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Environmental Management & Monitoring الادارة والمراقبة البيئية

# Performance Evaluation Of Sand Filter In Improvement Of Effluent Wastewater From Gaza Wastewater Treatment Plant

## تقييم أداء المرشح الرملي في تحسين نوعية المياه الخارجة من محطة معالجة المياه العادمة لغزة

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A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Environmental Science – Environmental Management And Monitoring

1435هـ – 2014م

( رب أوزعني ان اشكر نعمتك التي انعمت على وعلى والدى وان اعمل صالحا ترضاه
وادخلني برحمتك في عبادك الصالحين)

(النمل الآية: 19)


"O my Lord! So order me that I may be grateful for Thy favours,

which Thou has bestowed  on me and on my parents, and that I may

work the righteousness that will please Thee: and  admit me, by Thy

Grace, to the ranks of Thy Righteous Servants."

# DEDICATION

I wish to dedicate this thesis to my parents who supported me all the way since the beginning of my studies .

Also, this thesis is dedicated to my wife, beloved sons Mohammed, Tariq, Osama, Amar, beloved sun Hassan , and beloved daughters Haneen, Neveen, and Myruam who have been a great source of motivation and inspiration .

Finally, this thesis is dedicated to my brothers, sisters, friends, colleagues at the Islamic university, and all those who believe in the richness of learning.

# ACKNOWLEDGMENT

# Abstract

Sand filters in different types are considered tertiary treatment which have the ability to remove pollutants from effluent of secondary waste water treatment plants. In the period from August to December 2013, field and laboratory test were conducted to assess performance of sand filters in both types (planted and unplanted slow sand filter) in south of Al Zaytoun for its ability to remove pollutants such as biochemical oxygen demand($BOD_5$), total suspended solid (TSS), fecal coliform( FC) and Nitrogen.

Results showed that Sand filters in both types (planted and unplanted slow sand filter) have the ability to remove $BOD_5$, COD, TSS, FC, and nitrogen compound. An interesting outcome of the study is that sand filter removed 71% of TSS, 52% $BOD_5$, 32% COD, 93% FC, 39% TKN and 35% $NH_4$.

The study showed that similarity in efficiency of sand filters(planted and unplanted slow sand filter) this is due to monitoring period from the first period to reed (growth stage). Moreover a decrease in efficiency to remove pollutants with time during 24hr. also by increase of infiltration rates were observed.

It can be concluded that application of sand filters may significantly improve the quality of treated waste water.

The study revalued that increasing retention time in the sand filters considerably increased the removal efficiency.

مستخلص

تعتبر المرشحات الرملية بأنواعها المختلفة احدى طرق المعالجة الثلاثية القادرة على ازالة الملوثات من مخرج محطات المعالجة الثانوية. في الفترة الممتدة من اغسطس الى ديسمبر 2013 , تم قياس العديد من الفحوصات المخبرية والميدانية بهدف تقييم اداء المرشح الرملي بنوعيه (المرشح البطيء والمرشح المزروع بنبات البوص) في منطقة جنوب الزيتون من خلال قدرته على ازالة الملوثات .

أظهرت نتائج التحاليل قدرة المرشح الرملي بنوعيه على ازالة الاكسجين المستهلك حيويا والاكسجين المستهلك كيميائيا والمواد الصلبة العالقة بالإضافة الى البكتيريا القولونية, ومجموعة النيتروجين .

أزال المرشح الرملي خلال برنامج المراقبة 71 % من المواد العالقة , 52 % من الاكسجين المستهلك حيويا , 32 % من الاكسجين المستهلك كيميائيا , 93 %من البكتيريا القولونية , 39 % من نيتروجين كلدال الكلى 35,%من الامونيا , كنتيجة لتحويل النشادر الى نترات.

وقد خلصت الدراسة بأنه يوجد تقارب في كفاءة نظامي الترشيح (المرشح البطيء والمرشح المزروع بنبات البوص) وذلك من خلال  فترة المراقبة في الدورة الاولى لنبات البوص (مرحلة النمو) , كما اظهرت الدراسة انخفاض كفاءة ازالة الملوثات مع الزمن خلال 24 ساعة وايضا بزيادة معدل الترشيح .

وقد خلصت الدراسة أن التطبيقات للمرشح الرملي تحسن من جودة المياه المعالجة, وبينت بأن زيادة فترة المكوث في المرشح الرملي يتبعه زيادة في الكفاءة.

## List Of  Abbreviation

| | |
|---|---|
| **APHA** | American Public Health Association |
| **AWWA** | American Water Works Association |
| **BOD5** | Biochemical Oxygen Demand |

| | |
|---|---|
| **BZU** | Birzeit University |
| **CFU** | Colon Fecal Unit |
| **CMWU** | Coastal Municipal Water Utility |
| **COD** | Chemical Oxygen Demand |
| **DOC** | Dissolved Organic Carbon |
| **EFF** | Effluent |
| **FC** | Fecal coliform |
| **GWWTP** | Gaza  Wastewater  Treatment Plant |
| **H.R** | Hydraulic Rate |
| **I.R** | Infiltration Rate |
| **IAMP** | Integrated Aquifer Management Plan |
| **INF** | Influent |
| **JCP** | Job Creation Program |
| **KFUPM** | King Fahd University of Petroleum and Minerals |
| **KFW** | Kreditanstalt  Für Wiederaufbau |
| **MCM** | Million Cubic Meter |
| **MF** | Membrane Filters |
| **MOA** | Ministry Of Agriculture (Palestine) |
| **MOH** | Ministry Of  Health (Palestine) |
| **MOPIC** | Ministry Of  Planning and International Cooperation (Palestine) |
| **NH4** | Ammonia |
| **NO3** | Nitrate |
| **P** | Polyvinyl Chloride – Un plasticized |
| **PCBS** | Palestinian Central Bearue of Statistics |
| **PCSWM** | Pierce County Storm Water Management |
| **PHG** | Palestinian  Hydrologeen  Group |
| **PWA** | Palestinian Water Authority |
| **R** | Planted slow sand filter |
| **S** | Unplanted slow sand filter |
| **SAT** | Soil Aquifer Treatment |
| **TKN** | Total Kjeldahl Nitrogen |
| **TSS** | Total Suspended Solid |
| **UNDP** | United Nations Development Programme |
| **UPVC** | Polyvinyl chloride |
| **USAID** | United States Agency for International Development |
| **USEPA** | United States Environmental Protection Agency |
| **WEF** | Water Environment Federation |
| **WWTPs** | Wastewater Treatment Plants |

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# CHAPTER 1
# INTRODUCTION

## 1.1   Environmental Background:

Gaza Strip suffers from lack of water resources. Therefore, the reuse of treated wastewater for irrigation of orchards and fodder crops became a potential solution to minimize the shortage of water. Gaza Strip's wastewater treatment plants produce around 115,000 m$^3$ daily of partially treated wastewater (CMWU, 2012). Most of the effluent is discharged to the sea without significant reuse.

Freshwater shortage is becoming an increasingly acute problem in Gaza strip. As a substitute for freshwater irrigation, wastewater has an important role to play in water resources management. By releasing freshwater sources for potable water supply and other priority uses, wastewater reuse makes a contribution to water conservation and takes an economic dimension. Moreover, wastewater reuse schemes, if properly planned and managed, can have positive environmental impact.

Reuse of reclaimed wastewater has two major objectives:  it improves the environment quality by reducing the level of contaminants load into the receiving water resources or to the Mediterranean Sea,  and  it conserves  water  resources by  lowering the demand for freshwater abstraction. In the process, reuse has the potential to reduce the cost of both.

The limited reliable data on existing situation and absence of clearly defined reuse policy for wastewater based on economic and health basis make the reuse of wastewater issue top priority and many activities targeted this question. the   most existing  wastewater  treatment  plants  in  Palestine  are  overloaded  and impose serious environmental problems (CMWU, 2012).

The quality of the effluents would nearly meet Class C , PWA- Palestine Standards. Currently, the reuse of treated wastewater is very   restricted to a few illegal irrigation  sites  beside  the  treatment   plants, or limited to research activities. The public  acceptance    to  use  treated wastewater is a crucial aspect to ensure

the success of any reuse project. The prospects of upgrading of the existing treatment plant and the new planned plants may have less environmental problems.

However in turns of wastewater reuse it can be categorized into 4 class (PS 742 = 2003), as shown in Table (1.1).

Standards for effluent reuse have recently been adopted ( PS 742 / 2003). These set conditions on a range of reuse options, aquifer recharge and sea discharge, with associated limit values for physical, chemical and microbiological parameters , although discharge to Wadi is not mentioned. The approach and limit values are broadly consistent with the precautionary approach adopted in neighboring countries , but some parameters are significantly more stringent than the well-established WHO and FAO guidelines. The major difference in approach in the Palestinian standard to others in the region is how restrictions (or barriers) on reuse are applied in relation to effluent quality (i.e. lower quality effluent requires more barriers). This is, in theory , more flexible that the conventional approach of designated standards for specific uses) for instance, the Israeli-Palestinian MOU on effluent reuse) but they are more complicated in application .

**Class A**: unrestricted irrigation

Very low levels of microbiological indicators, safe for most end uses, including those that could involve occasional human contact, can be used for: cooked vegetables, parking areas, play grounds, side of roads and inside cities.

**Class B**: restricted irrigation

Only to be used with appropriate control measures in place. Can be

used for: plenteous trees and green areas, side of roads outside cities.

**Class C:** Strictly controlled irrigation

Has the lowest microbiological quality with very limited number of recommended uses, i.e. field crops, industrial crops and forestry.

**Class D** : requires up to four barriers depending on crop type. Vegetables are specifically excluded.

**Table (1.1)** describe the classification of effluent quality ,where biological oxygen demand ($BOD_5$), total suspended solid(TSS) and fecal coliform (FC).

**Table (1.1**) Classification of effluent quality (PS 742/2003)

| Class | Quality | $BOD_5$ | TSS | FC |
|-------|---------|---------|-----|------|
| A | HIGH | 20 | 30 | 200 |
| B | Good | 20 | 30 | 1000 |
| C | Medium | 40 | 50 | 1000 |
| D | Low | 60 | 90 | 1000 |

Source PS 742-2003

## 1.2 Current and future   wastewater collections and treatment facilities:

The coverage of wastewater network in Gaza strip is presented in Table 1.2. It can be seen that not all population in Gaza strip are connected to the wastewater collection networks. These differences may be due to fragmentation of bind rays or in lays of bind rays.

**Table (1.2)** The coverage of wastewater network in 2009

| Region | Population | Coverage % |
|--------|-----------|------------|
| **North Gaza** | 286,246 | 80 |
| **Gaza City** | 519,027 | 90 |
| **Middle Area** | 215,808 | 65 |
| **Khan Younis** | 283,286 | 40 |
| **Rafah** | 182,449 | 65 |

Source: CMWU, 2009 and PCBS, 2009

### 1.2.1 Existing Wastewater Treatment Plants:

There are four wastewater treatment plants operating in the Gaza Strip: Beit Lahia wastewater treatment plant (BLWWTP) in the north, Gaza wastewater treatment plant (GWWTP) in the Gaza city, Khan Younis and Rafah wastewater treatment plant ( KY, R WWTP) in the south. The existing three WWTP is heavily overloaded as the actual flow far exceeds the design flow. The total effluent of Beit Lahia, Gaza and Rafah WWTPs is approximately 41 MCM / year. The Mediterranean Sea acts as the final disposal of most treated or partially treated wastewater in Gaza strip ( CMWU, 2012 ).

Moreover, the general characterization of municipal wastewater are shown in ( Table 1.3). It is obvious that variety of treatments are available in all areas.

**Table (1.3)** General Characteristics of Municipal Wastewater Treatment Plants

| Municipalities WWTP | Type of Treatment | Construction date | Effluent Quantity m3/d | Effluent Disposal Method |
|---|---|---|---|---|
| **Beit Lahia** | Stabilization ponds and aerated lagoons | 1976 | 25,000 | 100% Infiltration basins East & North of Gaza Strip |
| **Gaza** | Anaerobic ponds followed with bio-towers | 1977 | 60,000 | 100% to sea (50,000 partially 10,000 Raw) |
| **Khan Younis** | Anaerobic lagoon followed by aerobic lagoon | 2007 | 8,000 | 100% to sea (partially treated) |
| **Rafah** | Anaerobic ponds followed with bio-towers | 1983 | More than 10,000 | 100% to sea 10.000 partially |

Source: CMWU, 2012 and BZU, 2010

### 1.2.2 Description of Gaza Wastewater Treatment Plant :

The GWWTP plant is located on an elevated location to the south of the city (the area of Sheikh Ejleen). It has an area of 130,000 m$^2$. Originally the plant

was constructed in 1977 as a two-pond treatment system. It was enlarged in 1986 by UNDP with two additional ponds. Part of this enlargement includes reuse facilities, consisting of three large recharge basins, a booster pumping stations, a 5,000 m³ storage tank, a distribution piping system and an overflow pipeline to the Wadi Gaza. GWWTP was also developed in 1996 by USAID, including the addition of two trickling filters. In 2006, the Gaza Municipality commenced construction of an additional fourth anaerobic pond. In 2010, the Gaza Municipality and CMWU commenced construction of an additional four (bio-tower) trickling filter, and sediment channel and dry bed for sludge from KFW project ( Dorsch consult October 2009).

## 1.2.3 Wastewater Quality

The quality of wastewater has been based on the composed samples collected from the WWTPs. BOD, COD and TSS parameters were monitored at a monthly basis during the last years. The result of parameters to all treatment can be shown in Table 1.4. Gaza WWTP has better quality effluent for irrigation than that for Beit Lahia, Rafah, and or Kan yonis WWTP. More details are shown in Table 1.4. Although a little improvement has been introduced to Beit Lahia WWTP, a recent upgrading for Rafah WWTP has been made.

**Table (1.4)** Efficiency of Existing Wastewater Treatment Plants (Gaza Strip)

| WWTP | BOD | | | COD | | | TSS | | |
|---|---|---|---|---|---|---|---|---|---|
| | Inf. mg/l | Eff. mg/l | removal % | Inf. mg/l | Eff. mg/l | Removal % | Inf. mg/l | Eff. mg/l | Removal % |
| **Gaza** | 500 | 105 | 79 | 1020 | 220 | 78 | 550 | 110 | 80 |
| **Rafah** | 560 | 120 | 81 | 1160 | 255 | 78 | 550 | 122 | 79 |
| **Kan Yonis** | 520 | 155 | 70 | 1090 | 322 | 70 | 580 | 141 | 76 |
| **Beit Lahia** | 440 | 133 | 70 | 980 | 250 | 74 | 480 | 222 | 71 |

Source: CMWU (2012).

It can be seen that % removal of BOD is the highest in Rafah followed by gaze WWTP, whereas khan Younis and Beit Lahia are the lowest. The same trends were found for COD and TSS.

## 1.3 Problem Definition:

The coastal aquifer is the sole source to meet the fresh water needs of the residents of the Gaza Strip, but it has a limited capacity to meet these needs. It is suffering from sharp and continuous attrition, which is expected to reach the water deficit 80-90 – MCM / year as a result of population growth (PCBS 2011). In the event of continuing the same policies that were pursued during the past decades (pumping, the absence of sustainable management), this may lead to a sharp deterioration of water resources, groundwater may become more saline due to sea water intrusion.

Palestinian Water Authority (2012) estimated the needed water for irrigation about 100 million cubic meters per year. Wastewater treatment plants in the Gaza Strip produces about 45 $m^3$ / year, and reach the degree of processing to the secondary treatment level. If the quantity of wastewater is reclaimed to a good quality, we can save the groundwater for other purposes. This falls under the principle of sustainability, recycling and reuse of available resources.

## 1. 4 Objectives

The main aim was to assess the performance of sand filters ( planted and non-planted slow sand filter) in improving the quality of effluent from wastewater treatment plant for Gaza .

**The specific objectives were:**

1. To investigate the role of sand filter on the improvement of effluent waste water quality.
2. To compare between the effect planted and unplanted slow sand filter
3. To study the effect of additional modifications on sand filter.
4. To measure the infiltration rate for both type of filter.

## 1.5 Methodology

To achieve the objectives of this research, the following tasks have been executed:

1. Conducting a literature review to the related subjects of the research.

2. Collecting data about the quality of treated wastewater in GWWTP.

3. Modification of the sand filter outlet pipes to achieve the design criteria.

4. Collecting samples from inlet and outlet of sand filters.

5. Making analyses for the samples in laboratory.

6. Discussing the results, conclusion and recommendations of the research that aimed to using sand filter to improve the quality of the treated wastewater from GWWTP.

# CHAPTER (2)
# LITERATURE REVIEW

This chapter consists of filtration definition, filter media, factors influencing on filtration and performance, slow sand filter, mechanism in slow sand filter, previous experience of treated wastewater reuse in Palestine, demonstration and piloting activities, and potential of wastewater reuse.

Filtration with sand media has been used for over a century to treat water and wastewater. The use of sand filtration for treatment of storm water has been developed to treat runoff from streets, parking lots, and residential areas ( PCSWM, 2009).

Storm water runoff picks up debris, sediment, and other contaminants as it seeks lower areas, where it can pool and cause flooding problems. Common contaminants of storm water runoff include sediment, nutrients, toxic substances, oxygen-demanding materials, and bacteria all of which can seriously degrade the quality of receiving waters ( Balousek, 2002).

Filtration is defined as an interaction between a suspension and a filtering material, pollutants are removed from the solution when they become attached to the media or to previously captured particles, using of sand filtration is common for drinking water and wastewater treatment, Sand filters are also popular as storm water runoff treatment ( Clark and Pitt, 1999).

## 2.1 filter media

AWWA (2001), Torrens et al., (2009), Anderson et al., (1985), and Woelkers et al.,(2006) stated that the successful choice of a filter media as sand filter to produce satisfactory desired pollutant removal performance depended upon the proper choice of the depth of the filters, type of sand, sand size distribution, conditions of influent water, quality of effluent, the filtration rate, and dosing regime and resting period duration, all affected the hydraulic performance and purification efficiency of the filters.

Torrens et al., (2009) stated that the sand used as the filter medium must be fine enough to ensure the biological analyses, and coarse enough to avoid surface clogging and maintain correct aeration. Granular media that is too coarse limited the retention time to a point where adequate biological decomposition is not attained. Too fine media limits the quantity of water that may be successfully filtered due to early filter clogging Anderson et al., (1985). Coarser sands have larger pore spaces that have high flow-through rates but pass larger suspended particles. A very fine sand, or other fine media filter has small pore spaces with slow flow-through rates and filter out smaller TSS particles ( Urbonas, 2003).

Afiffi et al., ( 2013) used reed bed system for wastewater treatment and reuse in urban semi / Urban Community in Gaza – Palestine , since the outcomes of a study of a reed bed system for decentralized the appropriateness of the system for small communities or single households in remote areas , and a BOD removal efficiency of close 80%. Reed bed units have been shown to be a cost effective system for disposal and treatment of wastewater , providing opportunity for effluent reuse. The biological complexity of the system within the root zone of the reed bed results in powerful water cleansing capability which is often much less constrained than in many chemical or mechanical treatment .

## 2.2 Factors  influencing the filtration performance

Overall filtration performance depends on many factors such as the desired treatment rate, the quality of the water resource and the physical characteristics of the media, type, size distribution, depth, and hydraulic loading rate (Clark, 2007). In general, filter performance has been evaluated by one or more of the following parameters, which were used in Clark 2007 study: the effluent of water quality (turbidity, suspended solids concentration, particle size distributions, dissolved organic carbon concentration DOC, effluent heavy metal and/or organic concentrations , water production (unit filter run volume) and head-loss development (rate and time to backwash or media replacement if no backwash is used).

Culp et al., (1978) reported that the main factors influencing the filtering and trapping processes. He found that the filtration efficiency improves with larger particulate size, the space between the grains determines the size of particulate that can be trapped, the angular grains participate more in the mechanical straining

process, filtration efficiency decreases with increasing velocity, and the higher the water temperature is the more efficient filtration is, although it normally cannot be controlled. 6 - Chemical properties of the water and particle: A chemical filter aid may be added to promote adhesion.

Flow rate is considered also from factors influencing the filtering performance. Khan (1995) reported that the removal efficiency of coli phage decreased from 79 % to 75 % when the flow rate increased from 10 to 20 l/min keeping the sand depth and sand size constant. Similar trends of reduced efficiencies at increased flow rates were found for total coliforms, fecal coliforms and standard plate counts at 150 cm sand depth and 0.5 mm of sand size.

## 2.3 Slow sand filter

Huisman and Wood (1974) illustrated that in slow filtration, the media used is considered as a fine sand, and the designed rate of downward flow of the water under treatment normally lies between 0.1 and 0.4 $m^3$/h per square meter of surface, The sand media used has size of 0.2 to 0.4 mm ( KFUPM, 2008).

It is the oldest type of large-scale filter, the sand removes particles from the water through adsorption and straining, also removed a great deal of turbidity from water using biological action.  A layer of dirt, debris, and microorganisms builds up on the top of the sand. This layer is known as schmutzdecke, which is German for "dirty skin. "The schmutzdecke breaks down organic particles in the water biologically, and is also very effective in straining out even very small inorganic particles from water (MECC , 2002).

The slow sand filter may run for weeks or even months without cleaning. The suspended solids and colloidal matter are deposited at the very top of the bed, from which they can be removed by scraping off the surface layer to a depth of one or two centimeters. This infrequent operation may be carried out by unskilled laborers using hand tools or by mechanical equipment ( Huisman and Wood, 1974).

Slow sand filter according to its specifications has very low hydraulic rate, because they do not have backwash systems. Slow sand filter generally has been used to treat

storm water, and considered mechanically simple in comparison to rapid sand filtration but requires a much larger filter area ( PCSWM, 2009).

## 2.4 Mechanism in slow sand filtration

The purification achieved in a slow sand filter may be considered to be principally the result of straining through the developed filter skin and the top few millimeters of sand, together with biological activity. However, Huisman (1978) suggested mechanical straining, sedimentation, adsorption, and chemical and biological activity as the important process of slow sand filtration:

Sedimentation and straining take place usually during the first few days of operational. The supernatant water above the sand bed is about 100 - 150 cm deep, depending upon the design of filters. The average time that the sample remains above the sand bed ranges from 3 to 12 hours, depending upon the filtration rate. The heavier particles of suspended matter start to settle while the lighter particles are drawn into the pores between the sand grains and removed by straining on the top few millimeters. During the filtration process, a layer of inert deposits and biological matter forms on the top layer of the sand bed. This layer is referred to as Schmutzdecke. Moreover, biological growth also occurs within the sand bed and within the gravel support.  Both the schmutzdecke and the biological growth have significant effect in the purification mechanism (Farooq et al., 1993).

Also  SM et al., (2012) studied the evaluation of the giant reed (Arundo donax) in horizontal subsurface flow wetlands for the treatment of recirculating aquaculture system effluent and found that the similarity of the performance of the A. donax- and P. australis-planted beds indicates that either may be used in horizontal subsurface flow wetlands treating aquaculture wastewater, although the planting of A. donax provides additional opportunities for secondary income streams through utilization of the energy-rich biomass.

Moreover Khan and Farooqi  (2011) studied the roughing filtration as an effective pre-treatment system for high turbidity water, and found that the process has always been tedious in terms of high coagulant dosage, large volumes of sludge and short filter runs especially after wet spells , since A laboratory-scale study was conducted

to see if roughing filtration, as the pre-treatment process, would help in reducing coagulant dose and sludge volume and improving effluent quality.

In addition Lee and Oki (2013) investigated the slow sand filters effectively reducing Phytophthora after a pathogen switch from Fusarium and a simulated pump failure. They found that Phytophthora reduction by the slow sand filter was equally effective before and after the simulated pump failure. Reduction of Fusarium was not seen by the slow sand filter.

Moreover Clark et al., (2012) studied the slow sand filter: design, implementation, accessibility and sustainability in developing countries. They found that implementation of slow sand water filter and the utilization of micro financing services, developing countries will not only have access to clean, drinkable water, but will also have the opportunity to break out of a devastating cycle of poverty.

Langenbach et al., (2009) showed that slow sand filtration of secondary clarifier effluent for wastewater reuse is technologies which needed for disinfection of wastewater to allow safe reuse, and a simple technology used for pathogen and particle removal in drinking water purification, since The key process parameters hydraulic loading rate, sand grain size distribution, and filter bed depth were systematically varied. Slow sand filters for tertiary treatment of wastewater seem promising for wastewater reuse, especially in arid developing countries.

LiY et, al., (2012) studied that estimation and modeling of direct rapid sand filtration for total fecal coliform removal from secondary clarifier effluents. They reported that direct rapid sand filters can remove 0.6-1.5 log-units of fecal coliform, depending on the loading rate and grain size distribution.

In the way around, Schijven et al., (2013) found a mathematical model for removal of human pathogenic viruses and bacteria by slow sand filtration under variable operational conditions. Since a model was developed to predict removal of human pathogenic viruses and bacteria as a function of the operational conditions.

Pundsack et, al., (2005) studied that Effect of alternative on-site wastewater treatment on the viability and cultivability of Salmonella choleraesuis.

Storm water runoff picks up debris, sediment, and other contaminants as it seeks low areas, where it can pool and cause flooding problems. Common contaminants of storm water runoff include sediment, nutrients, toxic substances, oxygen-demanding materials and bacteria all of which can seriously degrade the quality of receiving waters ( Balousek, 2002).

Furthermore Hajjaj (2011) investigated the purification of storm water using sand filter since purification and simulation for the infiltration of storm water through sand filter depth of 2 meters, in order to find the relationship between the depth-of-hand, and the removal of suspended solids and fecal coliforms bacteria on the other hand, to know the effective depth influential that gets the purification.

## 2.5 Previous Experience of Treated Wastewater Reuse in Palestine

Responding to the short-term strategy of PWA, many small wastewater reuse pilot projects carried out in Palestine. These experiments aimed principally to demonstrate the practical feasibility of treated wastewater for agricultural purposes in a sustainable development, which should take into account the technical, economic and social existing, constrains. In addition to aware the farmers and the public that adapted agricultural reuse of treated wastewater is acceptable and feasible in terms of good production, minimum health risks and good economic results. There are currently many reuse pilot projects within Palestine in which wastewater and marginal quality water is used for irrigation. Some of the pilot projects use treated wastewater for irrigation fodder and fruit orchards. Other pilot projects use the soil-aquifer technique to treat the sewage water before being used for irrigation, and another pilot project, uses grey water for gardening.

## 2.6 Demonstration and Piloting Activities for Wastewater Reuse

### 2.6.1 Beit Lahia Project

The first pilot project was located in Beit Lahia aimed to demonstrate  that uses water from the artificial lake (constituted by the effluent of the Beit Lahia Lake water treatment). Fodder crops (alfalfa, Sudan grass and ray grass) were irrigated and used for feeding the small animals. The total area cultivated by Alfalfa is extended to 45 dunums and enlarged to 140 dunums in 2010 by Italian fund. A comprehensive monitoring system is also carried out to examine and detect the hygienic and

environmental problem and it is extended to cover crop, soil, ground water and the effluent. The other running components of the French funded project includes short training courses for the farmers as well the agricultural engineers to qualify the target groups and strengthen the capacity building in PWA, MoA and NGO's beside launching public awareness for the interested farmers and agricultural associations. A field visit for 4 farmers to Jordan has been organized to introduce the Jordanian expertise and pilot projects funded by the French Embassy (MREA) in Jordan.

### 2.6.2 Sheikh Ejleen Pilot Project

The second proposed pilot farm aimed to demonstrate the interest of using treated wastewater for the irrigation of citrus and olive orchards. Farmers interested in experiencing this new source of water have been contacted in the area around the Gaza city treatment plant. This area is located around the Salah el Eden road, close to the network conveying the TWW from The Gaza city (WWTP) to the infiltration basins and wades. In 2004, the Job Creation Program (JCP) in cooperation with Palestinian Hydrologists Group has proposed a project to use treated wastewater from Sheikh Ejleen WWTP for irrigating 100 dunums of citrus and olive trees. The project has been established under French fund and the supervision of PWA and Municipality of Gaza with coordination with MoH and MoA. This project was relatively successful, thereafter; extension has made until the last Israeli invasion in 2008 that led to the destruction of some of infrastructure of the project. However, rehabilitation is currently done under the French and Spanish funds. This project was operated again on November 2010 covering 186 dunums.

### 2.6.3 Almawasi Pilot Project

With a fund of the Catalan Government, the JCP in close cooperation with PWA and CMWU launched a small pilot project for reuse of treated effluent with Soil-Aquifer Treatment system or SAT system. The project started with 60 dunums in 2008 and expanded to 90 dunums in 2010 cultivated with Jawaffa and Palm trees. The BOD resulted from the recovery wells reaches 20-25 mg/l.

Soil Aquifer Treatment (SAT) is an infiltration of the sewage effluent into the aquifer, and the natural movement of the effluent through soil layers (60cm) reaching the groundwater acts as a natural filter to treat wastewater, decreasing BOD, TSS,

bacteriological presence and metal concentration. Since the soil and aquifer are used as natural treatment, such system is called Soil-Aquifer Treatment system or SAT system. Soil-aquifer treatment is, essentially, a low-cost, advanced wastewater treatment system. It also has an aesthetic advantage over conventionally treated sewage in that water recovered from SAT system is not only clear and odor-free but it comes from a well, drain, or via natural drainage, rather than from a sewer treatment plant. Thus, the water has lost its connotation of sewage and the public see the water more as coming out of the ground (groundwater) more than as sewage effluent. This could be an important factor in the public acceptance of sewage reuse schemes.

### 2.6.4 European Hospital in Khan Younis Project

In a project funded by the European Commission, a small scale wastewater treatment plant was installed in the European Hospital in Khan Younis in 2001. This plant is generating 150 - 200 $m^3$/day in summer and a 300 m3/day in winter. The effluent from the plant used for irrigating ( by sprinkler) 90 dunums of olive, and other trees. The main partners involved are MoA and PWA.

### 2.6.5 Birzeit University Project

Birzeit University (BZU) is a leading University in the application of reclaimed wastewater reuse for irrigation. The effluent from an activated sludge plant is used for landscape irrigation (drip) and for toilet flushing. The system is working properly and is a model for institutions and new communities that are willing to make a commitment, for the eventual reuse of the reclaimed wastewater ( PWA, 1998).

However, the impact on groundwater has to be assessed and the water has to be disinfected to ensure the absence of pathogens. BZU also envisaged the importance of reuse via previous and on-going projects within the framework of a Dutch funded program.

### 2.6.6 Al-Bireh project

Within the framework of the USAID project for the Hebron Wastewater Treatment Plant, a demonstration reuse project has been conducted in 2004 at the site of Al-Bireh wastewater treatment plant. Reuse of both bio-solids and reclaimed wastewater has been practiced in partnership with the PWA, the Al-Bireh Municipality, and

MOA. The main activity of the demonstration project was the composting of bio-solids generated at the Al-Bireh Plant in a wind row system and subsequent reuse in agriculture. The main objective of the project was to generate compost (3 months) that complied with the strictest standards under Israeli and United State Environmental Protection Agency (USEPA) regulations for unrestricted land application of the composted sludge. It was reported that the composted bio-solids obtained the required low level of pathogens and heavy metals (IWS, 2006).

## 2.7 Potential of Wastewater Reuse in Gaza

In Palestine, the reuse of treated wastewater effluent for irrigated agriculture is possible in all areas particularly in Gaza Governorates. Secondary and tertiary treated wastewater is being used more and more for irrigation of field crops, landscape and other applications. However, the use of treated wastewater for irrigation is subject to major concerns because of the probable escalating of hygienic and environmental problems.

For instance recent study ( EL- Nahhal et al. 2013) showed the ability of TWW to increase the agricultural products, and to change the soil properties. Moreover, the study revealed the potential negative impacts of heavy metal contamination in crops. Furthermore (EL- Nahhal et al. 2014a) revealed the importance of application of sewage sludgy to increase plant growth. In the way around ( EL- Nahhal et al., 2014b) reported that application of sewage sludgy may increase hydrophocity of soil.

Wastewater reuse will provide an alternative to groundwater for irrigation when tangible quantities of well treated wastewater can be used for irrigation by year 2015, and about 90 MCM of wastewater will be generated in the year 2020, partially that can be directly reuse for irrigation purposes or recharged after treatment to most valuable section of the aquifer. Irrigated agriculture is a vital component of total agriculture and supplies many of the food needs for human beings and animals. By the year 2020 Gaza population is expected to grow to 2 million inhabitants. This will cause huge increases in demand for agricultural products confined in a small area; but urban use of land and water will also increase enormously. The Palestinian experience in the reuse of reclaimed wastewater is short and fairly poor. Two projects for reuses wastewater in the Gaza Strip have been attempted during the

eighties. The first attempt was in Gaza City in 1986 funded by UNDP . The project constructed two additional ponds to the existing two ponds and an effluent reuse scheme for irrigation was constructed. The UNDP and Jabalya village council made the second attempt in Beit Lahia area. The main goal of this attempt was to irrigate citrus farms in the northern area by treated wastewater.

Unfortunately the two projects were failed for the following reasons:

- The farmers refused the idea out of fear that the Israeli Civil Administration would strengthen its control over the water resources.
- Lack of technical and operational trained staff in the municipalities to properly function the system.
- Lack of available funds.
- The acceptability of wastewater reuse by the farmers was immature.
- Private lands surrounded the miss-location of the treatment plants.
- The absence of follow and institutional set up system.

During the agricultural year 2009/2010, cultivated land area constituted 960,321 dunums in the Palestinian Territory which is 16.0% of the total area of Palestinian Territory divided in 885,166 dunums in West Bank which is 15.7% of West Bank total area and 75,154 dunums in Gaza Strip which is 20.6% of the total area of Gaza Strip ( Table 2.1). The highest land area planted in Jenin amounted to 176,189 dunums which comprises 18.4% of the total cultivated land area in the Palestinian Territory, and about 30.2% of the total area of the governorate. The lowest cultivated land area was in North Gaza and Gaza, where it reached 1.2% for each governorate of the total land area cultivated in the Palestinian Territory, and 18.9%, 15.6% in respect to the total area of the governorate respectively. (PCBS and MoA, 2011).

**Table ( 2.1)** Cultivated and Area in the Agricultural Holdings in Palestine

| Region | Total Area (Dunums) | Cultivated Land Area (Dunums) | Percent % |
|--------|---------------------|-------------------------------|-----------|
| West Bank | 5,655,000 | 885,166 | 15.7 |
| Gaza Strip | 365,000 | 75,154 | 20.6 |
| Total | 6,020,000 | 960,321 | 16 |

( Data is not collected for cultivated areas where the total surface area is less than one dunum for open cultivated areas or less than half dunum for protected cultivated areas).

The agricultural sector in Gaza Strip in average consumes around 75 - 80 MCM of water annually. The entire water comes from the groundwater wells. The seasonal crop water requirements showed that more two thirds of the total cultivated area is irrigated area (110,000-120,000 dunums out of the total cultivated area 160-170,000 dunums), Irrigated agriculture is a vital component of total agriculture and supplies many of the food needs for human beings and animals. By the year 2020 Gaza population is expected to grow to be likely 2 million inhabitants. This will cause huge increases in demand for agricultural produce and products confined in a small area; but urban use of land and water will also increase enormously. The amount of fresh water allocated for agriculture will be reduced radically to meet the increasing demand for the municipal purposes. The water allocated to the farmers depends upon soil conditions and the type of crop cultivated as shown in Table 2.2.

**Table ( 2.2)** Estimated water requirments for crops in Gaza Governorates

| Crop | m³/dunum/year |
|---|---|
| Citrus | 1000 |
| Strawberry | 1000 |
| Vegetables | 700 |
| Olives and Almonds | 300 |
| Alfalfa | 1500 |
| Cut- Flowers | 1800 |

Source: PCBS and  MOA (1997)

The maximum area that can be irrigated by treated wastewater depends on many factors like the distribution of crop patterns, land tenure and on the peak demand of the mix of crops and the flow available at this time.

The areas of land that could be irrigated to satisfy peak demand with the effluent flow available during these periods are demonstrated in the Table 2.3. Although the time of peak demand differs among many assumptions, the areas required ranges from 60,000 to 100,000 dunums including the fields' crops beside the orchards area. Accordingly, the maximum quantity of treated effluent may be used in Gaza Strip – in case of accounting for all the fruits areas and converting the rain-fed areas to irrigated areas, maximally, the quantity of effluent will be used is about 53 MCM / year. Citrus was originally the principal fruit tree crop but the deterioration in water quality has led to abandonment of many orchards. Olives now occupy a similar area to citrus. The favored traditional variety of orange in the Gaza Strip is Shamouti but yields have been seriously affected by increasing water salinity and high chloride concentrations. Many farmers have changed to Valencia as this variety is rather more tolerant of poor quality water ( EC 2.1 dS/m compared with 1.1 dS/m for 100% yield). The other fruit crops are mainly date and almond, although almond production is very low.

**Table ( 2.3**) Potential areas and  quantities of effluent may be used in Gaza Strip

| Crop Pattern | Area (dunums) | CWR,m3/dunums/yr. | Total Irrigation MCM/yr. |
|---|---|---|---|
| **Vegetables** | 59,931 | 700 | Excluded from WW reuse irrigation |
| **Fruits (Citrus & Olives etc.** | 62,864 | 300-1000 | 41 |
| **Field Crops** | 39,066 | 300 | 12 |
| **Herbs** | 140 | | Excluded from WW reuse Irrigation |
| **Total** | 162,001 | | 53 |

Source: PCBS and  MOA( 2011).

The reuse of treated wastewater effluent for irrigated agriculture is possible in all areas particularly in Gaza Governorates. Secondary treated wastewater is being used for irrigation of field crops, landscape and other applications. However, the use of treated wastewater for irrigation is subject to major concerns because of the probable escalating of hygienic and environmental problems.

# Chapter (3)
# MATERIALS AND METHODS

This chapter consisted layout of experimental,  Sand filter design , monitoring of Infiltration Rate,  Sample Collection, Analytical work and satirical analysis.

## 3.1 Layout of Experimental :

The layout of the  planted (R) and unplanted (S) slow sand filter and is presented in Figure (3.1). The five units are fed from one central header of inlet channel. By means of inlet gates or overflow weirs the water is distributed over the filters.

At the bottom of the filters a herringbone drain is installed to collect the filtered water. This drain is made of UPVC pipes with a diameter of $6^{\\}$, the slope of the filters is approximately 1 - 2% .The lining of a filter is impervious, durable   and able  to  resist  penetration  by  macrophyte  roots.

Acceptable liners include:-

double layer of construction grade PVC liner ( minimum 0.2 mm thickness per layer ) , Suitable thickness of reinforced concrete. The outlet of the planted and unplanted slow sand filter are separated. They are provided with an adjustable level gate in order to control the flow rate and the retention time. Besides, both outlets are provided with water meters and sample locations.
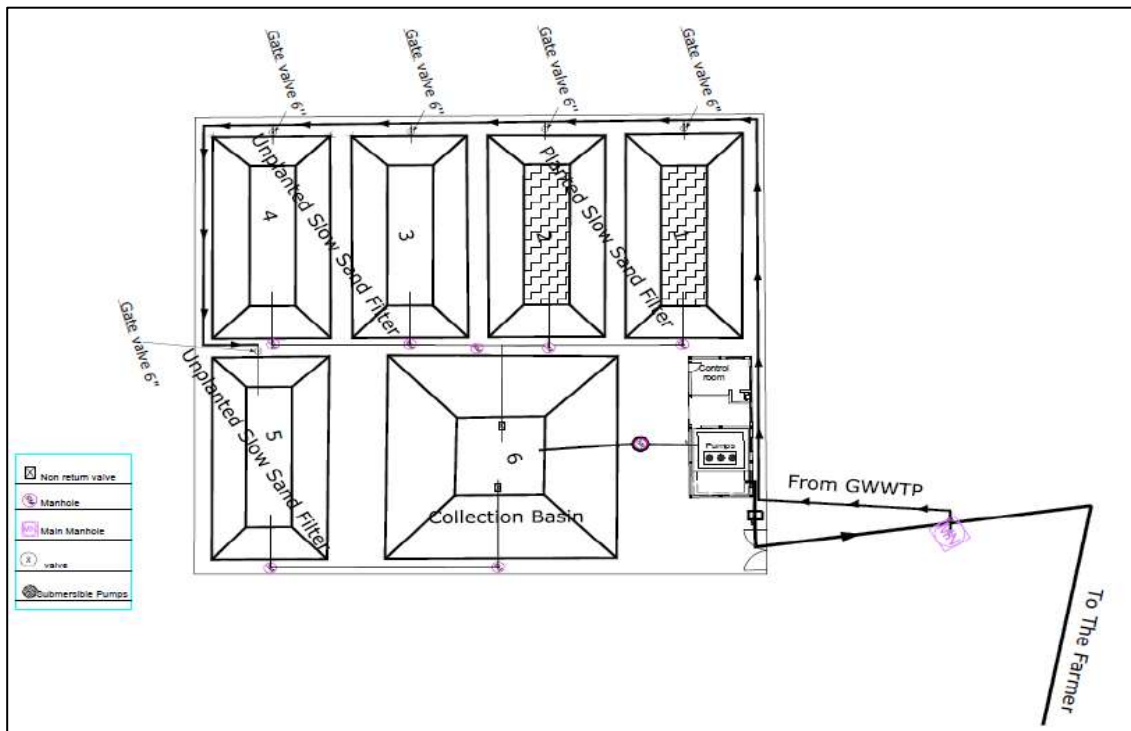
**Figure (3.1):** Layout of sand filter

## 3.2 Sand Filter Design:

Materials of Sand with different grain (0.015 – 0.35mm) and grovels with size ( 1-7 cm) were purchased from ( Pioneer Company – 1948 cease-fire line).

Reed plants were collected from Wadi Gaza and GWWTPS) Polyvinyl chloride sheet (0.2mm thickness) PVC were purchased from (Taken company – 1948 cease-fire line). Table (3.1) explained structure of sand filter. The sand filter was backed with different grain size starting from layer size (5-7cm) in the bottom of the sand filter up to fine particles (0.015- 0.035cm) in the top more details of a cross-section of a sand filter is presented in Table ( 3.1) For the reed bed filters, the top 20 cm of sand was basted by reed (PWA, 2013).

**Table (3.1)** Construction of sand filter

| Depth(cm) | layer | diameter (cm) |
|-----------|-------|---------------|
| 0 -10 | Gravel | 5 -7 |
| 10 -30 | Gravel | 3-5 |
| 30 -50 | Gravel | 1-3 |
| 50-60 | Gravel | 1 |
| 60-70 | Gravel | Less than 1 |
| 70-160 | Sand | 0.5-0.35 mm |

## 3.3 Planting and plant growth:

Reed bed was planted with the reed Phragmites australis, planting was carried out on the 20th may 2013 , and the plants were provided from two different locations in the Gaza strip the first location is a natural wetland area in Gaza ( Wadi Gaza) which is a saline area where the water electrical conductivity reaches more than 30 Ms/ cm.



Figure ( 0.2) Reeds after 2 month



Figure (3.3) Reeds after 5 month

The second locations are GWWTP near the sedimentation lagoon, the reeds were planted at as pacing of 50- 70 cm between centers and the other bed was left unplanted. Treated water was applied to the beds immediately after the reeds were planted in the first forty days the reeds were watered by treated  water twice a week for each bed 70 m$^3$. Some of the reeds became brown but regained their green color after one week. The growth of the reeds were monitored for seven month



Figure (0.4) Reeds after 7 month

, the average growth rate of the reeds were about 30 cm / month , after seven month the reeds attained an average height of  2 meter .

In winter time ( from November till February ) , parts of the plants became brown but they did not dry out completely even in December and January (Fig.3.4).

## 3.4 Monitoring of Infiltration Rate

Following to the procedure previously described (Nasser, 2003) the infiltration rate (IR) was calculated by measuring the amount of water infiltrated through the surface area of the sand filter during 24 h, as shown in next equation:

IR = Q/A    , where Q the quantity of water (m$^3$) and A surface area in ( m$^2$) respectively

At the beginning, the first reading of the water level was taken, and then every 3 hours during 24 hour and finally calculate the I. R to each reading as calculated

$$IR = \frac{HR*1000}{Surface\ area}$$   m$^3$/m$^2$/ day   Nassar (2003), where IR infiltration rate and HR hydraulic rate.

## 3.5 Increasing Wastewater Retention Time in the Sand Filter.

Two different modifications producing were introduced to the sand filter to increase the retention time of TWW and consequently reducing the flow rate.

**1- Diameter reduction**

Some plastic adjustments were installed at the outlet of the sand filter to reduce the diameter from 6 to 2 as shown in Figure 3.3 A and B ( 5/ 7/ 2013).

**2- Changing outlet level**

Changing the outlet level was achieved by installing aplastic pipe with adjustment to the original sand filter outlet. Three levels were considered 30, 50 and 70 cm more details are shown in Figure 3.3 (5/ 7/ 2013).

Some plastic adjustments to the sand filter for changing diameter line director from 6" to 2", in order to fit the design conditions and access to appropriate filtration rate as shown in the following figure.
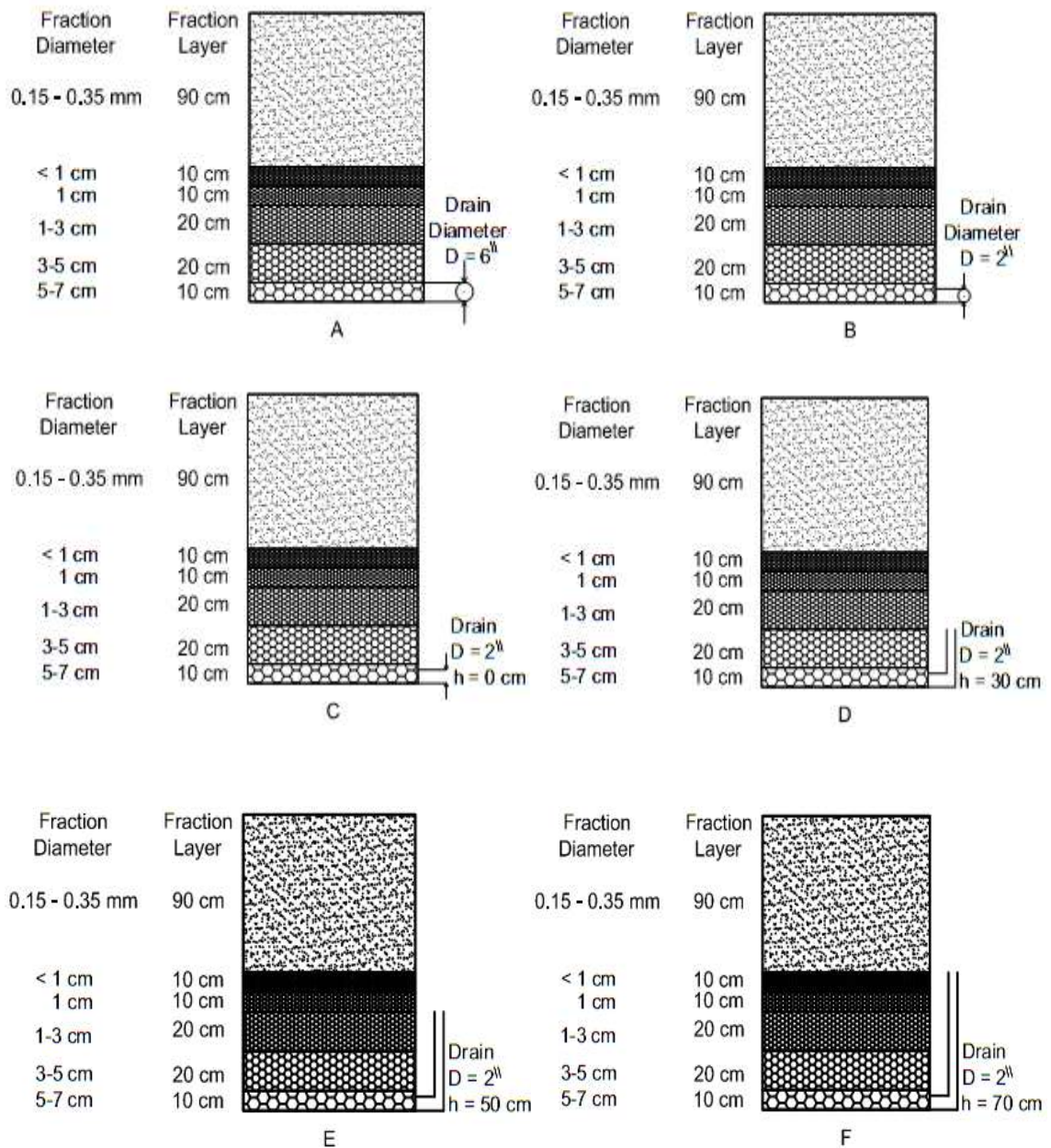


**Figure ( 3.5)** Changing outlet diameter and outlet levels

### 3.6 Sample Collection

The samples were collected from the places specified , after an hour of running sand filter  in clean plastic bottle  2 -liter and put in ice box , also collected  samples for microbiological analysis in sterile bottle  and then sent to the laboratory.

The sample collection started on 3/8/2013 and ended on 26/10/2013 as shown in Table 3.2.

**Table (3.2)**: Sample collection Location from 3/8/2013 to 26/10/2013.

| location | R.0 | R .30 | R.50 | R.70 | S.0 | S.30 | S.50 | S.70 | INF.S |
|----------|-----|-------|------|------|-----|------|------|------|-------|
| **Sample no.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Where R 0, R30, R50,  R70 are planted slow sand filter at 0, 30, 50, 70 cm level respectively and  S 0, S 30, S 50, S 70  are unplanted slow sand filter at 0, 30, 50, 70 cm level respectively.

During 24 hours samples were collected on Friday 27/12/2014 during 24 hours each 3 hr. increment.

### 3.7 Analytical work

### 3.7.1 Biochemical Oxygen Demand (BOD$_5$)

BOD was measured using OxiTop measuring system according , the quantity of samples was taken after well mixing according to corresponding measuring range recommended in the manufacturer manual. The samples  discharged  into OxiTop bottles followed   by placing a magnetic stirring rod.  Rubber quiver inserted in the neck of the bottle. Three sodium hydroxide tablets were placed into the rubber quiver with a tweezers. OxiTop  bottle was directly tightly closed and  pressed  on  S  and M  buttons  simultaneously  for  two  second until the display shows 00. The bottles were placed in the stirring tray and incubated for 5 days at 20 ºC. Readings of stored values  was  registered  after  5 days  by pressing  on m  until  values  displayed for 1 second ( Modified from OxiTop Manual).

### 3.7.2 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant according ( APHA, AWWA, WEF,1998 Standard Methods for the Examination of Water and Wastewater, 20th Edition 9222 D ) The closed dichromate reflux method (Colorimetric Method) was used to determine COD. Two ml of the sample is refluxed in strongly acid solution vessel. After digestion in COD reactor at 160 C for 2 hr. , oxygen consumed is measured against standard at 620 nm with a spectrophotometer.

### 3.7.3 Ammonia (NH4)

Ammonia in wastewater was determined according to keldahyl methods without digestion in this procedure, Distillation method was used followed by titration step to determine the concentration of ammonia. NaOH solution was added to wastewater sample and ammonia distilled into a solution of boric acid. The ammonia in the distillate was determined titrimetrically with standard HCl (APHA 1998).

### 3.7.4 Total Kjeldahl Nitrogen (TKN)

The total Kjeldahl nitrogen method is based on the wet oxidation of nitrogen using sulfuric acid and digestion catalyst. In the presence of $H_2SO_4$ , potassium sulfate $(K_2SO_4)$, and copper Sulfate $(CuSO_4)$ - catalyst, organic nitrogen and ammonia were converted to ammonium. After addition of base, organic nitrogen and ammonium were converted to ammonia. which is distilled from alkaline medium and absorbed by boric acid. The ammonium was finally determined by titration against standard hydrochloric acid.

### 3.7.5 Fecal Coliforms (FC)

The membrane filter method (APHA, AWWA, WEF,1998 Standard Methods for the Examination of Water and Wastewater, 20th Edition 9222 D) provides direct enumeration of the fecal coliform group without enrichment or subsequent testing. The results of the membrane filter test are obtained in 24 hours. An appropriate volume of water sample or its dilution is passed through a membrane filter that retains the bacteria present in the sample. The filter containing the microorganisms is placed on MFC agar in a petri

dish. The dish is incubated at 44.5 ± 0.2°C for 24 ± 2 hours. After incubation, the typical blue colonies are counted under low magnification and the number of fecal coliforms is reported per 100 ml of original sample (Figure 3.3)The concentration of fecal coliforms bacteria in water is measured to determine the likelihood of contamination by microbiological organisms. Fecal coliforms are expressed in colony forming units per 100 mL, CFU/100 mL, of water tested .

### 3.7.6 Suspended Solid (TSS)

The method 2540 D (APHA, AWWA, WEF, 1992 Standard Methods for the Examination of Water and Wastewater, 18th Edition) is used for determining the total suspended solids . A well - mixed sample is filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103°C to 105°C. The increase in weight of the filter represents the total suspended solids. If the suspended material clogs the filter and prolongs filtration, it may be necessary to increase the diameter of the filter or decrease the sample volume. To obtain an estimate of total suspended solids, calculate the difference between total dissolved solids and total solids.

### 3.7.7 Nitrate (NO$_3$-N)

As mentioned in El –Nahhal et al., (2014). NO$_3$ concentration in wastewater was determined according to salicylic acid method. In this method 5 g salicylic acid dissolved in 100ml H$_2$SO4. Then 2ml of the solution was transform to test tubes contained the 1ml of standard solution concentration.

The system is left for 20 min. to allow the reaction. The 18 ml of NaOH $_6$N is added to the tubes. A yellow color of salicylic acid is developed. The color in the standard solutions and a known samples were measured at 420 nm. The liner relationship between the optical description and concentration was used to determine the NO$_3$ concentration in the unknown samples.

### 3.8 Statistical Analysis

We used SPSS analysis to determine the average result, P value , and error bar for both planted and unplanted slow sand filter.

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# Chapter (4)
# RESULTS and DISCUSSION

The designed planted and unplanted slow sand filter are filters with different pore size from the top to the bottom of the filter. They have the same structure: the only difference is that planted slow sand filter was grown in the top 20 cm.

The average results for both systems (sand planted and unplanted slow sand filter) outlet was taken for different level (0, 30, 50, 70 cm) for all pollution parameters on part 4.1 due to error bar as indicator to presence of different result between different heights for both systems, for more details see appendix.

## 4.1 Efficiency for Planted and Unplanted Slow Sand Filter

### 4.1.1 Removing Efficiency Of TSS

Removal Efficiency of TSS by both systems are shown in Figure (4.1). It can be seen that % removal by both systems ( R and S) are high in 3 August 2013 a little decrease in September 2013 followed by an increase in October 2013 in both systems.
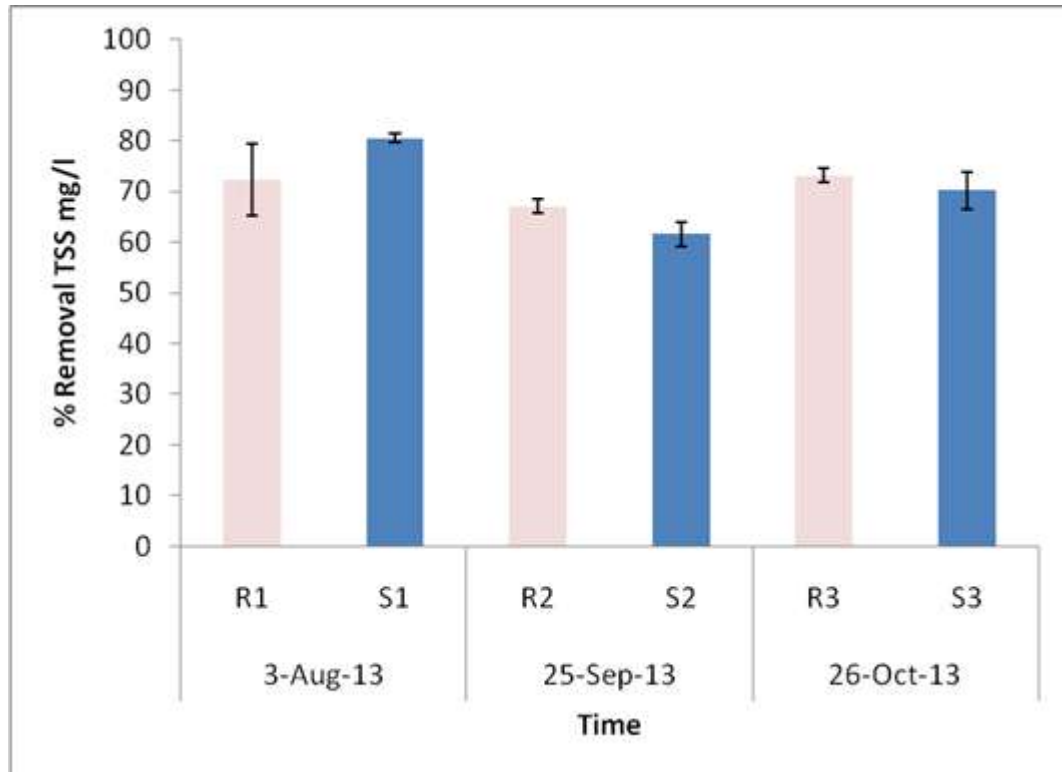
**Figure (4.1):** TSS removal efficiency with time relationship for planted and unplanted slow sand filter.

However, Figure (4.1) explains the relationship between planted and unplanted slow sand filter and time, the primary removal mechanisms of total suspended solids ( TSS) are physical filtration and sedimentation . Infiltration systems provide filtration of run off but the percent removal of solids depends on among other variable , particle size and the size of the pore opening between soil particles (Weiss et al., 2008). Total suspended solids( TSS) are solids in wastewater that can be trapped by a filter ( Buechter, 2008).  Our results demonstrated that sand and reed system were able to remove high fraction of TSS. This is probably due to adsorption or sieving properties. Similar explanations were given to sand filter previously (Farooqi et al., 1993) and ( Huisman 1978). Moreover similar results were obtained previously (Torrens et al., 2009) and (Woelkers et al., 2006).

Decrease of efficiency in the second period related to natural of inlet water to sand filter and particle size and this agree with ( Urbonas, 2003 and Culp et al., 1978)

The low error bar of our results indicates the homogeneity  for different outlet level and this agree with ( Weiss et al., 2008).

Moreover comparison between planted and unplanted slow sand filter to remove TSS from statistical analysis indicated no significant difference in first period (03/ 08 / 2013) and third period (26/ 10/ 2013)as P value above 0.05 and significant difference in the second period  (25/ 09/ 2013) as P value below 0.05.  Table (4.1)

Table (4.1) shows that  the p value for different mean efficiency between planted and unplanted slow sand filter system.

**Table (4.1)**: P value of TSS mean removal efficiency between planted and unplanted slow sand filter.

| Date | Experimental | P value |
|------|--------------|---------|
| 03/08/2013 | R1 | 0.064 |
|  | S1 |  |
| 25/09/2013 | R2 | 0.007 |
|  | S2 |  |
| 26/10/2013 | R3 | 0.191 |
|  | S3 |  |

## 4.1.2 BOD5 Mean Removal Efficiency for Planted and Unplanted Slow Sand Filter:

If sufficient oxygen is available , the aerobic biological decomposition of an organic waste will continue  until all of the waste is consumed.

Three more or less distinct activities  occur. First , apportion of waste is oxidized to end products to obtain energy for cell maintenance and the synthesis of new cell tissue.

Simultaneously . some of the waste is converted in two new cell tissue using part of the energy released during oxidation. Finally, when the organic matter is used up. The new cells begin to consume their own cell tissue to obtain energy for cell maintenance. This third process is called endogenous respiration . using the term COHNS (which represents the elements carbon , oxygen ,hydrogen , nitrogen and sulfur)to represent the organic waste and the term $C_5H_7NO_2$ ( first proposed by Hoover and Proges (1952) to represent cell tissue ,the three process are defined by the following generalized chemical reactions.

Oxidation:

COHNS + $O_2$ + bacteria $\rightarrow$ $CO_2$ + $H_2O$ + $NH_3$ + other end products + energy

Synthesis:

CONHS + $O_2$ + bacteria + energy $\rightarrow$ $C_5H_7NO2$

Endogenous respiration:

$C_5H_7NO_2$ + $5O_2$ $\rightarrow$ $5CO_2$ + $NH_3$ + $2H_2O$

If only the oxidation of organic carbon that is present in the waste is considered , the ultimate BOD is the oxygen required to complete the three reaction given above . this oxygen demand is known as the ultimate carbonaces or first stage BOD, and is usually denoted as UBOD ( Metcalf and Eddy )

Removal percent of $BOD_5$ is shown in Figure (4.2). It can be seen that both systems planted and unplanted slow sand filter were able to remove more than 50% of BOD in all periods. This indicated the efficiency of both systems to remove BOD. However the trend of BOD removal is similar to TSS (Figure 4.1). This suggests that removal of TSS is associated with BOD removal by sand filters.

However the low % removal of BOD by both systems probably due to solubility of organic carbon in wastewater which may give energy to bacteria to be able to survive in the anaerobic system like sand filter. Similar supports to our discussion can be obtained from Culp et, al., (1978) and Urbonas (2003).
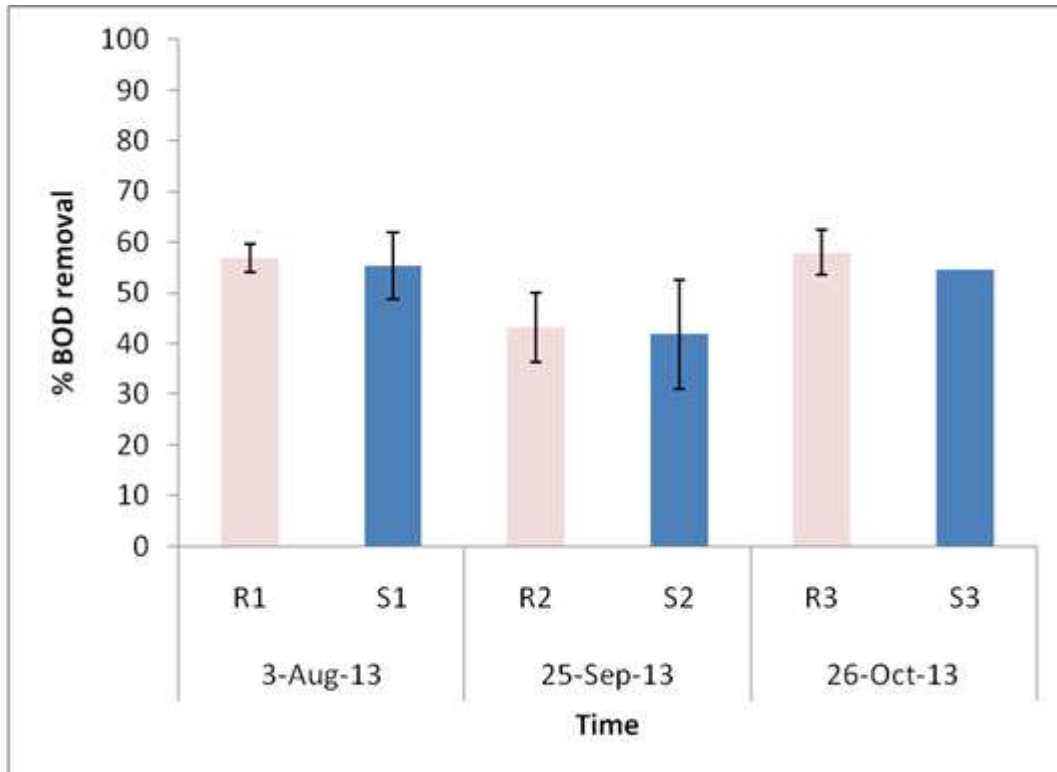
**Figure (4.2)**: $BOD_5$ removal efficiency with time for planted and unplanted slow sand filter.

Moreover comparisons between reed and sand systems to remove BOD indicate no significant difference as P value above 0.05 (Table 4.2). This suggests that reed system has the same ability of sand filter in removing BOD.

**Table (4.2)**: P value of $BOD_5$ mean removal efficiency between planted and unplanted slow sand filter.

| Date | Experimental | P value |
|------|------------|---------|
| 03/08/2013 | R1 | 0.680 |
| | S1 | |
| 25/09/2013 | R2 | 0.844 |
| | S2 | |
| 26/10/2013 | R3 | 0.174 |
| | S3 | |

### 4.1.3 Removal of COD

The nature of COD that contain $BOD_5$ and the ratio between COD / BOD determined the most appropriate methods for wastewater treatment since the percent of BOD / COD is greater than 0.5 means biological treatment able to remove organic load , but if the percent less than 0.5 means presence of chemicals and need more treatment to remove pollutants . The inlet water of planted and unplanted slow sand filter , ratio of BOD/COD $= 0.4$ since average BOD for inlet water 90 mg/l and average of COD 215 mg/l (Table 4.1).

This explain the decrease of removal percent for planted and unplanted slow sand filter , so the process that happen is physical and biological .

Removal of COD by both systems are shown in Figure 4.3. It can be seen that low of COD fraction ( less than35%) of COD was removed in the 1st period (3- Aug. 2013) or in 2nd period ( 25-Sep. 2013). A little increase was observed in the 3rd period ( 26-Oct. 2013). Comparison with TSS or BOD removal Figures (4.1 - 4.2), indicate low percent of removal on both systems.
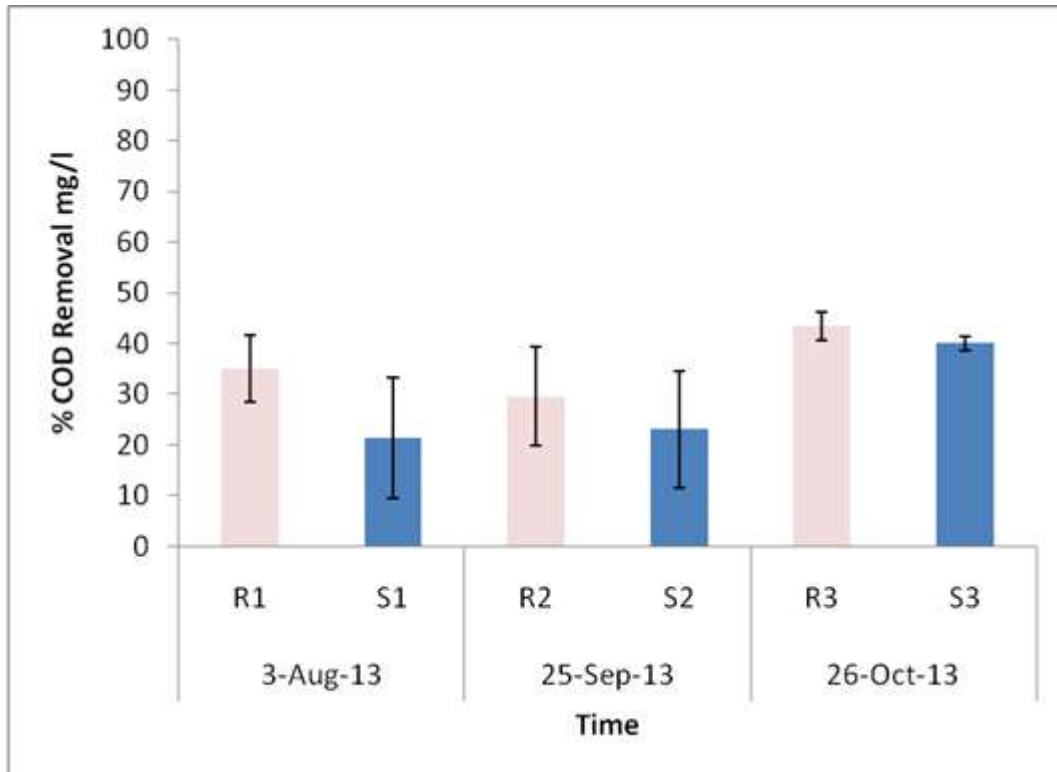
**Figure (4.3)**: COD mean removal efficiency &time relationship for planted and unplanted slow sand filters.

Figure (4.3) shows low ability for both systems to remove COD and this is related to nature of pollutants, since COD removal depended on physical and biological process ,which agree with (Huisman 1978) and (Farooqi et al., 1993), since removal materials in COD is related to the removal of $BOD_5$ and TSS and this is considered to be part of COD.

It is obvious that R- system is more able than S- system to remove COD. This probably due to chemical change that may take place in R- system due to growth of reed plant.

Statistical analysis of COD% removal in the 3rd periods did not discriminate significant difference as shown by the value of P in Table (4.3) in all case P values are above 0.05.

**Table (4.3)**: P value of COD mean removal between Sand &Reed systems

| Date | Experimental | P value |
|------|------|------|
| 03/08/2013 | R1 | |
| | S1 | 0.093 |
| 25/09/2013 | R2 | |
| | S2 | 0.418 |
| 26/10/2013 | R3 | |
| | S3 | 0.066 |

### 4.1.4 Fecal coliform (FC) Mean Removal Efficiency for Planted and Unplanted Slow Sand Filters.

Removal of FC is shown in Figure 4.4.  It can be seen that both systems, planted and unplanted slow sand filters , were able to remove nearly 100% of FC in the 1st and in the 3rd period. A little reduction was observed in 2nd period ( 25- Sep. 2013). However, the data in Figure 4.6 clearly demonstrates the efficiency of both systems to remove FC .These results are in accord with previous report Culp et, al., (1978). More support to our results comes from Langenbach et al., (2009), lee and Oki (2013) and Hajjaj (2011), who demonstrated the efficiency of high sand filter (1.5 – 2 m height) to remove FC from TWW. Since mechanism of FC removal is similar to that find in TSS in both systems.
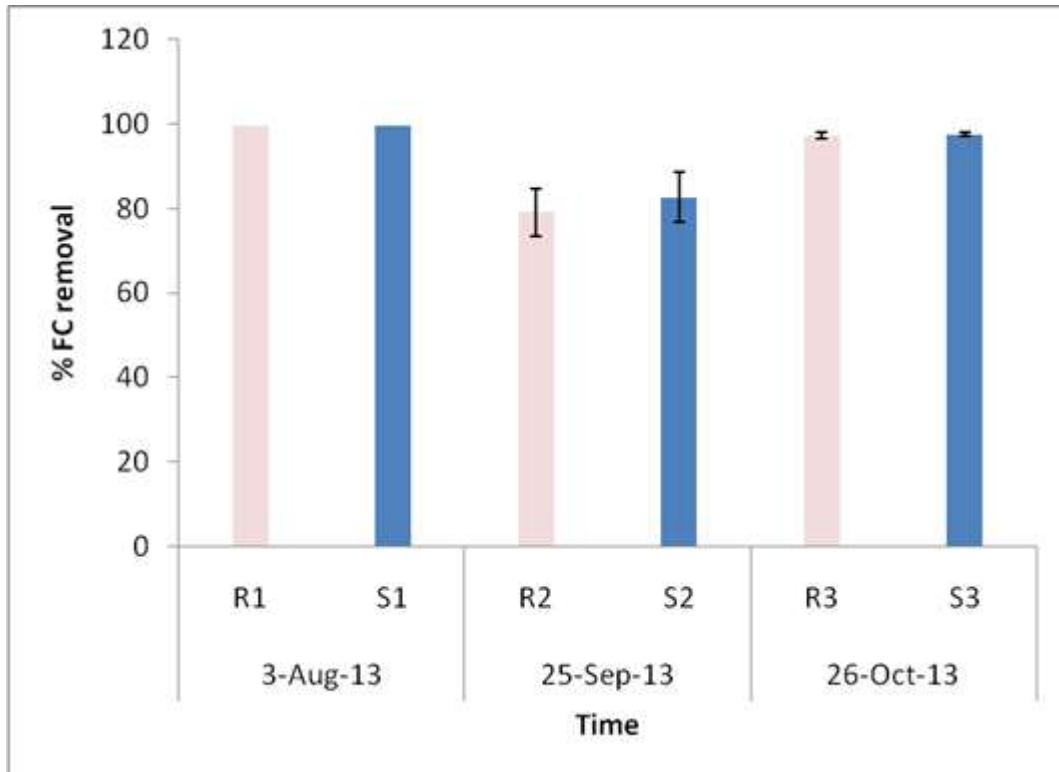
**Figure (4.4)**: FC mean removal efficiency and time relationship for planted and unplanted slow sand filters.

Statistical analysis showed significant differences between the 1st period and the other two period as indicated by low P value Table 4.4.

**Table (4.4)**: P value for FC mean removal deficiency between planted and unplanted slow sand filters.

| Date | Experimental | P value |
|------|------|------|
| 03/08/2013 | R1 | |
| | S1 | 0.000 |
| 25/09/2013 | R2 | |
| | S2 | 0.424 |
| 26/10/2013 | R3 | |
| | S3 | 0.554 |

### 4.1.5 Total Kjeldahl Nitrogen (TKN) Mean Removal Efficiency for Planted and Unplanted Slow Sand Filters

Removal of TKN is presented in Figure 4.7. Regardless to the large value of stander deviation, it is obvious that R- system were able to remove considerable fraction of TKN. However in the 1st period (3- Aug. 2013). R- System removed about 50% TKN, followed by sharp reduction in 2nd and 3rd periods. Moreover S- system choose considerable increase in TKN removal. the explanation of these results is that in R-system, the activity of plant roots may change the metabolic pathways of organic nitrogen compounds, beside the fact that identifying bacteria because less active in the acidity media around plant roots. Moreover, the ability of sand filter to remove TKN emerges from the fact that identifying bacteria are may active in nearly alternative media as shown in sand filter.

Reed bed worked to transfer oxygen in the air to root zoon which led to change condition of slow sand filters and increase nitrogen conversion.

Our results agree with EL- Nahhal et, al., (2013) who demonstrated the activity of cyanobacteria to remove acetochlor (organic nitrogen home bed) from water and soil systems. More supports to our explanation come from Safi et, al., (2014) who demonstrated partial activity of cyanobacteria to remove diversion from water and soil systems.
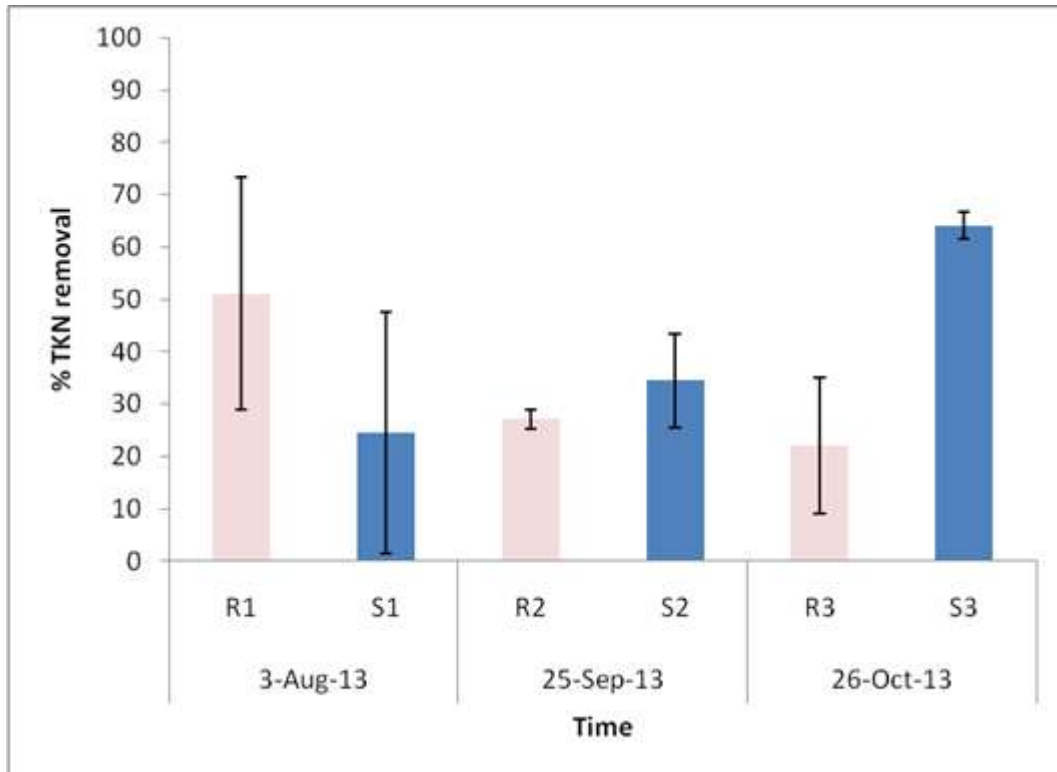
**Figure (4.5):** TKN mean removal efficiency & time relationship for planted and unplanted slow sand filters.

Statistical analysis show significant differences with the 3rd period of TKN removal as shown low P value (Table 4.5).

**Table (4.5)**: P value of TKN mean removal between planted and unplanted slow sand filters.

| Data | Experimental | P value |
|------|-------------|---------|
| 03/08/2013 | R1 | 0.147 |
|  | S1 |  |
| 25/09/2013 | R2 | 0.156 |
|  | S2 |  |
| 26/10/2013 | R3 | 0.001 |
|  | S3 |  |

## 4.1.6 Ammonia (NH4) mean removal efficiency for planted and unplanted slow sand filters:
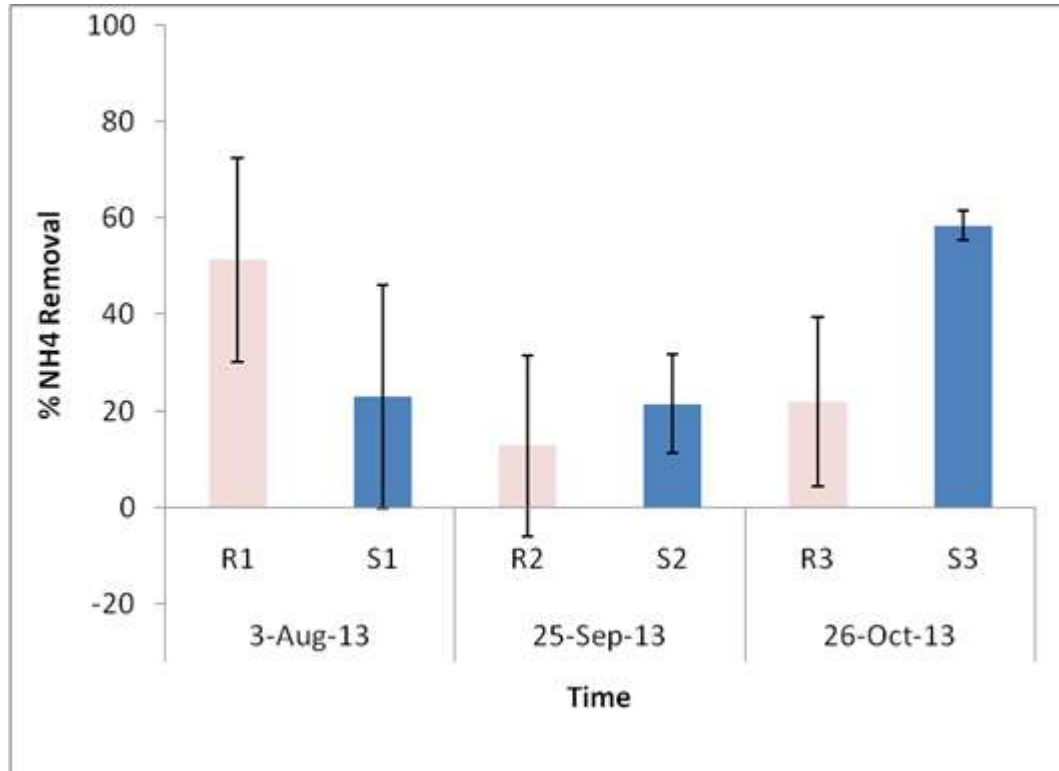


**Figure (0.6):** NH$_4$ mean removal efficiency &time relationship for planted and unplanted slow sand filters.

Removal of ammonia by both systems is shown in Figure 4.8 . Regardless to the high value of the standard deviation, the removal of NH$_3$ is similar to that of TKN the explanation of these results is similar to that of TKN . Moreover , it can be known there is anaerobic condition are created by increasing time from 3 Aug. 2013 to 26-Oct.2014 this condition enhance the reduction of NO$_3$ to N$_2$ accordingly more removal were obtained. The significant differences differ as obtained the 3$^{rd}$ period of analysis similar to that of TKN.

$2 NO_3^- + 10 e^- + 10 H^+ \rightarrow N_2 + 2 OH^- + 4 H_2O$
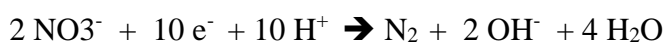
**Table (4.6)**: P value for $NH_4$ mean removal efficiency between Sand and Reed systems.

| Date | Experimental | P value |
|------|--------------|---------|
| **03/08/2013** | R1 | 0.122 |
| | S1 | |
| **25/09/2013** | R2 | 0.447 |
| | S2 | |
| **26/10/2013** | R3 | 0.006 |
| | S3 | |

### 4.1.7 Nitrate ($NO_3$) mean increasing efficiency for planted and unplanted slow sand filters.

Figure (4.7) explains the ability of both planted and unplanted slow sand filters to increase $NO_3$ in effluent water from sands and this is due to conversion of $NH_4$ to $NO_3$ through sands filter ( nitrification process) that plant absorb it easily which is considered as nutrients to plant growth, and there is increasing trend ability of sands through time. Since concentration of $NO_3$ in inlet sand filter very low less than 1 mg/ l , due to partial conversion of $NH_4$ to$NO_3$ led to increase concentration to outlet sand, for more details see appendix.

Error bar is big that explain different high of effluent for both systems to increase converting $NH_4$ to $NO_3$ to find linear relationship.
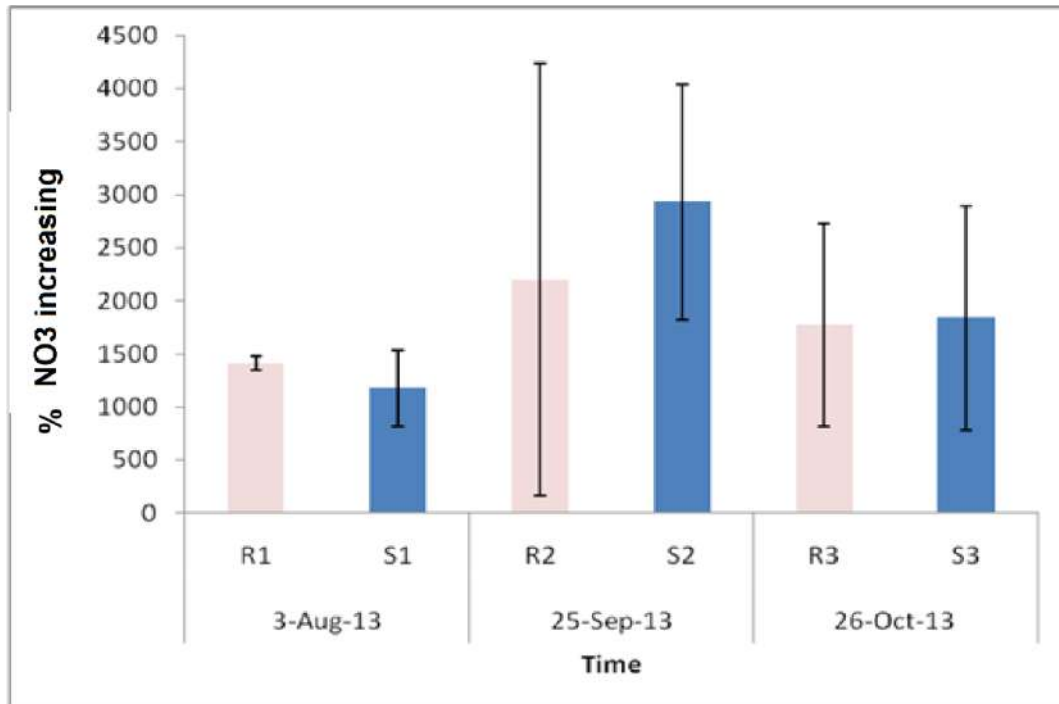
**Figure (4.7):** NO$_3$ mean increasing efficiency &time relationship for planted and unplanted slow sand filters.

Removal of NO$_3$ is shown in Figure 4.9.

**Table (4.7):** P value NO$_3$ mean increasing efficiency between planted and unplanted slow sand filters:

| Date | Experimental | P value |
|---|---|---|
| **03/08/2013** | R1 | 0.241 |
| | S1 | |
| **25/09/2013** | R2 | 0.550 |
| | S2 | |
| **26/10/2013** | R3 | 0.928 |
| | S3 | |

## 4.2 Influence of the systems in the filtration rate

24 hr. infiltration rate vs. time is presented in Figure (4.8) for four months, after modification for diameter effluent sand filter from 6 to 2 on 11 / 7/ 2013. Since before modification infiltration rate was 12 m$^3$ / m$^2$ /day. 24 hr. infiltration

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measured one weekly . Based in the result shown in the Figure , the following notes can be noted.

For planted slow sand filter infiltration rate in July , August , September months is greater than October infiltration rate increase from 0.96 m / day in October to 2 m / day in the first of September to 2.5 m / day in July because temperature in summer is high (Culp et al., 1978). The value of $R^2$ is 0.726 this mean that time affected significantly infiltration rate . For unplanted slow sand filter the infiltration rate in July is greater than August , September and October infiltration rate increase from 1.1 m / day in September to 1.63 m / day in the first of August to 2.5 in July. $R^2$ is 0.574 this mean that time affected significantly infiltration rate. From $R^2$ found that infiltration rate relationship with time in planted slow sand filter is stronger than in unplanted slow sand filter. The trend is similar in both system. Due to the same backing materials in both systems, the slight changes probably due to the presences of reed in the system.
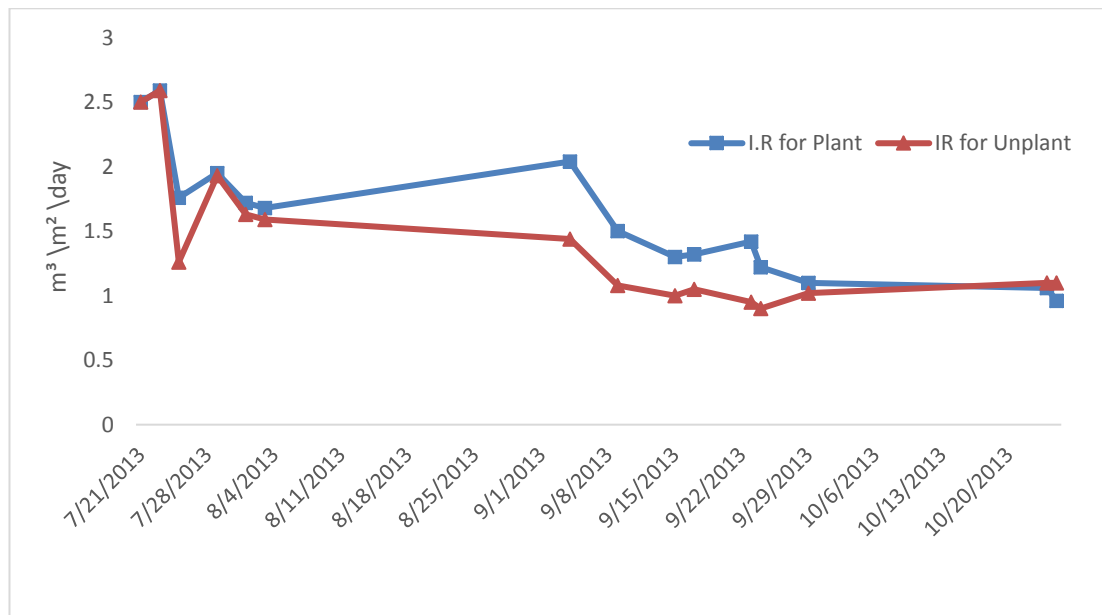


**Figure (4.8): weekly infiltration rate m³/m²/day.**

## 4.3 Kinetic removal for both systems (slow and reed) during 24 hours

### 4.3.1 Removal of TSS, BOD, COD and FC during 24 hr. are shown in Figure 4.9
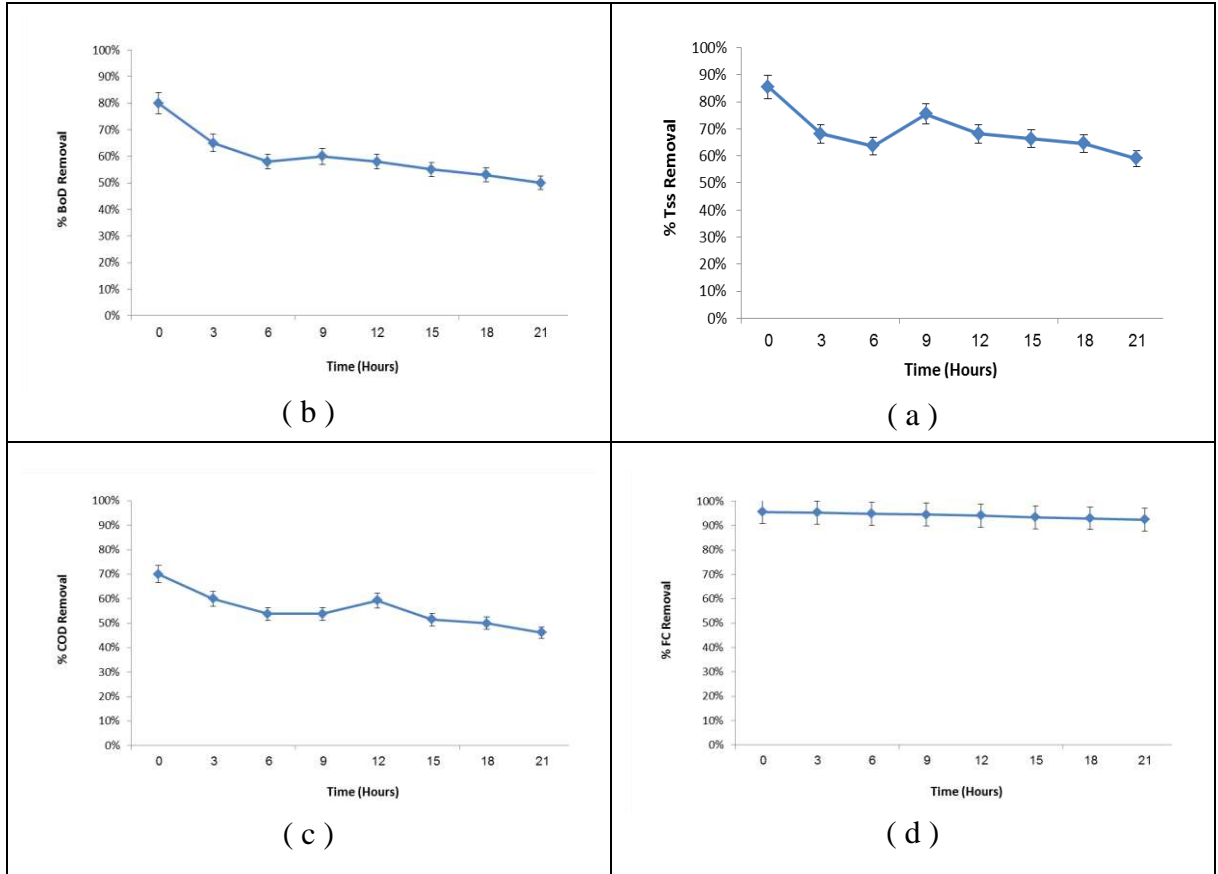


**Figure (4.9):** kinetics removal of TSS, BOD, COD and FC.

Figure (4.9 a ) explain relationship between efficiency of sand filter to remove TSS with time , and noted that at starting the efficiency was 85.5%, whereasand after 21 hr. became 59.1 %. This mean it is decreasing with time.

$R^2$ is 0.518 and P value is 0.044 which means that time affect significantly TSS removal.

The Figure (4.9 b ) explain relationship efficiency of sand filters to remove $BOD_5$ with time and noted that at starting the efficiency was 80% , whereas , after 21 hr. became 50%, means decreasing with time.

$R^2$ 0.774 and P value is 0.004 this mean that time affected significantly $BOD_5$ removal.

Figure (4.9 c ) explain relationship efficiency of sand filters to remove COD with time and noted that at starting the efficiency to remove COD 70% after 21 hr. become 46.5%, means decreasing with time.

$R^2$ 0.740 and P value is 0.006 this mean that time affected significantly COD removal.

Figure (4.9) shows a decreasing of efficiency in the sixth hr. from starting. This related to mechanism of feedback to sand filters with water , since pumping water not more than 2 hr. which lead to high of water on the surface of sand filters which lead to increase pressure to sand filters and increase infiltration rate,  which meets decreasing in efficiency (AWWA 2001).

 Figure (4.9 d) explains relationship efficiency of sand filters to remove FC with time and noted that when starting work found efficiency to remove FC 95.6% or 92.4% after 21 hr. become 46.5%, means decreasing with time.

From Figure (4.9 d) noted increase  in efficiency of sand filters in the sixth of work not affected on efficiency to remove FC .

$R^2$ 0.990 and P value is 0.000 this mean that time affected significantly FC removal.

### 4.3.2 Total Kjeldahl Nitrogen (TKN) removal efficiency during 24 hr.

Removal of N- fractions are shown in Figure 4.10.

It can be seen that TKN at $NH_4$ have similar removal trend whereas $NO_3$ has different one. The explanation of their different is that removal of TKN and NH4 needs reduction condition, less $O_2$ and alkaline pH whereas $NO_3$ needs more $O_2$ and acidic media.

Figure (4.10) explained the decrease of efficiency of conversion  $NH_4$ to $NO_3$ during time and this is related to increase anaerobic condition during filtration  period which lead to decrease of conversion $NH_4$ to $NO_3$ .

Figure (4.10 a) explained relationship efficiency of sand filters and time to remove TKN and converting TKN to other shapes from nitrogen as nitrate , at starting work the converting efficiency  64.8 % to 38.9 % after 21 hr.

$R^2$ 0.764 and P value is 0.005 this mean that time affected significantly TKN converting.

Also the Figure (4.10 b) explained relationship efficiency of sand filters and time to remove $NH_4$ and converting $NH_4$ to other shapes from nitrogen as nitrate , at starting work the converting efficiency 75.6% to 46.7% after 21 hr.

 $R^2$ 0.799 and P value is 0.003 this mean that time affected significantly $NH_4$ converting.

Moreover the Figure (4.10 c)  explained relationship efficiency of sand filters &time to increase $NO_3$.  At starting work the increasing efficiency 3560.7% to 566.7% after 21 hr.

$R^2$ is 0.883, P value is 0.001 this mean that time affected significantly with  $NO_3$ increasing.

( a )

( b )

( c )
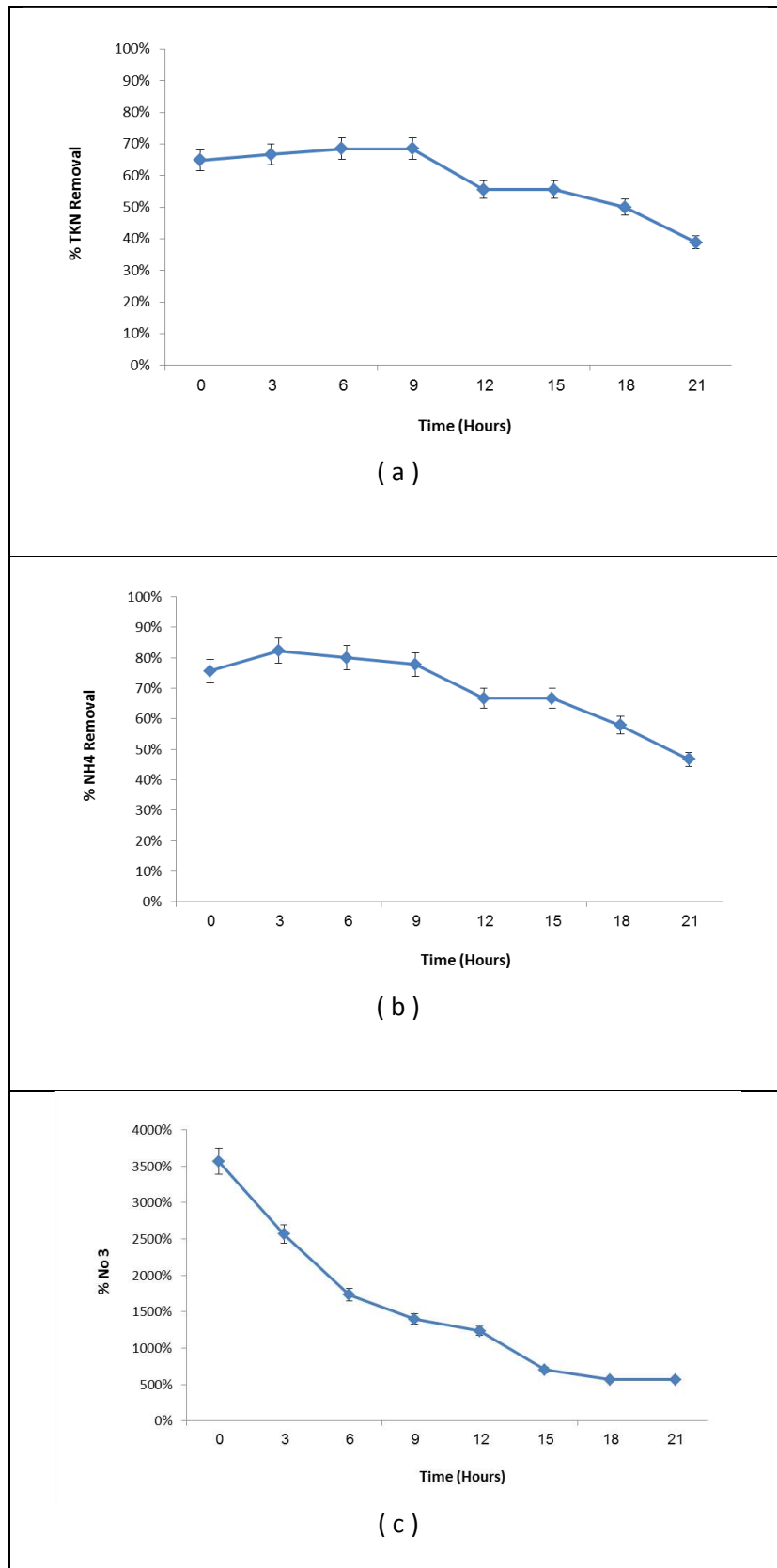
**Figure (4.10):** Kinetics removal of N – fraction.

## 4.4 Infiltration Rate ( IR ) Efficiency During 24 hr.

Figure (4.11) explains relationship efficiency infiltration rates &time, and noted that at starting work it was 1.1 m/day and decreased to 0.68 m/ day after 21 hr. (AWWA 2001). Also there was fast increasing of IR after starting work until 5 hr. That was due to increase high influent water on the surface of sands, since pumping on the sands in short time and big quantity of water, and IR after 3 hr. 2.8 m/day also found stability of efficiency to IR during 24 hr. ( Clark, 2007).
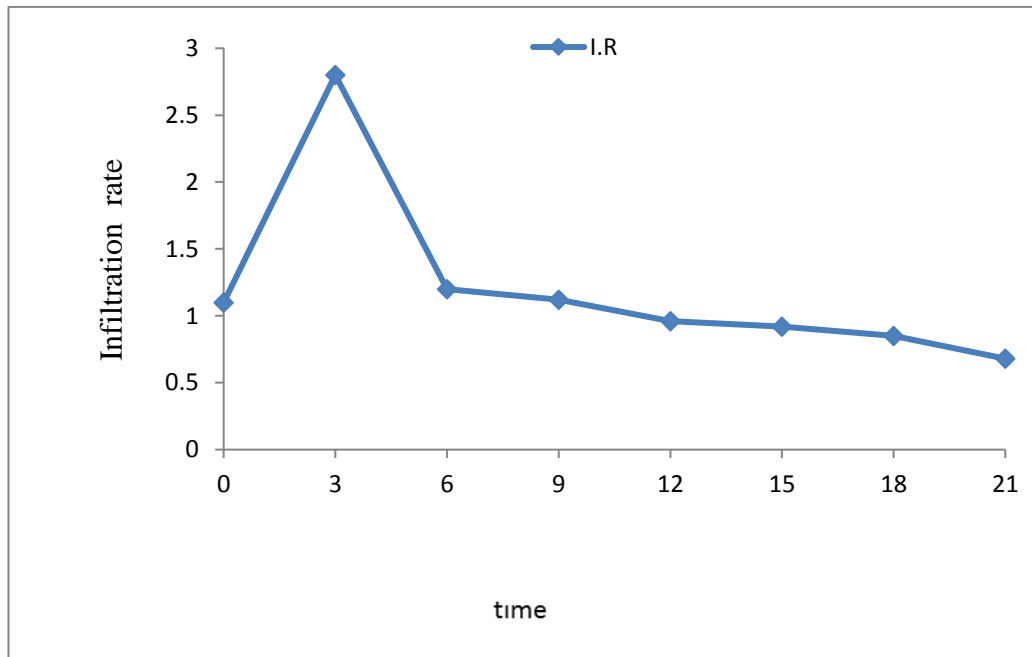


**Figure (4.11):** 24hr. Infiltration rates $m^3/m^2$/day.

**Table (4.8):** Characteristics of influent and effluent of sand filters ( planted and unplanted slow sand filter ) and the parameters design of sands filters and Palestinian standard properties to reuse in agricultural fields.

| parameters | Influent | Effluent - S | Effluent - R | Palestinian standard for agriculture | Sands parameters design |
|---|---|---|---|---|---|
| TSS  mg/l | 80 | 23 | 23 | 40 | 50 |
| BOD$_5$  mg/l | 90 | 43 | 42 | 45 | 30 |
| COD  mg/l | 215 | 154 | 137 | 150 | 100 |
| FC colon/100ml | $3*10^6$ | $2.1*10^5$ | $2.5*10^5$ | $1*10^3$ | $1*10^3$ |
| TKN-N  mg/l | 69 | 38 | 47 | 100 | 45 |
| NH$_4$- N  mg/l | 54 | 32 | 39 | - | - |
| NO$_3$- NO$_3$ mg/l | 0.44 | 9.2 | 8 | 50 | 6.8 |

The table showed that pollutant value of inlet wastewater to sand filter was TSS =80 mg / l, BOD5 = 90 mg / l, cod = 215 mg / l, FC 3 *$10^6$ colons / 100 unit , TKN = 69 mg/ l, nh4 = 54 mg/l, NO$_3$ = 0.44 mg/ l . the high removal efficiency was TSS, BOD5 and this explained the nature of pollutant work , since  the most common treatment was    physical process as sedimentation and adsorption , the percent removal 71%, 52% respectively was equal in both planted and unplanted slow sand filter. The removal of COD in planted system is better  than unplanted system since percent of removal was 36% and 28% respectively . for removal of FC in both system was high but the FC value was high due to high concentrated in influent water and the  removal percent reach to 91.5%,  93% in both  unplanted and planted slow sand filter respectively. Behavior of nitrogen group and its conversion was clear, but NH$_4$ not completely conversion to NO$_3$ which explained anaerobic condition of sand filter and probably conversion of NO. 3 to No. 2 (denitrification process). TKN and NH$_4$ removal 44 %, 40 % in unplanted slow sand filter respectively and 31%, 28% in planted slow sand filter respectively. High increase of NO3 due to low concentration of inlet wastewater to sand filter since the percent was 0.44 % mg / l  and any increase lead to high percent.

# Chapter (5)
# CONCLUSION and RECOMMENDATION

## 5.1 Conclusions

The constructed sand filter and reed systems shows similar ability to remove TSS, BOD, COD and FC in similar trend (Figures 4.1 – 4.4). Moreover, removal of N-fractions (TKN and $NH_4$) was a little lower than monitored above.

An intensity outcome of the study is that kinetic removal of TSS, BOD, COD and FC remain in high level during 24 hrs. Furthermore changing the outlet level significantly change the removal of the mentioned. It is still not obvious to us to recommend the product water for agriculture irrigation.

The two types of sand filter slow& reed has the ability to improve quality of TWW from Gaza.

The mean of pollution parameters of influent water for sands filter TSS 80mg/l, $BOD_5$ (90 mg/l), COD (215mg/l), TKN- N (69 mg/l) , $NH_4$- N (54 mg/l), $NO_3 – N$ (0.44mg/l), FC ($3*10^6$ colons/100ml) .

The mean of pollution parameters of effluent water for reed bed are TSS 23mg/l, $BOD_5$ (42mg/l), COD (137mg/l), TKN-N (47 mg/l) , $NH_4$ - N (39mg/l), NO3 – N (8 mg/l), FC ($2.5*10^5$ colons/100ml).

The mean of pollution parameters to effluent water for slow sands TSS 23 mg/l, $BOD_5$ (43 mg/l), COD (154 mg/l), TKN-N (38 mg/l) , $NH_4$ -N (32 mg/l) , $NO_3 – N$ (9.2 mg/l), FC ($2.1*10^5$ colons/100ml).

The results of sands filters in both types purified standard properties for agriculture except FC and COD which were greater than the Palestinian standards since FC in standard properties ($1*10^{3)}$, and COD(100mg/l).

Sands efficiency had strong relation to infiltration rates so we must conserving infiltration rates according to design properties.

Removal efficiency to pollutions parameters decrease with time during 24 hrs.

## 5.2 Recommendations

1- This study purified ability of sand filters to improve waste waters and reuse in agriculture so we recommended to build more units in GWWTP treatment in Gaza especially that all treatment units produce partially treated waste water which need to improvement to use in agriculture.

2- Constructing reservoir about 2000 $m^3$ to pump the water that coming from GWWTP and then use it to feedback sand filters in right way, also not affected on infiltration rates and efficiency of sand filters.

3- Adding sterilization unit to sand filters to kill or decrease pathogens that found in effluent water in sands to meet the stander parameters and protect farmers to decrease pollutions by chlorination.

4- Increasing effluent level of sand filters to increase retention time and improve efficiency.

5- Further studies to identify other new pollutants especially heavy metals and detergents.

6- Monitoring system to reed during second period to compare results with the first period also with slow sand filters system.

7- Prefer using sand filters to improve quality of wastewater from filtration through land layer to reach to aquifer then pump water during recovery well because pollution risk to aquifer negative in sand filters.

# GLOSSARY

**Chemical Oxygen Demand (COD)** : A quick chemical test to measure the oxygen equivalent of the organic matter content of wastewater that is susceptible to oxidation by a strong chemical.

**Biochemical Oxygen Demand (BOD$_5$):** A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. The greater the **BOD$_5$** the greater the degree of pollution.

**Detention Time:** The theoretical length of time for water to pass through a basin or tank, if all the water moves with the same velocity.

**Dissolved Oxygen (DO):** The oxygen dissolved in water, wastewater, or other liquid ;usually expressed in milligrams per liter, parts per million, or percent of saturation .

**Effluent**: treated wastewater discharged from a water or wastewater treatment plant .

**Filter:** A screening device or porous substance used to remove solid material from liquids. Filters, made out of a layer a coal and a layer of sand, trap dirt or bacteria in the water treatment process.

**Grab Sample**: A single sample collected at a particular time and place that represents the composition of the water, air, or soil only at that time and place.

**Influent:** The flow of raw sewage entering the plant .

**Kjeldahl Nitrogen:** The combined amount of organic and ammonia nitrogen. Also called total Kjeldahl nitrogen (**TKN**.)

**Milligrams per liter (mg/L):** The weight of a substance measured in milligrams contained in one liter. It is equivalent to 1 part per million in water measure .

**Monitoring:** Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

**Nitrate**: A form of nitrogen found in oxygenated wastewater. Nitrate is a nutrient for plants so it can contribute to prolific weed growth in waterways .

**Nutrients:**  Key nutrients associated with wastewater are nitrogen and phosphorous . Nutrients are an important   contaminant   in wastewater   as they cause prolific weed growth in waterways, adversely affecting ecology .

**Primary treatment**: The first stage of wastewater treatment that removes settle able or floating solids only; generally removes 40% of the suspended solids and 30-40% of the $BOD_5$ in the wastewater .

**Sampler:**  A device used with   or without   flow measurement   to obtain an aliquot portion of water or waste for analytical purposes. May be designed for taking single sample ( grab ), composite sample, continuous sample, or periodic sample .

**Sampling Frequency**: The interval between the collections of successive samples .

**Secondary   treatment**:  The wastewater   process where bacteria   are used to digest organic matter in the wastewater .

**Total   Suspended   Solids   (TSS):**  A laboratory   measurement   of the quantity  of suspended   solids present in  wastewater   that is one  of  the  main indicators  of  the quantity of pollutants present .

**Treated Wastewater:** Wastewater that has been subjected to one or more physical , chemical, and biological processes to reduce its potential of being a health hazard.

**Hydraulic Loading Rates:** Amount of water or liquid biosolids applied to a given treatment process and expressed as volume per unit, or volume per time per surface area.

**Wastewater**: Dissolved or suspended waterborne waste material. Sanity or domestic wastewater refers to liquid material collected from residences, offices, and institutions. Industrial wastewater refers to wastewater from manufacturing facilities.

**Municipal wastewater**: General term applied to liquid treated wastewater in municipal treatment facility and usually includes a mixture of sanitary and pre-treated industrial wastes.

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# Appendix

## Results of COD values

| Item | COD mg/1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | **Read 1** | **Read 2** | **Average** | **Read 1** | **Read 2** | **Average** | **Read 1** | **Read 2** | **Average** |
| INF. | 196.0 | 204.0 | 200.0 | 216.0 | 218.0 | 217.0 | 196.0 | 204.0 | 200.0 |
| R.0 | 143.0 | 147.0 | 145.0 | 200.0 | 206.0 | 203.0 | 143.0 | 147.0 | 145.0 |
| R.30 | 118.0 | 124.0 | 121.0 | 134.0 | 140.0 | 137.0 | 118.0 | 124.0 | 121.0 |
| R.50 | 116.0 | 118.0 | 117.0 | 174.0 | 178.0 | 176.0 | 116.0 | 118.0 | 117.0 |
| R.70 | 133.0 | 141.0 | 137.0 | 130.0 | 136.0 | 133.0 | 133.0 | 141.0 | 137.0 |
| S.0 | 160.0 | 166.0 | 163.0 | 163.0 | 167.0 | 165.0 | 160.0 | 166.0 | 163.0 |
| S.30 | 178.0 | 184.0 | 181.0 | 162.0 | 168.0 | 165.0 | 178.0 | 184.0 | 181.0 |
| S.50 | 122.0 | 126.0 | 124.0 | 150.0 | 156.0 | 153.0 | 122.0 | 126.0 | 124.0 |
| S.70 | 158.0 | 164.0 | 161.0 | 145.0 | 149.0 | 147.0 | 158.0 | 164.0 | 161.0 |

## Results of  TSS  values

| Result | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | TSS mg/l | | | | | | | | |
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 53.0 | 57.0 | 55.0 | 41.0 | 43.0 | 42.0 | 92.0 | 98.0 | 95.0 |
| R.0 | 19.0 | 21.0 | 20.0 | 15.0 | 17.0 | 16.0 | 24.0 | 28.0 | 26.0 |
| R.30 | 16.0 | 18.0 | 17.0 | 13.0 | 15.0 | 14.0 | 26.0 | 28.0 | 27.0 |
| R.50 | 12.0 | 12.0 | 12.0 | 13.0 | 13.0 | 13.0 | 24.0 | 26.0 | 25.0 |
| R.70 | 11.0 | 13.0 | 12.0 | 12.0 | 14.0 | 13.0 | 22.0 | 26.0 | 24.0 |
| S.0 | 10.0 | 12.0 | 11.0 | 13.0 | 15.0 | 14.0 | 32.0 | 32.0 | 32.0 |
| S.30 | 9.0 | 11.0 | 10.0 | 14.0 | 16.0 | 15.0 | 29.0 | 31.0 | 30.0 |
| S.50 | 10.0 | 12.0 | 11.0 | 13.0 | 17.0 | 15.0 | 26.0 | 28.0 | 27.0 |
| S.70 | 11.0 | 11.0 | 11.0 | 16.0 | 18.0 | 17.0 | 23.0 | 25.0 | 24.0 |

# Results of FC values

| Item | FC CFU/100ml | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8/3/2013 | | | 9/25/2013 | | | | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 8.0E+05 | 1.2E+06 | 1.0E+06 | 1.9E+05 | 2.1E+05 | 4.0E+05 | 4.8E+06 | 5.2E+06 | 5.0E+06 |
| R.0 | 4.7E+03 | 5.3E+03 | 5.0E+03 | 5.8E+05 | 6.2E+05 | 1.2E+06 | 9.0E+04 | 1.1E+05 | 1.0E+05 |
| R.30 | 4.6E+03 | 5.4E+03 | 5.0E+03 | 8.3E+05 | 8.7E+05 | 1.7E+06 | 1.7E+05 | 1.9E+05 | 1.8E+05 |
| R.50 | 4.5E+03 | 5.5E+03 | 5.0E+03 | 5.9E+05 | 6.1E+05 | 1.2E+06 | 1.1E+05 | 1.3E+05 | 1.2E+05 |
| R.70 | 4.8E+03 | 5.2E+03 | 5.0E+03 | 5.3E+05 | 5.7E+05 | 1.1E+06 | 1.4E+05 | 1.6E+05 | 1.5E+05 |
| S.0 | 4.7E+03 | 5.3E+03 | 5.0E+03 | 4.5E+05 | 4.9E+05 | 9.4E+05 | 1.0E+05 | 1.0E+05 | 1.0E+05 |
| S.30 | 4.4E+03 | 5.6E+03 | 5.0E+03 | 2.8E+05 | 3.2E+05 | 6.0E+05 | 1.1E+05 | 1.3E+05 | 1.2E+05 |
| S.50 | 4.5E+03 | 5.5E+03 | 5.0E+03 | 4.5E+05 | 4.7E+05 | 9.2E+05 | 1.2E+05 | 1.6E+05 | 1.4E+05 |
| S.70 | 4.4E+03 | 5.6E+03 | 5.0E+03 | 6.9E+05 | 7.1E+05 | 1.4E+06 | 1.3E+05 | 1.5E+05 | 1.4E+05 |

# Results of NH$_4$ values

| Item | NH4-N mg/l | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 36.0 | 40.0 | 38.0 | 48.0 | 50.0 | 49.0 | 72.0 | 76.0 | 74.0 |
| R.0 | 31.0 | 29.0 | 30.0 | 44.0 | 48.0 | 46.0 | 66.0 | 70.0 | 68.0 |
| R.30 | 19.0 | 17.0 | 18.0 | 46.0 | 48.0 | 47.0 | 64.0 | 70.0 | 67.0 |
| R.50 | 15.0 | 13.0 | 14.0 | 47.0 | 47.0 | 47.0 | 53.0 | 59.0 | 56.0 |
| R.70 | 11.0 | 13.0 | 12.0 | 46.0 | 50.0 | 48.0 | 38.0 | 42.0 | 40.0 |
| S.0 | 38.0 | 38.0 | 38.0 | 27.0 | 31.0 | 29.0 | 31.0 | 33.0 | 32.0 |
| S.30 | 33.0 | 37.0 | 35.0 | 34.0 | 38.0 | 36.0 | 27.0 | 29.0 | 28.0 |
| S.50 | 22.0 | 28.0 | 25.0 | 35.0 | 37.0 | 36.0 | 31.0 | 35.0 | 33.0 |
| S.70 | 18.0 | 20.0 | 19.0 | 34.0 | 38.0 | 36.0 | 28.0 | 32.0 | 30.0 |

## Results of TKN values

| Item | TKN mg/1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 40.0 | 44.0 | 42.0 | 58.0 | 60.0 | 59.0 | 90.0 | 94.0 | 92.0 |
| R.0 | 30.0 | 36.0 | 33.0 | 54.0 | 56.0 | 55.0 | 82.0 | 86.0 | 84.0 |
| R.30 | 17.0 | 19.0 | 18.0 | 52.0 | 54.0 | 53.0 | 75.0 | 79.0 | 77.0 |
| R.50 | 14.0 | 16.0 | 15.0 | 51.0 | 53.0 | 52.0 | 68.0 | 72.0 | 70.0 |
| R.70 | 13.0 | 15.0 | 14.0 | 51.0 | 53.0 | 52.0 | 54.0 | 58.0 | 56.0 |
| S.0 | 37.0 | 43.0 | 40.0 | 48.0 | 52.0 | 50.0 | 34.0 | 36.0 | 35.0 |
| S.30 | 36.0 | 40.0 | 38.0 | 46.0 | 48.0 | 47.0 | 28.0 | 32.0 | 30.0 |
| S.50 | 27.0 | 29.0 | 28.0 | 42.0 | 46.0 | 44.0 | 34.0 | 36.0 | 35.0 |
| S.70 | 19.0 | 21.0 | 20.0 | 39.0 | 41.0 | 40.0 | 30.0 | 34.0 | 32.0 |

## Result of $NO_3$ values

| Item | NO3 mg/l | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 1.10 | 0.90 | 1.00 | 0.30 | 0.30 | 0.30 | 0.28 | 0.32 | 0.30 |
| R.0 | 14.00 | 16.00 | 15.00 | 6.60 | 7.40 | 7.00 | 1.40 | 1.60 | 1.50 |
| R.30 | 15.00 | 15.00 | 15.00 | 4.30 | 4.90 | 4.60 | 6.50 | 7.50 | 7.00 |
| R.50 | 14.00 | 15.00 | 14.50 | 2.80 | 3.20 | 3.00 | 5.70 | 6.30 | 6.00 |
| R.70 | 15.00 | 17.00 | 16.00 | 4.00 | 4.00 | 4.00 | 7.60 | 8.40 | 8.00 |
| S.0 | 7.00 | 9.00 | 8.00 | 15.30 | 16.70 | 16.00 | 1.20 | 1.40 | 1.30 |
| S.30 | 11.00 | 13.00 | 12.00 | 13.60 | 14.40 | 14.00 | 5.20 | 6.80 | 6.00 |
| S.50 | 15.00 | 15.00 | 15.00 | 6.70 | 7.30 | 7.00 | 7.70 | 8.30 | 8.00 |
| S.70 | 15.00 | 17.00 | 16.00 | 8.10 | 8.70 | 8.40 | 7.50 | 8.50 | 8.00 |

# Result of BOD values

| Item | BOD mg/5 | | | | | | | | |
|------|----------|--------|---------|--------|--------|---------|--------|--------|---------|
| | 8/3/2013 | | | 9/25/2013 | | | 10/26/2013 | | |
| | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average | Read 1 | Read 2 | Average |
| INF. | 62.0 | 68.0 | 65.0 | 69.0 | 71.0 | 70.0 | 105.0 | 115.0 | 110.0 |
| R.0 | 28.0 | 32.0 | 30.0 | 60.0 | 64.0 | 62.0 | 37.0 | 43.0 | 40.0 |
| R.30 | 26.0 | 28.0 | 27.0 | 55.0 | 59.0 | 57.0 | 42.0 | 48.0 | 45.0 |
| R.50 | 25.0 | 27.0 | 26.0 | 58.0 | 62.0 | 60.0 | 47.0 | 51.0 | 49.0 |
| R.70 | 26.0 | 32.0 | 29.0 | 43.0 | 47.0 | 45.0 | 49.0 | 53.0 | 51.0 |
| S.0 | 30.0 | 34.0 | 32.0 | 53.0 | 55.0 | 54.0 | 48.0 | 52.0 | 50.0 |
| S.30 | 30.0 | 36.0 | 33.0 | 54.0 | 54.0 | 54.0 | 47.0 | 53.0 | 50.0 |
| S.50 | 26.0 | 28.0 | 27.0 | 48.0 | 52.0 | 50.0 | 48.0 | 52.0 | 50.0 |
| S.70 | 23.0 | 25.0 | 24.0 | 45.0 | 49.0 | 47.0 | 50.0 | 50.0 | 50.0 |

## Results during 24 hr. for all parameters

| location | I.R | TSS | | | BoD5 | | | COD | | | TKN | | | NO$_3$ | | | NH$_4$ | | | F.C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INF. | - | 106 | 114 | 110 | 95 | 105 | 100 | 254 | 266 | 260 | 51 | 57 | 54 | 0.27 | 0.33 | 0.3 | 42 | 47 | 44.5 | 6.60E+06 | 7.00E+06 | 6.80E+06 |
| ZERO-TIME | 1.1 | 15 | 17 | 16 | 19 | 21 | 20 | 75 | 81 | 78 | 18 | 20 | 19 | 10.5 | 11.5 | 11 | 10 | 12 | 11 | 2.90E+05 | 3.10E+05 | 3.00E+05 |
| AFTAR-3H | 2.8 | 32 | 38 | 35 | 33 | 37 | 35 | 101 | 107 | 104 | 16 | 20 | 18 | 7.5 | 8.5 | 8 | 7.6 | 8.4 | 8 | 3.10E+05 | 3.30E+05 | 3.20E+05 |
| AFTAR-6H | 1.2 | 38 | 41 | 39.5 | 41 | 43 | 42 | 116 | 124 | 120 | 17 | 17 | 17 | 5.3 | 5.7 | 5.5 | 8.3 | 9.7 | 9 | 3.40E+05 | 3.60E+05 | 3.50E+05 |
| AFTAR-9H | 1.12 | 26 | 27 | 26.5 | 38 | 42 | 40 | 118 | 122 | 120 | 16 | 18 | 17 | 4.1 | 4.9 | 4.5 | 9.6 | 10.4 | 10 | 3.70E+05 | 3.90E+05 | 3.80E+05 |
| AFTAR-12H | 0.96 | 34 | 36 | 35 | 41 | 43 | 42 | 102 | 110 | 106 | 23 | 25 | 24 | 3.7 | 4.3 | 4 | 14 | 16 | 15 | 3.90E+05 | 4.10E+05 | 4.00E+05 |
| AFTAR-15H | 0.92 | 36 | 38 | 37 | 43 | 47 | 45 | 121 | 131 | 126 | 22 | 26 | 24 | 2.3 | 2.5 | 2.4 | 14.3 | 15.7 | 15 | 4.30E+05 | 4.70E+05 | 4.50E+05 |
| AFTAR-18H | 0.85 | 37 | 41 | 39 | 45 | 49 | 47 | 126 | 134 | 130 | 26 | 28 | 27 | 1.95 | 2.05 | 2 | 18 | 20 | 19 | 4.60E+05 | 5.00E+05 | 4.80E+05 |
| AFTAR-21H | 0.68 | 44 | 46 | 45 | 49 | 51 | 50 | 138 | 142 | 140 | 32 | 34 | 33 | 1.9 | 2.1 | 2 | 22 | 26 | 24 | 5.10E+05 | 5.30E+05 | 5.20E+05 |

Infiltration rate values

| date | filtration type | | I. R |
| | Reed | slow | m/ day |
|---|---|---|---|
| 7/21/2013 | × | | 2.5 |
| | | × | 2.5 |
| 7/23/2013 | × | | 2.59 |
| | | × | 2.59 |
| 7/25/2013 | × | | 1.76 |
| | | × | 1.26 |
| 7/29/2013 | × | | 1.95 |
| | | × | 1.93 |
| 8/1/2013 | × | | 1.72 |
| | | × | 1.63 |
| 8/3/2013 | × | | 1.68 |
| | | × | 1.59 |
| 9/4/2013 | × | | 2.04 |
| | | × | 1.44 |
| 9/9/2013 | × | | 1.5 |
| | | × | 1.08 |
| 9/15/2013 | × | | 1.3 |
| | | × | 1 |
| 9/17/2013 | × | | 1.32 |
| | | × | 1.05 |
| 9/23/2013 | × | | 1.42 |
| | | × | 0.95 |
| 9/24/2013 | × | | 1.22 |
| | | × | 0.9 |
| 9/29/2013 | × | | 1.1 |
| | | × | 1.02 |
| 10/24/2013 | × | | 1.06 |
| | | × | 1.1 |
| 10/25/2013 | × | | 0.96 |
| | | × | 1.1 |