acid is a very strong acid, which results in very fast dissociation as it is in interaction with water : (Kiely, 1996)



- ✚ Phosphoric acid (H₃PO₄), which is not very volatile, but its concentration in natural water environments is low. (Kiely, 1996)
- ✚ Sulfate occurs in natural water as organic sulfur, hydrogen sulfide (H₂S). Hydrogen sulfide (H₂S) is toxic for many organisms and is a source of odors in water, can also combine and precipitate heavy metals such as iron, zinc and cobalt. These metal elements are required for bacterial growth, therefore high levels of H₂S may inhibit growth. (Kiely, 1996)

CHAPTER Three:-Wastewater Treatment Process

In this chapter wastewater treatment processes in Nablus western wastewater treatment plant was analyzed. The flow rate of wastewater influent to the plant is about 12000 m³/day resulting from the western area of the Nablus city and the towns of Deir Sharaf, Beit Iba, Beit wazan, Qusin and Zawata. The collected wastewater from the aforementioned locations is transferred to the plant by means of 80 cm diameter concrete pipe. The concrete pipe is connected at the end side with short pipe of larger diameter 1m to assure low velocity influent to the plant.(PI 2)

The wastewater treatment process are divided into three main processes which are shown in figure 2:

- a. Pretreatment
- b. Primary treatment
- c. Secondary treatment.

The details of these process are explained in the following sections.

3.1 Pretreatment

Pretreatment may be physical and/or chemical process, it is a process that prepare the wastewater to a condition that it can be furtherly treated in conventional secondary biological process. There are two main process in the pre-treatment process: screening and grit and grease removal. (PI 2)

3.1.1 Screening

The objective of screening is to remove large floating material such as rags, plastics bottles..etc., to protect mechanical equipment such as pumps and aerators from damage. There are two types of screens that are used in the plant:

- (i) Coarse screens: two stages are used, the first one which is shown in figure 3, consists of bars screens of 15mm spacing while the second one which is shown in figure 4, has 10 mm spacing.
- (ii) Fine screens with 5mm openings. (PI 2)



Figure 3: First stage of course screening



Figure 4: Second stage of coarse screening

3.1.2 Grit Chamber

Grit is inorganic sand or gravel particles of size about 1 mm, Grit is removed after screening because its inclusion within the system can abrade mechanical equipment and also because it can settle out in biological treatment plant, reducing its space efficiency, its removed by using helical flow aerated grit chamber which is shown in figure 5, in this chamber air is introduced along one side of the channel near the bottom and this causes a spiral motion perpendicular to the main flow direction. The heavier grit particles settle while the lighter organic matter remains in suspensions in the retention time of 3-6 min. the sand is removed from the bottom of the chamber is washed in a special machine which is shown in figure 6. The washing water is recycled to the chamber.(PI 2)



Figure 5: Grit chamber in Nablus treatment plant



Figure 6: Sand wash machine

3.2 Primary Treatment

Primary treatment is often called clarification, sedimentation or settling. This is the unit process where the wastewater is allowed to settle for a period of 2 hours in a settling tank which is shown in figure 7. In this period the suspended particles will settle to the bottom as sludge and raked toward a center hopper where the sludge is withdrawn to digester. (PI 2)

The benefits of primary treatment include:

- *Reduction in suspended solids
- *Reduction in the amount of waste activated sludge in the activated sludge plant
- *Removal of floating material
- *Partial equalization of flow rates and organic load



Figure 7: First sedimentation tank

3.3 Secondary Treatment

Secondary treatment as shown in figure 8, this process is intended to remove the soluble organics and colloidal matter, which remain after primary treatment and to achieve further removal of suspended solid and in some cases also to remove nutrients such as phosphate and nitrogen. Secondary treatment using a biological process due to its higher removal efficiency and less cost. The main purpose of secondary treatment is reduced BOD value of the end product liquid effluent. (PI 2)

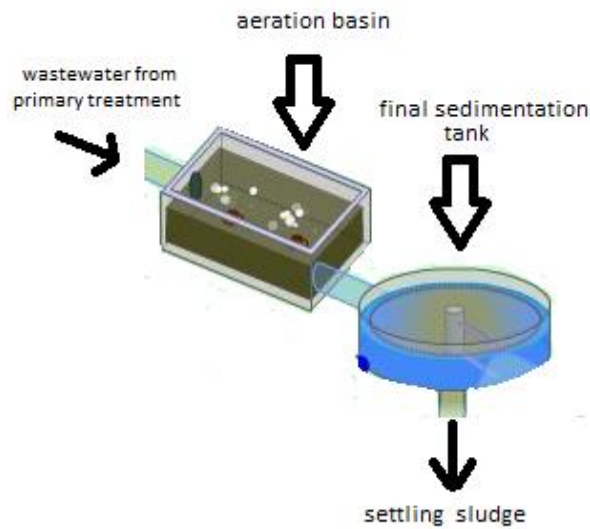


Figure 8: Secondary treatment stage

After primary treatment for wastewater, it flows into the aeration basin which is the first step in biological treatment. In this basin, oxygen is added using a unit called MAMMOTH (surface aerator). It is installed horizontally at an optimum depth of 20-30 cm inside the wastewater. The MAMMOTH continuously adds oxygen to the basin until the dissolved oxygen concentration reaches $0.8-2 \text{ mg oxygen/m}^3$. This creates a good environment for bacterial growth. The bacteria feed on the organic matter that exists in wastewater as a result of this the BOD value decreases. (PI 2)



Figure 9: MAMMOYH (surface aerator)

For aeration tanks there is two tanks in the station as shown in figure 10. with total volume of 15000m^3 . The main tank which is used continuously is 9000 m^3 . The other tank is semi-batch tank, used just in certain cases.(PI 2)



Figure 10: two aeration tanks in the station

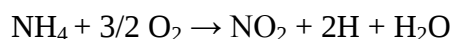
The usage of bacteria is very expensive, and high electrical consumption process so that the bacteria is recycled at percentage of (80-100)%. And reused in aeration tank. This bacteria called return activated sludge (RAS). (PI 2)

After leaving aeration basin the wastewater goes to final sedimentation tank shows in figure (10), where the flow of wastewater stay laminar and All remaining sludge settle. The flocculants is added to collect the light suspended solid and colloidal material(which stay suspended by its valent), then force it to settle and accumulate in the bottom, while the treated water Clustered in the top. This tank has Drawbridge rotate one circular twist every one hour for raising the Dead bacteria to the wastewater surface. (PI 2)

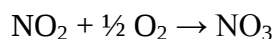
If the algae is found in treated wastewater this means the existence of nutrients (nitrogen and phosphor). Nitrogen in wastewater is generally in the forms of organic N and ammonia. Organic N and ammonia are undesirable in wastewater effluents since both a nitrogenous oxygen demand and ammonia is toxic. To solve presence of ammonia and Organic N in waste water the nutrients must be removed by something called Nitrification. (PI 2)

Nitrification is the biological process happen in aeration tank, using nitrifying bacteria and supplying more oxygen to convert ammonia to nitrite then to nitrate in two process steps:

nitrosamines bacteria



Nitrobacter bacteria



After nitrification anoxic condition applied by stop supplying oxygen for entrance of aeration tank. This force bacteria to attack the bond between nitrate to have oxygen this produce nitrogen as N_2 gas. (PI 2)

The property of inlet and outlet influent from Nablus western wastewater treatment plant is shown in the table 2 where the standard values are given in table 3. (Khader, 2006)

Table 2: Property of inlet and outlet effluent from plant

Properties	Inlet	Outlet
BOD (mg/L)	547	29
COD (mg/L)	1347	60
TDS (mg/L)	1185	835
TSS (mg/L)	700	10
FecColiform	16.6	52
TotalColiform	91	6.8

Table3: Palestinian standard inlet and outlet of effluent in treatment plants

Test	Water inlet	Water outlet
pH	6.93	7.68
Conductivity (mili-siemens)	2.25	2.08
TDS (mg/L)	1055	905
TSS (mg/L)	293	12
Arsenic (mg/L)	0.494	0.431
Boron (mg/L)	0.436	0.505
Cyanide	NO detected	NO detected
Ammonia (mg/L)	95.05	4.54
Phosphorus (mg/L)	578	124
BOD (mg/L)	609	28
COD (mg/L)	1269	146
Total Coliform(cfu/100mL)	79×10^12	483×10^6
Fecal Coliform (cfu/100mL)	9.5×10^5	69
Salmonella	NILL	NILL

CHAPTER Four:- Targeted Fields For Reuse Of Resulted Water

The goal of this project is to utilize as much as possible of wastewater and convert it to water can be exploited in the agricultural and industrial areas.

Targeted filed of this project are:

- (1) Agricultural filed: by treat the wastewater to agriculture water with following property as show in table 4.(PI 1)
- (2) Tanning plant: There is a tanning factory next of the treatment plant this factory consumes 80 m³/ day of water and agriculture water property are considered suitable for consumption of this factory.(PI 3)
- (3) Stone cutting plants: there is a lot of stone cutting plants near the waste water treatment plant which are consume a lot of water with cost about 7000 NIS/week and agriculture water property are considered suitable for consumption of stone saw.(PI 4)
- (4) Concrete industry: can be use the result water from advanced treatment to mix it with cement and other material to produce concrete but that filed need to make experiment to make sureof the possibility.

Table4: Quality of treated water

Maximum limits for chemical and biological properties	Quality of Treated Water			
	High Quality (A)	Good Quality (B)	Medium Quality (C)	Low Quality (D)
Biological Oxygen Demand (BOD ₅)	20	20	40	60
Total Suspended Solids (TSS)	30	30	50	90
FC (COLONY /100 ML)	200	1000	1000	1000
Chemical Oxygen Demand (COD)	50	50	100	150
Dissolve Oxygen (DO)	1>	1>	1>	1<
Total Dissolve Solids (TDS)	1200	1500	1500	1500
PH	6-9	6-9	6-9	6-9
FAT,OIL, & GREASE	5	5	5	5
PHENOL	0.002	0.002	0.002	0.002
MBAS	15	15	15	25
NO ₃ -N	20	20	30	40
NH ₄ -N	5	5	10	15
TOTAL -N	30	30	45	60
Cl	400	400	400	400
SO ₄	300	300	300	300
Na	200	200	200	200
Mg	60	60	60	60
Ca	300	300	300	300
SAR	5.85	5.38	5.83	5.83
PO ₄ -P	30	30	30	30
Al	5	5	5	5
Cu	0.2	0.2	0.2	0.2
Fe	5	5	5	5
Mn	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2
Pb	0.2	0.2	0.2	0.2
Se	0.02	0.02	0.02	0.02
Cd	0.01	0.01	0.01	0.01
Zn	2	2	2	2
Cn	0.05	0.05	0.05	0.05
Cr	0.1	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001
Co	0.05	0.05	0.05	0.05
B	0.7	0.7	0.7	0.7
E. coli (COLONY / 100ML)	100	100	100	100
Nematodes (Eggs/L)	1≥	1≥	1≥	1≥

CHAPTER Five:-Advanced Wastewater Treatment

The main objective of the project is to find a feasible technologies of advanced wastewater treatment to treat the conventionally treated wastewater to produce water with desired property.

In this chapter different type of advanced wastewater treatment was investigated, these types include (1) ion exchange (2) activated carbon (3) nanofiltration (4) reverse osmosis (5) sand filter.

5.1 Ion Exchange

Cations and negatively charged anions, which allows the water to conduct electrical currents and are therefore called electrical conductivity is thus a measure of water purity, with low conductivity corresponding to a state of high purity. (Cheremisinoff, 2002)

Water contain of dissolved salts which dissociate to form charged particles called ions. These ions are the positively charged. These ions can be removed using the ion exchange, with the advantages of other operations:

-  Ionic impurities may be present in rather low concentrations.
-  Modern ion-exchange resins have high capacities and can remove unwanted ions preferentially.
-  Modern ion-exchange resins are stable and readily regenerated, thereby allowing their reuse.
-  The process and equipment are a proven technology.
-  There are many models of ion-exchange systems on the market which keep costs competitive.

- ✚ Temperature effects over a fairly wide range (from 0 to 35 C) are negligible.
- ✚ The technology is excellent for both small and large installations, from home water softeners to large utility industrial applications.

Ion exchange is a well-known method for softening or for demineralizing water. Although softening could be useful in some instances, the most likely application for ion exchange in wastewater treatment is for demineralization. Many ion-exchange materials are subject to fouling by organic matter. It is possible that treatment of secondary effluent for suspended-solids removal and possibly soluble organic removal will be required before carrying out ion exchange. Many natural materials and, more importantly, certain synthetic materials have the ability to exchange ions from an aqueous solution for ions in the material itself.(Cheremisinoff, 2002)

Cation-exchange resins can, for example, replace cations in solution with hydrogen ions. Similarly, anion-exchange resins can either replace anions in solution with hydroxyl ions or absorb the acids produced from the cation-exchange treatment. A combination of these cation-exchange and anion-exchange treatments results in a high degree of demineralization.(Cheremisinoff, 2002)

Ion Exchange Systems

• Water Softening

The ion exchange water softener as shown in Figure11 is one of the most common tools of water treatment. Its function is to remove scale forming calcium and magnesium ions from hard water.. A standard water softener has four major components: a resin tank, resin, a brine tank to hold sodium chloride, and a valve or controller.(Cheremisinoff, 2002)

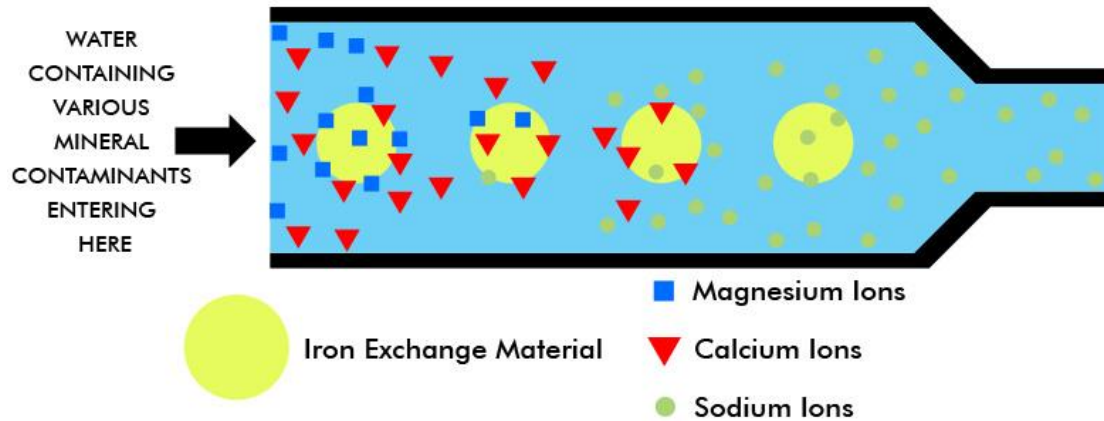


Figure 11: The ion exchange water softener

• Deionization (DI)

Ion exchange deionizers use synthetic resins similar to those in water softeners. Typically used on water that has been pre filtered, DI uses a two-stage process to remove virtually all ionic material in water. Two types of synthetic resins are used: one to exchange positively-charged ions (cations) for H^+ and another to exchange negatively-charged ions (anions) for OH^- . (Cheremisinoff, 2002)

Cation deionization resins (hydrogen cycle) release hydrogen (H^+) in exchange for cations such as calcium, magnesium and sodium. (Cheremisinoff, 2002)

Anion deionization resins (hydroxide cycle) exchange hydroxide (OH^-) ions for anions such as chloride, sulfate and bicarbonate. (Cheremisinoff, 2002)

The displaced H^+ and OH^- combine to form H_2O . (Cheremisinoff, 2002)

• Two-Bed and Mixed-Bed Deionizers

Two-bed deionizers have separate tanks of cation and anion resins. In mixed-bed deionizers the two resins are blended together in a single tank or vessel. Generally mixed-bed systems will produce higher-quality water, but with a lower total capacity than two-bed systems. (Cheremisinoff, 2002)

5.2 Activated Carbon

Activated carbons are profusely used as adsorbents for decontamination processes because of their extended surface area, high adsorption capacity.

Activated carbon is a crude form of graphite. It differs from graphite by having a random imperfect structure which is highly porous over a broad range of pore sizes from visible cracks and crevices to molecular dimensions. The graphite structure gives the carbon its very large surface area which allows the carbon to adsorb a wide range of compounds. Activated carbon can have a surface of greater than 1000 m²/g. Adsorption is the process by which liquid or gaseous molecules are concentrated on a solid surface. Activated carbon can be made from many substances containing a high carbon content such as coal, wood and coconut shells. The raw material has a very large influence on the characteristics and performance of activated carbon. Raw materials such as coal and charcoal do have some adsorption capacity, but this is greatly enhanced by the activation process. There are three main forms of activated carbon:

- 1) Granular Activated Carbon (GAC) - irregular shaped particles with sizes ranging from 0.2 to 5 mm. This type is used in both liquid and gas phase applications.
- 2) Powder Activated Carbon (PAC) - pulverized carbon with a size predominantly less than 0.18mm. These are mainly used in liquid phase applications and for flue gas treatment.
- 3) Pelleted Activated Carbon - extruded and cylindrical shaped with diameters from 0.8 to 5 mm. These are mainly used for gas phase applications because of their low pressure drop, high mechanical strength and low dust content. (Cheremisinoff, 2002)

Activated carbon (AC) filtration is most effective in removing organic contaminants from water. Organic substances are composed of two basic elements, carbon and hydrogen. Because organic chemicals are often responsible for taste, odor, and color problems, AC filtration can generally be used to improve aesthetically objectionable water. AC filtration will also remove

chlorine. Activated carbon is used for the adsorption of mainly organic compounds along with some larger molecular weight inorganic compounds such as iodine and mercury. (Cheremisinoff, 2002)

Adsorption process depends on the following factors: 1) physical properties of the AC, such as pore size distribution and surface area; 2) the chemical nature of the carbon source, or the amount of oxygen and hydrogen associated with it; 3) chemical composition and concentration of the contaminant; 4) the temperature and pH of the water; and 5) the flow rate or time exposure of water to AC.(Cheremisinoff, 2002)

Adsorption usually increases as pH and temperature decrease. Chemical reactions and forms of chemicals are closely related to pH and temperature. When pH and temperature are lowered many organic chemicals are in a more adsorbable form. The adsorption process is also influenced by the length of time that the AC is in contact with the contaminant in the water. Increasing contact time allows greater amounts of contaminant to be removed from the water. Contact is improved by increasing the amount of AC in the filter and reducing the flow rate of water through the filter.(Cheremisinoff, 2002)

Adsorption is the process where molecules are concentrated on the surface of the activated carbon. Adsorption is caused by London Dispersion Forces, a type of Van der Waals Force which exists between molecules .London Dispersion Forces are extremely short ranged and therefore sensitive to the distance between the carbon surface and the adsorbate molecule They are also additive, meaning the adsorption force is the sum of all interactions between all the atoms.(Cheremisinoff, 2002)

In general, the adsorbability of a compound increases with:(1) increasing molecular weight (2) a higher number of functional groups such as double bonds or halogen compounds, and (3) increasing polarisability of the molecule.(Cheremisinoff, 2002)

5.3 Nanofiltration (NF)

Nanofiltration (NF) Membrane technology has been the most water treatment technique as it provides good quality of treated water . Its process allows separating monovalent from multivalent ions, which are retained by the membrane with pores in 0.001–0.01 μm size range. The process can be used for separation organic compounds of moderate molecular weight from monovalent ions present in the solution.(Zakrzewska, 2013)

Nanofiltration use gradient pressure to selectively transport solvent and certain solutes through a membrane. The selectivity of nanofiltration membrane is determined by two parameters, retention and permeability. retention depends on the size of compound and molecular weight. permeability function of the valence of the salts and compounds in the solution. that mean diluted solutions of mono-valent ions can permeation through a nanofiltration membrane unhindered while multi-valent ions (i.e sulfate and carbonate) anions, and Cation can't permeation through the membrane .Now the available Membranes have good chemical resistance for treatment of acids, bases and oxidative media, this make the process suitable for large number of separation process. (Zakrzewska, 2013)

Nanofiltration membranes(NF) have applications in several areas. One of the main applications has been in wastewater treatment for agriculture, and drinking water production NF can either be used to treat all kinds of water including ground, surface, and wastewater or used as a pretreatment for desalination. NF membranes have been shown to be able to remove turbidity, microorganisms and hardness, as well as a fraction of the dissolved salts. This results in a significantly lower operating pressure and thus provides a much more energy-efficient process. Similar to other membrane processes, a major problem in NF membrane applications is fouling. (Zakrzewska, 2013)

In waste water treatment the main advantage for nanofiltration membranes :

- *softens of water by removing calcium and magnesium ions.
- *Separation of organic impurities (pesticides, insecticides)
- *Filtration of acids and bases

- * Reduction of salt contents of slightly brackish water
- *Desalination of organic materials
- *The removal of heavy metals from wastewater
- * Nitrates removal

NF is similar to reverse osmosis, nanofiltration membranes are composite membranes similar to reverse osmosis membranes consisting of a carrier structure and thin selective layer. Because nanofiltration uses less fine membranes and is slightly more permeable, less pressure is required for the separation compared to RO systems (which mean less operation energy is required). Also the fouling rate is lower compared to RO systems. Generally Reverse osmosis focuses on the removal of all salts from water, whereas NF is useful for removal of specific salts such as $MgSO_4$. The main difference between NF and RO is shown in table 5. (Zakrzewska, 2013)

Table 5: Water from properties from RO & nanofiltration. (W2)

Parameter	NF system	RO
Sodium ion, Na^+	77%	99%
Calcium & magnesium ions, Ca^{++} & Mg^{++} (Hardness)	94%	99%
Iron ion, Fe^{++}	95%	99%
Chloride, Cl^-	83%	99%
Sulfate, So_4^{2-}	98%	99%
Bicarbonate, HCO_3^-	92%	99%
Total organic compounds	98%	99%
TDS	50%	98%
Benefits		
Pressure needed	Low (50-100 psi)	High (150-200 psi)
Flow Rate	High	Low
Storage tank	Depends	Always needed
Post filter	Yes (if storage tank needed)	Yes
Fouling (Maintenance)	Low	High
Corrosive effluent	No	Yes
Cost – effectively	Yes (~50% less)	No
Waste water %	30%	Up to 85%
Environmental friendly	Yes	No
Membrane life	3-5 year (low pressure etc)	1-3 year (high pressure etc)
Energy saving	Yes	No

To get better Results in treatment process use combination from nanofiltration and reverse osmoses.

Nanofiltration Used as pre-filter for reverse osmosis in wastewater treatment systems this give the opportunity to catch smalleparticles and disposal from pollutants much as its possible also to get the maximum quality for treated water and special properties of nano sized particles can be exploited in this combination Lower pressure required this give Lower operating cost.

5.4 Reverse Osmosis (RO)

Phenomenon osmotic happened when pure water and a salt solution are introduced on opposite sides of a semipermeable membrane in a vented container, the pure water diffuses through the membrane and dilutes the salt solution, At equilibrium, the liquid level on the saline water side of the membrane will be above that on the freshwater side; this process is shown in Figure (12) . The driving force responsible for the flow is osmotic pressure. This pressure has a magnitude dependent on many factors such as membrane characteristics, water temperature, salt solution properties and concentration.(Cheremisinoff, 2002)

By applying pressure to the saline water, the flow process through the membrane can be reversed. When the applied pressure on the salt solution is greater than the osmotic pressure, fresh water diffuses in the opposite direction through the membrane and pure solvent is extracted from the mixed solution; this process is termed reverse osmosis (RO) is shown in Figure (12). Reverse osmosis is a means for separating dissolved solids from water molecules in aqueous solutions as a result of the membranes being composed of special polymers which allow water molecules to pass through while holding back most other types of molecules.(Cheremisinoff, 2002)

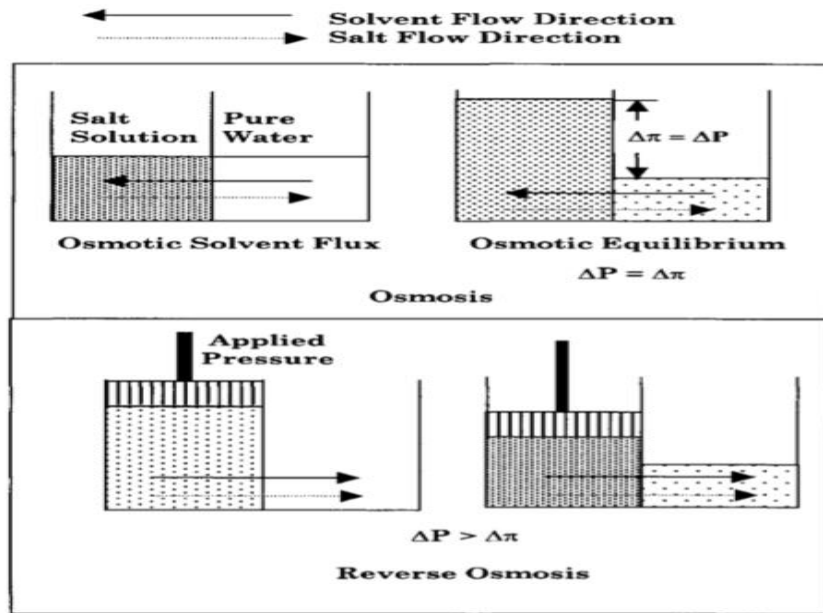


Figure 12: Principle of Reverse Osmosis.

The factors that affect the performance of a Reverse Osmosis System are: Incoming water pressure , Water Temperature , Type and number of total dissolved solids (TDS) in the tap water and The quality of the filters and membranes used in the RO System. (Cheremisinoff, 2002)

Reverse osmosis can removes turbidity, including microbes and virtually all dissolved substances. However, while reverse osmosis removes many harmful minerals, such as salt and lead, it also removes some healthy minerals, such as calcium and magnesium. This is why water that is treated by reverse osmosis benefits by going through a magnesium and calcium mineral bed. This adds calcium and magnesium to the water, while also increasing the pH and decreasing the corrosive potential of the water. Corrosive water may leach lead and copper from distribution systems and household water pipes. (Cheremisinoff, 2002)

Major problem inherent in general applications of RO systems is fouling. There are three technique to reduce the effect of fouling and to prevent structural damage to the membrane which are:

- (1) feed pre-treatment: Feed pre-treatment may include pH adjustment, filtration to remove particulates, use of complexing agents to ionize slightly soluble salts and metals and the addition of disinfectants for control of microbial growth.
- (2) membrane cleaning is another approach used to control membrane fouling
- (3) Use offfluid instabilities, which can be used to reduce one important cause of membrane fouling, namely, concentration polarization.(Abbas & Bastaki, 2000)

A typical reverse osmosis system consists of pretreatment and post-treatment filters as well as the RO membrane as shown in figure (13)

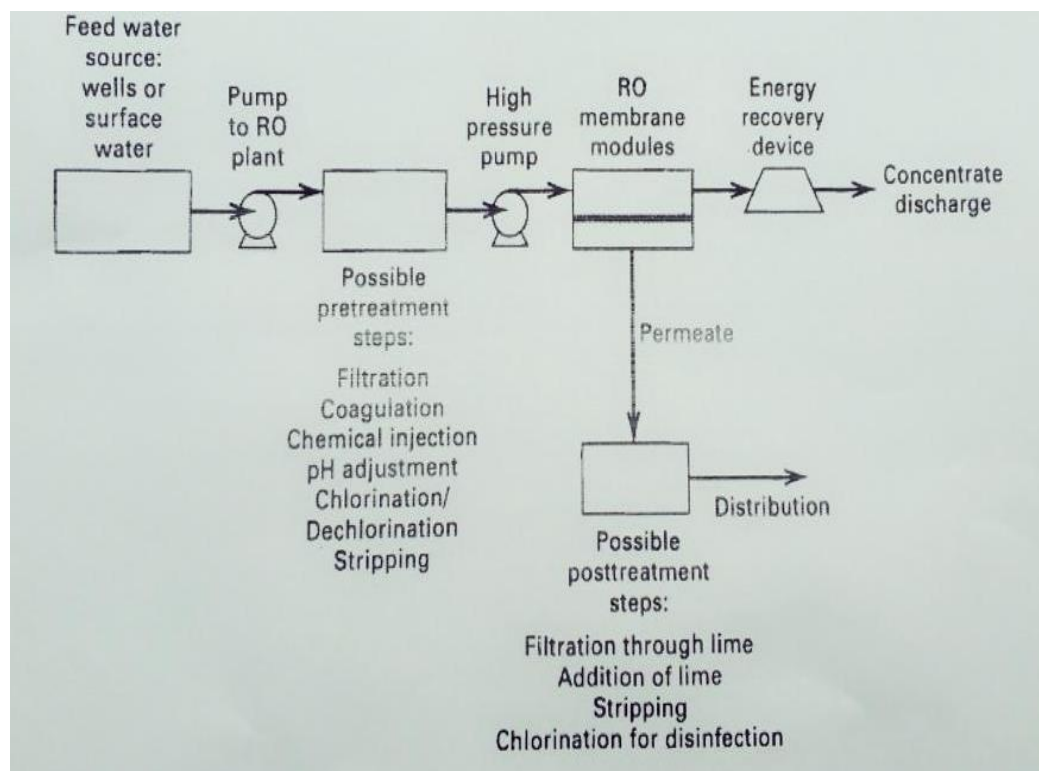


figure 13:Typical reverse osmosis system

5.5 sand filter

5.5.1 Definition:

type of filters which Remove solid particles from a suspension (two-phase system containing particles and liquid) by passage of the suspension through a porous medium. In granular filtration, the porous medium is a bed of granular material The main porous medium usually used in sand filter is sand . Filtration rate is the Key process variable in this filter. (Crittenden, et. al, 2012)

5.5.2 types of the sand filter according filtration rate :

- ✚ slow sand filtration
- ✚ rapid sand filtration

the difference between the previous types explain in the table 6. (Crittenden, et. al, 2012)

Table 3: difference between slow sand filtration and rapid sand filtration

Process Characteristic	Slow Sand Filtration	Rapid Filtration
Filtration rate	0.08–0.25 m/h (0.03–0.10 gpm/ft ²)	5–15 m/h (2–6 gpm/ft ²)
Media effective size	0.15–0.30 mm	0.50–1.2 mm
Media uniformity coefficient	<2.5	<1.4
Bed depth	0.9–1.5 m (3–5 ft)	0.6–1.8 m (2–6 ft)
Required head	0.9–1.8 m (3–6 ft)	1.8–3.0 m (6–10 ft)
Run length	1–6 months	1–4 days
Ripening period	Several days	15 min–2 h
Pretreatment	None required	Coagulation
Dominant filtration mechanism	Straining, biological activity	Depth filtration
Regeneration method	Scraping	Backwashing
Maximum raw-water turbidity	10 NTU	Unlimited with proper pretreatment

^aValues represent typical ranges. Some filters are designed and operated outside of these ranges.

5.5.3 Theory of sand filter design

The equations use in sand filter design are shown below (Crittenden, et. al, 2012):

$$\text{Filtration rate} = Q/A \dots\dots\dots(1)$$

$$\text{percentage of retained} = \frac{\text{Weight Retained}}{\Sigma \text{Weight Retained}} * 100\% \dots\dots\dots(2)$$

$$\begin{aligned} \text{percentage Commulative retained}_n &= \\ \text{percentage of retained}_n + \text{percentage of retained}_{n-1} &\dots\dots\dots(3) \end{aligned}$$

$$\text{percentage of pass} = 100 - \text{percentage Commulative retained} \dots\dots\dots(4)$$

$$\text{uniformity coefficient} = \frac{D_{60}}{D_{10}} \dots\dots\dots(5)$$

where:

Q= flow rate m/d

A= the area of filter

D_{60} : 60th percentile media grain diameter , mm

D_{10} : 10th percentile media grain diameter , mm

Chapter Six:- Experimental Work

In the experimental work, a purification pilot system of advanced treatment was designed and constructed. this system was used to purify water which was brought from Nablus western wastewater treatment plant. the design of this system was explained in section 6.1.

6.1 Design of pilot system

The pilot system which was used in purification includes several parts which are sand filter, static head, pipe, pump and microfilter. Different sampling point was taken to study the quality of water as shown in the figure14.

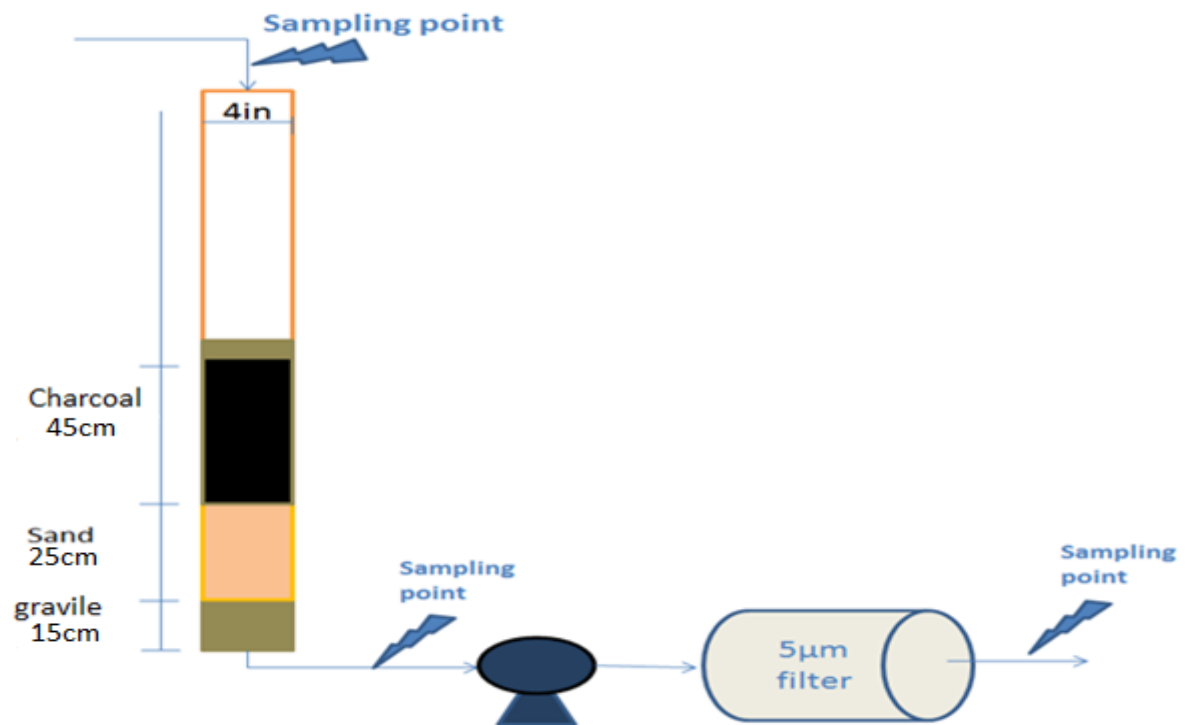


Figure 14: sand and microfiltration system.

6.1.1 sand filter design

Treated wastewater after secondary treatment was pumped at constant flow rate through the sand filter. The static head was kept constant. The sand filter was designed by using the previous theory as following:

6.1.1.1 Tri-media

filter consists of anthracite as the top layer but in experimental work charcoal was used because the anthracite is very expensive, sand as the middle layer, and gravel as the bottom layer. The charcoal layer is 0.45m deep, the sand layer is typically 0.25m deep, and the gravel layer is 0.15m deep according to table 7. as shown figure 15. **(Dives, 2002)**

Table 4: Design criteria for tri-media filters.

Parameter	Reported range	Recommended
Anthracite coal on top		
Effective size	0.9–1.4 mm	
Uniformity coefficient	1.4–1.75	
Shape factor (<i>f</i>)	0.46–0.73	
Porosity	0.53–0.60	
Specific gravity	1.45–1.75	
Depth of medium	0.4–0.5 m	
Sand in middle		
Effective size	0.45–0.55 mm	
Uniformity coefficient	1.4–1.65	
Shape factor (<i>f</i>)	0.7–0.95	
Porosity	0.4–0.47	
Specific gravity	2.65	
Depth of medium	0.15–0.3 m	
Garnet on bottom		
Effective size	0.20–0.35 mm	
Uniformity coefficient	1.2–2.0	
Shape factor (<i>f</i>)	0.6	
Specific gravity	3.6–4.2	
Depth of medium	0.075–0.15 m	
Filtration rate	10–25 m/h	≤15 m/h
Backwash rate	37–45 m/h	
Backwash duration ^a	10–20 min	≥15 min
Surface wash rate		
Revolving arms	1.2–1.8 m/h	
Fixed arms	4.9–10 m/h	
Underdrain		
Pipe lateral	Yes	
Block	Yes	
Air scour	No—if total depth of medium ≤0.75 m	
Air scour	0.6–1.5 m ³ /min · m ² if total medium depth > 1 m	

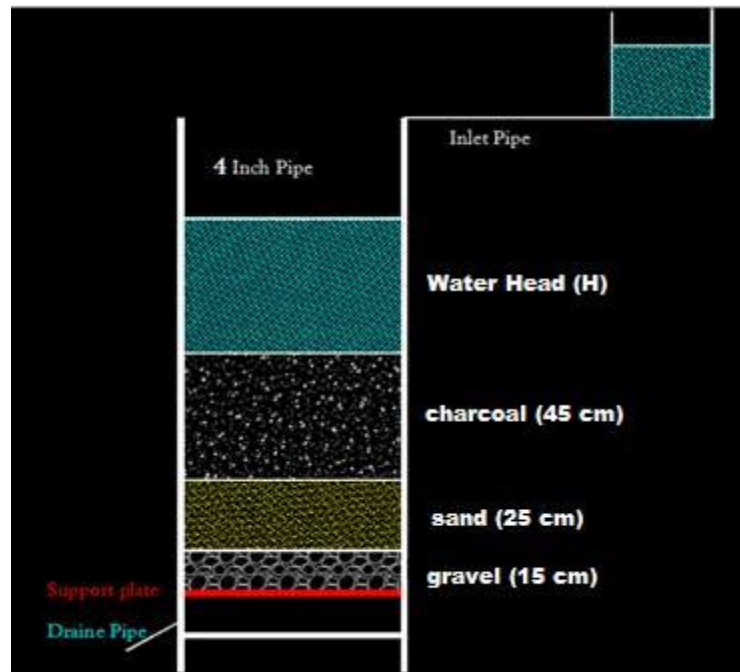


Figure15:pilot sand filter design

6.1.1.2 Sand flow rate

According the assumption filtration rate about $8\text{m}^3/\text{m}^2\cdot\text{d}$. the flow rate is equal $0.063\text{m}^3/\text{d}$.

by using equation (1) .

6.1.1.3 sieve analysis

sieve analysis for charcoal and sand was done to know particledistribution in sand filter and to determine uniformity coefficient UC for the media to make sure that is in standard range. Different mesh size was used to sift the media to separate the particles according to its size and determine the weight of particles in each mesh.The result of sieve analysis is shown in table8, 9. Sample of calculation was presented bellow to calculate UC.

Sample of calculation for charcoal head loss and uniformity coefficient :

According to equation 2:

$$\text{percentage of retained for mesh 2} = \frac{35}{751} * 100\%$$

$$= 4.66\%$$

According to equation 3:

$$\text{percentage cumulative retained} = 0.0 + 4.66$$

$$= 4.66\%$$

According to equation 4:

$$\text{Percentage of pass} = 100 - 4.66$$

$$= 95.34\%$$

→ Derive the relation between the percentage of pass VS the size of sieve mesh as figure 16

From figure 16

$$D_{60} = 1.5, D_{10} = 1.16$$

According to equation 5:

$$UC = 1.293$$

→ For anthracite UC it is in the range as shown in table 7

Sieve analysis result for charcoal

Table 5: mass distribution for charcoal

Sieve No.	Size(mm)	Weight Retained	% retained of	Cumulative retained %	% of pass
8	2.36	0	0.00	0.00	100.00
10	2	35	4.66	4.66	95.34
12	1.7	178	23.70	28.36	71.64
14	1.4	216	28.76	57.12	42.88
16	1.18	242	32.22	89.35	10.65
18	1	51	6.79	96.14	3.86
20	0.85	12	1.60	97.74	2.26
25	0.71	5	0.67	98.40	1.60
30	0.6	3	0.40	98.80	1.20
35	0.5	9	1.20	100.00	0.00
40	0.425		0.00	100.00	0.00
45	0.355		0.00	100.00	0.00
50	0.3		0.00	100.00	0.00
Pan			0.00	100.00	0.00
Sum		751.00	100.00		

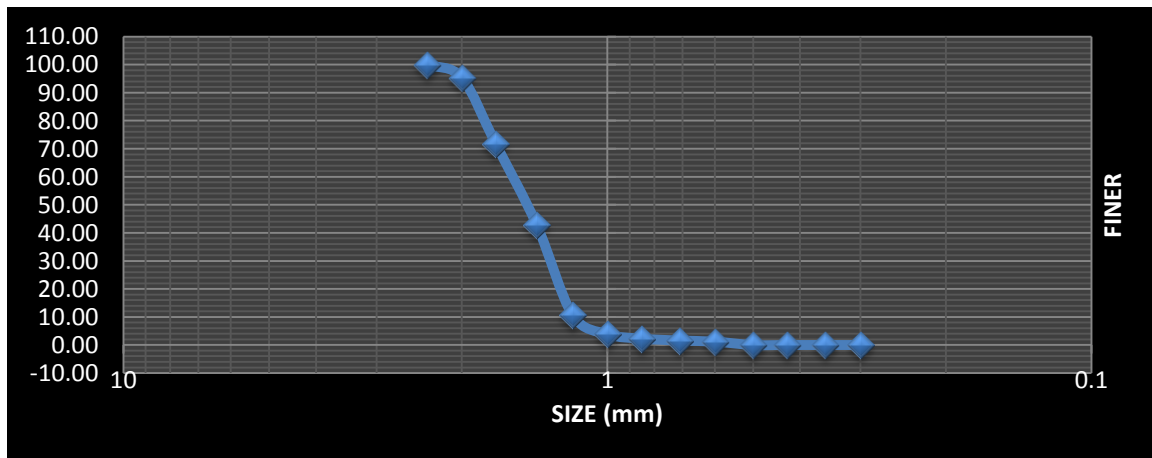


Figure 16: mass distribution for charcoal

$$D_{10} = 1.16$$

$$D_{60} = 1.5$$

$$U.C = 1.29 \text{ within the range}$$

Sieve analysis result for sand

Table 6: mass distribution for sand

Sieve No.	Size(mm)	Weight Retained	% of retained	Cumulative retained %	% of pass
8	2.36	0	0.00	0.00	100.00
10	2	0	0.00	0.00	100.00
12	1.7	0	0.00	0.00	100.00
14	1.4	0	0.00	0.00	100.00
16	1.18	0	0.00	0.00	100.00
18	1	0	0.00	0.00	100.00
20	0.85	23	2.67	2.67	97.33
25	0.71	217	25.23	27.91	72.09
30	0.6	325	37.79	65.70	34.30
35	0.5	151	17.56	83.26	16.74
40	0.425	71	8.26	91.51	8.49
45	0.355	49	5.70	97.21	2.79
50	0.3	4	0.47	97.67	2.33
Pan		20	2.33	100.00	0.00
Sum		860.00	100.00		

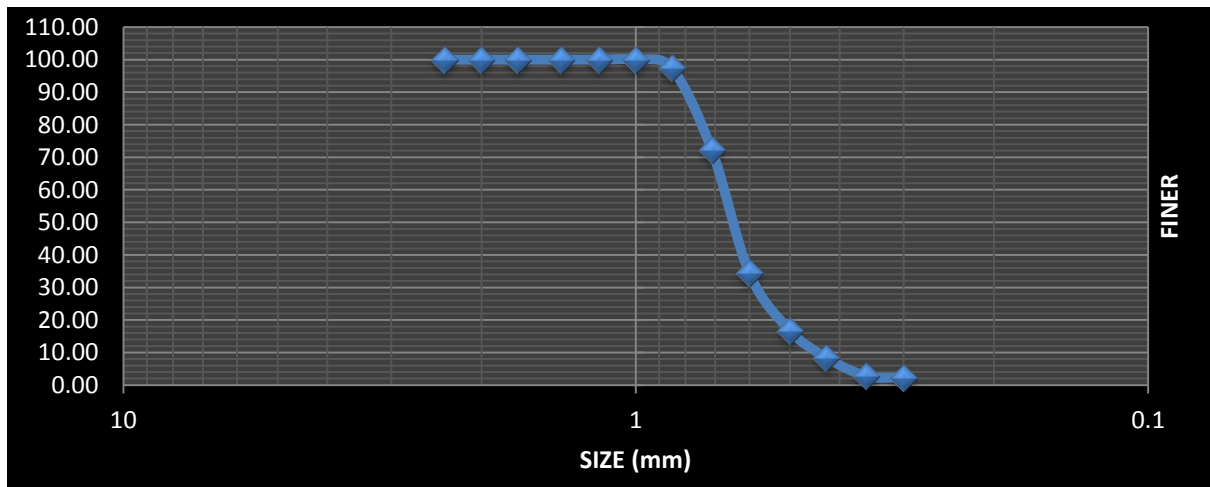


Figure 17: mass distribution for sand

$$D_{10} = .426$$

$$D_{60} = .68$$

U.C= 1.60 within the range



Figure 18: experimental sand filter

6.1.1.4 Static head design

On sand filter water was used for the first run. Many of trial was made at different head until the flowrate which is calculated($0.063\text{m}^3/\text{d}$) was achieved.the water head was found about 1.2m which was kept constant in all experiments.

6.1.2 Micro filter

The water after sand filter was pumped by using a 14.4wtpump to $5\mu\text{m}$ filter at constant flow of 0.01L/s .

6.1.3 chlorination

The chlorination was done on samples taken after sand filter and after microfilter. 10 w% sodium hypochlorite was diluted to the different weight present. The dilute sodium hypochlorite was added in different amount to water samples until the free chlorine reach to less than 0.002mg/L .

6.2 Analytical tests

The property of water was measured before and after each step of the system to find the optimum purification system that achieve the desired property of target field. The experiments were conducted to measure the quality was explain in the following tests.

6.2.1 Coliform and fecal test

Coliform and fecal were measured to calculate the amount of microorganisms in water. The procedure of the test is explained in the following points.

- 5.2g (M-Endo Agar LES, HIMedia Laboratories Pvt, India) was dissolved of 100mL deionized water this solution from now on will be mentioned as [S.1] as shown in figure 19.
- 5.2g (M-FC Agar, HIMedia Laboratories Pvt, India) Base was dissolved of 100mL deionized water this solution from now on will be mentioned as [S.2] as shown in figure 19.
- 7.62 (MEMBRANE LAURYL SULPHATE BROTH, HIMedia Laboratories Pvt, India) was dissolved of 100ML deionized water this solution from now on will be mentioned as [S.3] as shown in figure 19.



Figure 19: media (S1, S2) and layer (S3) solution's

- 0.5g sodium thiosulphate was dissolved in 500mL Deionized Water [S.4].
- 0.1 mL of (S.4) was put in 250 mL flask then add 100ml of sample of water and 1mL of (S3) to killing the free chlorine [S.5].
- 4 hr was waited.
- The filter was placed in filter vacuum cup -which is shown in figure 20 and S.5 was added to cylinder.
- The filter was placed in the dish.



Figure 20:filter vacuum cup

- i) (Steps e,f,g) were Repeated.
- j) Filter 1 was Immersed in (S.1).
- k) Filter 2 was Immersed in (S.2).
- l) The dishes was placed in Incubator, the incubator was shown in figure 21.
- m) 24 hr was waited at 45°C.



Figure 21: incubator

- n) The coliform colonies was Counted, the coliform colonies was shown in figure 22.

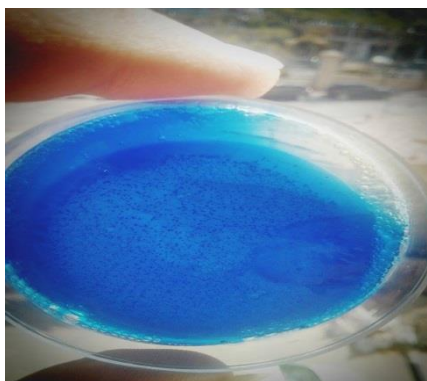


Figure 22: fecal sample

6.2.2 Conductivity test

Conductivity of water gives indication of the amount of dissolve solid in water. The details of the test is explained in the following points.

- a) The sample was placed in the 250mL beaker.
- b) Conductivity meter which is shown in figure 23 was turned on.
- c) The electrode was placed in the beaker for 2 min .
- d) The reading was recorded..



Figure 23: conductivity meter

6.2.3 Nitrate test

This test gives the amount of nitrate(NO_3) in mg/L. The details of the test is explained in the following points:

- a) The stored program number for low range nitrate nitrogen ($\text{NO}_3^- \text{N}$) was entered in colorimeter which is shown in figure 24(PROGM was pressed).
- b) 55 and ENTER were Pressed

- c) A 25 ML graduating mixing cylinder was Filled to the 15 mL mark with sample.
- d) Contents of one Nitrate Ver 6 Nitrate reagent powder pillow was Added to the cylinder.
- e) TIMER and ENTE were Pressed. A 3 minute reaction period was begin.
- f) The cylinder was Shaken throughout this three minute period.
- g) When the timer deeps, 2:00 TIMER 2 was appeared in the screen.
- h) ENTER was pressed.
- i) 10 mL of the sample was Put in sample cell.
- j) content of Nitrite Ver 3 Nitrite reagent powder was Added
- k) the sample cell was shaken for 30 second (the prepared sample)
- l) 15:00 TIMER 3 was showed in The screen.
- m) INTER was pressed.
- n) Another sample cell(the plank) was Filled with 10 mL of the sample.
- o) When the timer deeps, the plank was placed in the cell holder and ZERO icon was pressed.
- p) The prepared sample was Placed in the cell holder and READ icon was pressed.



Figure 24: colorimeter

6.2.4 Nitrite test

This test gives the amount of nitrite(NO_2) in mg/L. The details of the test is explained in the following points.

- a) The stored program number for low range nitrite nitrogen ($\text{NO}_2\text{-N}$) was Entered in colorimeter (PROGM was pressed).
- b) 60 and ENTER were Pressed.
- c) TIMER and ENTE were Pressed. A 15 minute reaction period was begin.
- d) 10 mL of the sample was placed in sample cell.
- e) Content of Nitrite Ver 3 Nitrite reagent powder was added.

- f) The sample cell was shaken for 5 minute (the prepared sample).
- g) Another sample cell(the plank) was filled with 10 mL of the sample.
- h) When the timer deeps, the plank was placed in the cell holder and ZERO icon was pressed.
- i) The prepared sample was Placed in the cell holder and READ icon was pressed.

6.2.5Ammonium test

This test gives the amount of ammonia(NH_4) in mg/L. The details of the test is explained in the following points.

- a) The ammonium meter –which is shown in figure 26- was set to the relative millivolt mode. If a relative millivolt mode is not available, use the millivolt mode.
- b) 100 mL of sample and 2 mL of buffer pH=4 was measured and the solutions was poured into a 150 mL beaker. the solution was stirred thoroughly.
- c) The electrode was rinse with ionize water, blot it dry and place the electrode into the beaker. When a stable reading is displayed, the meter was set to read 0.0 mV. If the reading cannot be adjusted to 0.0 mV, record the actual mV value.
- d) The appropriate amount of standard solution was Pipit into the beaker and Stirred the solution thoroughly.
- e) When a stable reading is displayed, the mV values were recorded.
- f) The mv is converted to M by using figure25 which was resulted from calibration

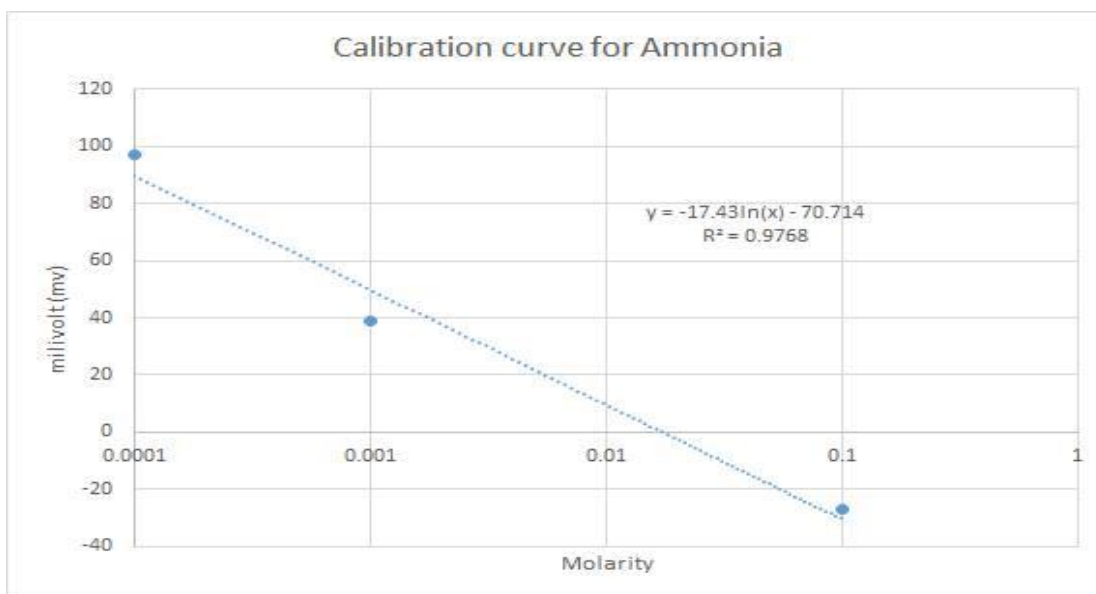


Figure 25: calibration curve for ammonium

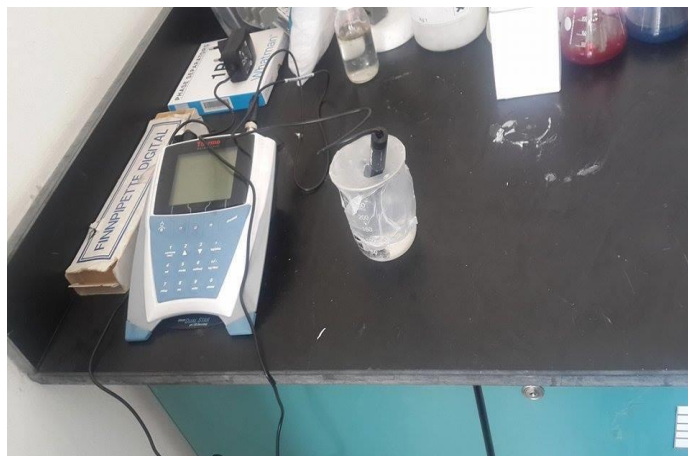


Figure 26: ammoniaelectrode

6.2.6 PH test

pH indicates the sample's acidity. The procedure of the test is explained in the following points.

- e) Placed the sample in the 250mL beaker.
- f) Turn on pH meter.
- g) Put the electrode in the beaker and wait 2 min.
- h) Take the value.

6.2.7 Suspended solid test

This test give the amount of suspended solid in g/L. The details of the test is explained in the following points.

- a) The filter paper was washed by Distilled water and dried .
- b) The filter paper dried was weighted.
- c) The 150 mL of water sample was filtered through a μm filter paper in vacuum flask.
- d) The filter paper was dried and weighted again to determine the total nonfilterable residue (TNR) of the sample reported as mg/L by the taken deferent between two weighted.

6.2.8 Residual chlorine test

This test gives the amount of free chlorine in water in mg/L. The details of the test are explained in the following points.

- a) The stored program number of free and total chlorine (Cl_2) was entered in colorimeter (PROGM was pressed).
- b) 9 and ENTER were pressed.
- c) 10 mL of the sample was put in sample cell.
- d) Content of DPD No.1 reagent tablet was added.
- e) The sample cell was shaken for 2 minutes (the prepared sample).
- f) Another sample cell (the plank) was filled with 10 mL of the sample.
- g) The plank was placed in the cell holder and ZERO icon was pressed.
- h) The prepared sample was placed in the cell holder and READ icon was pressed.

6.2.9 COD test

COD (chemical oxygen demand) test measures the total organic compound in water in mg/L. The details of the test are explained in the following points.

1. 2 mL of samples and standard deionized water are added to COD Kits.
2. The closed reactor, which is shown in figure 27, was operated even up to 150°C .
3. The kits were placed in reactor and pressed the start button for 2 hours.
4. The tubes of kits were left to cool.
5. The kits were read by colorimeter using program number 18.



Figure 27: COD reactor and colorimeter

6.2.10 Biochemical Oxygen Demand (BOD): Manometric method

This method is limited to the measurement of the oxygen consumption due only to carbonaceous oxidation

Procedure:

1. 100 mL of sample was kept in a BOD bottle fitted with a pressure sensor
2. A small amount of substance that absorbs carbon dioxide (typically potassium hydroxide) was added in the container above the sample level.
3. The BOD bottle was closed and the reads was zero.
4. the BOD bottle was stored for 5 days in the Incubation at 20 °C as shown in figure 28.

Oxygen is consumed and, as ammonia oxidation is inhibited, carbon dioxide is released. The total amount of gas, and thus the pressure, decreases because carbon dioxide is absorbed. From the drop of pressure, the sensor electronics computes and displays the consumed quantity of oxygen.



Figure 28: BOD incubator and meter

6.2.11 Turbidity test

Turbidity is caused by the presence of very fine suspended and clay particles and is a measure of the ability of water to scatter light. Turbidity is measured on nephelometric turbidity units by using this procedure:

- a) The turbidity meter- which is shown in figure 29 was turned on.
- b) 10 mL of the sample was placed in sample cell.
- c) The sample was placed in the cell holder.
- d) Test icon was pressed and the value was taken.



Figure 29: turbidity meter

Chapter seven: Result& Discussion

7.1Experiment result

Two different samples were brought from Nablus western wastewater treatment plant. samples were collected out of the rain time to avoid dilution. the first sample was taken before the plant began make nitrification, while the second sample was taken after nitrification.

The first sample was passed through two runs. The first run includes static head, sand filter and chlorination. The flow rate was kept constant through the run. 35mL of 1.02% sodium hypochlorite was added to the 90ml of water after sand filter. The quality of water through this run is shown in **Table 10**. The second run includes micro filter sand filter. 28ml of 1.02% sodium hypochlorite was added to the 90ml of water after micro filter. The quality of water through this run is shown in **Table 11**.

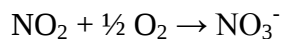
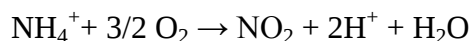
Table 7: quality of treated water passed through sand filter and chlorination(non-nitrified sample)

Properties	Outlet from plant	After sand filtration	After chlorination	Standard quality of treated water
BOD(mg/L)	200	50	2	20
COD(mg/L)	92	79	3	50
Conductivity(μ s)	1200	1275	11500	1350
Total coliform(cfu/100mL)	∞	5000	2	15
Fecal coliform (cfu/100mL)	70	25	0	10
PH	8	8	8.5	6-9
NO ₃ (mg/L)	0.14	0.04	0.55	20
NO ₂ (mg/L)	0.23	0.023	0.375	20
TSS (mg/L)	130	26	27	30

Table 8: quality of treated water passed through sand, micro filter and chlorination(non-nitrified sample)

Properties	Outlet from plant	After sand filtration	After Micro filtration	After chlorination	Standard quality of treated water
BOD(mg/L)	200	50	13	2	20
COD(mg/L)	92	79	15	4	50
Conductivity(μs)	1200μs	1275μs	1275 μs	11300	1350
Total coliform(cfu/100mL)	∞	5000	150	1	15
Fecal coliform (cfu/100mL)	70	25	4	0	10
Ph	8	8	8	8.5	6-9
NO ₃ (mg/L)	0.14	0.04	0.02	0.43	20
NO ₂ (mg/L)	0.23	0.023	0.01	0.34	20
TSS (mg/L)	130	26	2	2	30

The final quality of water in the first run is not acceptable in agriculture field. The water without nitrification has a big values of BOD, COD and ammonium. The large amount of ammonium leads to the need of large amount of sodium hyboclorite to chlorination. This large amount due to side reactions showed below :



Due to these reactions the amount of nitrate, nitrite and conductivity are increased. The micro filter was used in the second run to decrease the amount of ammonium, so that decreases the amount of side reactions and its bad effects.

After use micro filter, the conductivity was decreased but it is still very high. Therefore, there was a need to bring a sample of wastewater after the plant made nitrification.

The nitrified sample also pass through two runs .The first run was passed through a system that includes static head, sand filter and chlorination. The flow rate was kept constant through the run. 1ml of 0.0102% sodiumhypochlorite was added to 400 mL of water after sand filter. The quality of water through this run is shown in **Table 12**.The second run includes micro filter and sand filter .The water after micro filter didn't need chlorination. The quality of water through this run is shown in **Table 13**.

Table 9: quality of treated water passed through sand filter and chlorination (nitrified sample)

Properties	Outlet from plant	After sand filtration	After chlorination	Standard quality of treated water
BOD(mg/L)	7	4	0	20
COD(mg/L)	46	24	7	50
Conductivity(μs)	1271	1300	1320	1350
Total coliform(cfu/100mL)	∞	2000	0	15
Fecal coliform (cfu/100mL)	68	26	0	10
PH	7.6	7.6	8	6-9
NO₃ (mg/L)	0.14	0.09	0.09	20
NO₂ (mg/L)	0.035	0.02	0.02	20
TSS (mg/L)	117	23	23	30
Turbidity	10.9	4.16	4.16	-
Ammonium	9	5	0	5

Table 10: quality of treated water passed through sand and microfilter (nitrified sample)

Properties	Outlet from plant	After sand filtration	After microfiltration	Standard quality of treated water
BOD(mg/L)	7	4	1	20
COD(mg/L)	46	24	11	50
Conductivity(μ s)	1271	1300	1065	1350
Total coliform(cfu/100mL)	∞	2000	5	15
Fecal coliform (cfu/100mL)	68	26	2	10
PH	7.6	7.6	7.6	6-9
NO ₃ (mg/L)	0.14	0.09	0.04	20
NO ₂ (mg/L)	0.035	0.02	0.016	20
TSS (mg/L)	117	23	12	30
Turbidity	10.9	4.16	1.8	-
Ammonium	9	5	0	5

The final quality of water in the second sample is acceptable in agriculture field. When the plant makes nitrification, the amount of ammonium became very small. The amount of sodium hypochlorite needed to chlorination is very small. When the micro filter add to the system, there is no need to chlorination.

According to the obtained results, the best purification system which is most economical that achieved the standard quality of agriculture water includes nitrification, static head, sand filter and chlorination. **Figures 30 & 31** have shown the wastewater before and after sand filter.



Figure 30: wastewater from plant



Figure 31:wastewater after sand filter

7.2 Sand Filter scale up

1. Number of sand filters needed (N):

For smaller plants ($8,000 \text{ m}^3/\text{d}$), the minimum number of filters is two. For plants with a design capacity greater than $8,000 \text{ m}^3/\text{d}$, the minimum number of filters is four.

A rule-of-thumb estimate for larger plants may be made using Kawamura's suggestion (Crittenden J. et. al, 2012):

$$N = 0.0195(Q)^{0.5}$$

$$\text{Then } N = 0.195(12000)^{0.5} = 3.75$$

Then total number of filter is 4 filters (3 filters and 1 standby)

2. Cross section area calculation:

According to assumption for rapid sand filter

filtration rate = 15 m/h

$$A = Q / N * \text{Filtration rate}$$

$$\text{Then } A = 12000 / 15 * 4 * 24 = 8.3 \text{ m}^2$$

In case of using 3 filters: filtration rate modified = $12000 / (3 * 24 * 8.3 * 1.33) = 15.1 \text{ m/h}$

$$\text{Area modified} = 8.3 * 1.33 = 11.04$$

Assume 2 cell with width of 1.5 m .

$$\text{Then length} = 11.04 / (2 * 1.5) = 4 \text{ m}$$

Assume:

The depth of under drain block = 0.3 m

The depth of free board = 0.5 m

The depth of safety factor = 0.4 m

Then depth = $\Sigma \text{ layers depth} + \text{safety factor} + \text{depth of free board} + \text{depth of under drain block}$

$$= 0.45 + 0.15 + 0.25 + 1.2 + 0.4 + 0.5 + 0.3$$

$$= 3.25 \text{ m}$$

As final result the plant needs 4 filters (3 filters and 1 standby) the area of each filter is $4 \text{ m} \times 3 \text{ m} \times 3.25 \text{ m}$ and each filter include to cells.

Chapter Eight: Conclusion & Recommendations

8.1 Conclusion

The main objective of this project is to find advanced waste water treatment to purify the water effluent from Nablus west treatment plant.

The project include a detailed study of a characteristics of water, which are divided into physical, chemical and biological properties.

To attain better results, the plant was visited in order to know the mode of its operation. The wastewater treatment process in the plant are divided into three main processes which are. Firstly, the pretreatment. Secondly, the primary. Thirdly and lastly, the secondary treatment which known as a biological treatment.

The fields, where the treated water will be transferred, was studied. The amount and property of water needed are showed in the report above. Targeted filed of this project are agricultural field, stone saws, tanning factory and concrete industry.

To achieve the main objective, various advanced treatment were studied which are: Activated Carbons, Ion Exchange, Nanofiltration. Reverse Osmosis and sand filter.

Pilot system consists of sand filtration, microfiltration and chlorination was designed and constructed. purification was done with and without nitrification. Multiple experiments were conducted to study the properties of water system before and after purification. the best system was found consists of sand filter and chlorination with nitrification. the water quality of this system conforms with standards set for agricultural water in Palestine.

Based on the pilot study, a detailed design of the sand filter and chlorination systems was made for the treatment plant.

8.2 Recommendations

- ✚ The nitrification is important process for the plant so the plant must make it continuously.
- ✚ Heavy metals and other ions are not analyzed during this study and since some of them is very important in determining the quality of water they should be investigated and analyzed.
- ✚ A detailed study can be performed to compare between using either microfilter or chlorination.

References

1. Abbas A. ,Bastaki N. , (2000), " The Performance decline in brackish water film Tec spiral wound RO membranes", desalination, No136,p. 281-286.
2. BicaI., Daniela Z, Ivan P.,(2000),"Qualitative hydrology " ,Technical University of Civil Engineering, Bucharest, Romania (TUCEB) .
3. Cheremisinoff N., (2002), "Handbook of water and wastewater treatment technologies", Boston, p.(360-390).
4. Crittenden J., Trussell R., Hand D, Howe K., and Tchobanoglous G, (2012), "MWH's Water Treatment", 3th ed.,Hoboken, New Jersey.
5. Davis M., (2002), " Water and Waste-Water Engineering design principles and practice", 7thed., New York.
6. Hammer,J. M., (2002),"Water and Waste-Water Treatment Technology". 4th ed., India, New Delhi.
7. GiurmaI., Gheorghe C., Corina R., (2000),"Qualitative hydrology ",Technical University of Civil Engineering Bucharest, Romania (TUCEB) .
8. Kiely.G., (1996), "Environmental Engineering", London, p.(76-200).
9. Khader W., (2006),Master Thesis"Technical Evaluation for the Re-use of Wastewater Produced by Albereh Station", An-Najah National University- Nablus, Palestine.
10. Metcalf &Eddy, (1979)," Waste-Water Engineering Treatment, Disposal, Reuse", Second edition, California, P.(76-80).
11. Zakrzewska G., (2013)" Advances in membrane technologies for the treatment of liquid radioactive waste", Desalination, No.321,p. 119-120.

Internet References :

W1:http://www.populationinstitute.org/external/files/Fact_Sheets/Water_and_population.pdf.
(October 2014)

W2:<http://www.restaurantwaterfilter.com/nano-filtration.htm>. (October 2014)

Personal Interview (PI):

PI 1 : with manager of Water department. Municipality of Nablus City. Oct. 12, 2014.

PI 2:with deputy chief operator: Humeidan M. Nablus western wastewater treatment plant.
Nov. 20, 2014

PI3: with Manager of tannery factory. Beit Leed village. Oct. 26, 2014.

PI 4: with operator of stone cutting plants. Beit Iba village. Oct. 26, 2014.