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Faculty of Graduate Studies

Sustainable Improvements for Jenin Wastewater Treatment Plant

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Dedication

Acknowledgments

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Sustainable Improvements for Jenin wastewater treatment plant

أقربأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص ، باستثناء ما تمت الإشارة إليه حيثما ورد ، وأن هذه الرسالة ككل من أو جزء منها لم يقدم من قبل لنيل أية درجة أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Date: **التاريخ:** 03/5/2016

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List of Abbreviations

AL	Aerated Lagoon
APHA	American Public Health Association
AS	Activated sludge
BOD	Biochemical oxygen demand
CFD	Computational Fluid Dynamic
COD	Chemical oxygen demand
EC	Electrical Conductivity
EQA	Environment Quality Authority
IFAS	Integrated fixed film activated sludge
J-WWTP	Jenin wastewater treatment plant
P.P	Polishing pond
PCBS	Palestinian Central Bureau of Statistics
PE	Population Equivalent
PS	Palestinian Standard
PWA	Palestinian Water Authority
RTD	Residence time distribution
SAR	Sodium Adsorption Ratio
SF	Sand Filter
TC	Total Coliforms
TF	Trickling filter
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOD	Total oxygen demand
P	Phosphorus
TP	Total Phosphorous
TSS	Total Suspended Solid
TWW	Treated wastewater
UASB	Up-flow anaerobic sludge blanket
WHO	World Health Organization
WSP	Waste stabilization pond
WWTP	Wastewater treatment plant

Sustainable Improvements for Jenin wastewater treatment plant

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Abstract

Jenin wastewater treatment plant is one of the five largest wastewater treatment plants in the West Bank. It consists mainly of aerated lagoons with surface aerators and polishing ponds.

The objective of this research is to evaluate the performance of Jenin WWTP (J-WWTP); in order to investigate sustainable options to improve the quality of effluent to a level suitable for irrigation. The evaluation is come out through collecting composite and grab samples from different locations of the plant and analyzing them in the laboratory for physical, chemical and biological parameters.

The results of the samples showed that Jenin raw wastewater is characterized as high strength with high concentration of BOD, COD, TSS and nutrients.

GPS-X program was used to simulate the plant treatment processes, the results of the samples were used for building the model and for calibration. Once the model was calibrated, studies for different scenarios were conducted.

J-WWTP can treat BOD and COD efficiently, but less efficiency was achieved for removing TSS due to improper operation of the surface aerators. By improving of the management of the aeration in the lagoons; more influent can be treated (about 4300m^3/d), but within the few years and due to the increase in the number of population in Jenin governate, more wastewater will be generated, so the plant will be overloaded and upgrading is needed.

This upgrade can be done by using Floating Baffle system, a combination between the existing plant with Upflow Anaerobic Sludge Blanket (UASB) or Activated sludge (AS), or by complete replacement of the plant with alternatives like waste stabilization ponds (WSP), integrated fixed film activated sludge (IFAS) or a combination between Upflow Anaerobic Sludge Blanket and Activated sludge.

Using UASB at the beginning of the plant is considered as a sustainable way to upgrade the existing plant; it has high efficiency in removing BOD, COD, TSS and nitrate with low capital, maintenance and operation costs and it produces small amount of sludge.

Key words: sustainable development, GPS-X modeling, AL, UASB, WSP.

Chapter One

Introduction

1.1 General background

Sustainable improvement of wastewater treatment is a popular expression. It is the use of appropriate treatment technology taking into consideration environmental, economic, and social aspects. Environmental aspects include the ability of the technology to achieve a certain level of effluent quality and the energy needed for the operation of the plant. The economic aspects include capital, operation and maintenance costs, while the social aspects are about the public acceptance and improvements of the local environment (Muga and Mihelcic, 2008).

Developing countries can't afford very expensive and complex technology, so it is important to choose simple technology with low cost and with high effluent quality (at certain level).This can be achieved by using single unit process, or a combination of appropriate processes (Libhaber and Orozco-Jrramil, 2012).

Computer models can be used to evaluate different scenarios to optimize wastewater treatment processes (environmental and economic aspects).

Palestine is considered a developing country, it has many wastewater treatment plants, Jenin wastewater treatment plant (J-WWTP) is one of them. It was constructed in 1970 and used a simple technology which is aerated lagoon. The plant was designed to treat BOD and COD only. Sustainable developments are needed to produce high effluent quality which match Palestinian Standards to reuse it in irrigation.

Aerated lagoon technology is described as a high tech low cost treatment process. It has three types aerobic, facultative and anaerobic ponds. When it is used as a single treatment process in the plant; natural oxygenation should be enhanced using a mixed aerobic reactor, so the pond can be deeper and more removal efficiency with less hydraulic time can be achieved. Mechanical aerators provide oxygen, so the aerobic organisms stay suspended and mixed with water in order to increase the degradation of organic matter (Rose, 1999). The use of open ponds enhances pathogen removal by the effects of solar water disinfection (Curtis et al., 1992). On the other hand the use of mechanical aerators increases the complexity of the system and increases the operation and maintenance (O&M) cost due to energy consumption(Arthur, 1983).

1.2 Research Objectives

The main objectives of this research are:

1- Evaluate and model the performance of Jenin's existing wastewater treatment plant.

2- Investigate improvement options for the wastewater treatment plant.

3- Determine background pollutant and concentration in soil of Jenin irrigated lands (Marj Ibn Amer).

4- Propose sustainable improvement plan.

1.3 Research motivation:

J-WWTP is one of the largest treatment plants in Palestine; it uses a high tech low cost technology which is aerated lagoon. The plant was designed to treat BOD and COD only. In this research we tried to upgrade the plant to achieve high effluent quality which meets Palestinian standards to reuse it in irrigation, by molding aerated lagoon technology in a software computer, and study the models' ability to describe the behavior of the plant to treat other parameters like TSS, TN and TP.

This project is the first real project of reusing TWW in irrigation. The reuse may have many positive impacts especially for Jenin discrete, it consists of many plains; Marj Ibn Amer is one of them, it is known as an important fertile plain in West Bank in terms of its size and quality of soil. Jenin is also considered as the largest agricultural area in West Bank. It's Contribution in the Palestine agricultural production is about 16.2% (Abu-Madi et al., 2015).

1.4 Study area

1.4.1 Location

Jenin is located in the northern part of the West Bank, near the border of 1967, at the edge of Marj Ibn-Amer. The population of Jenin governate had been estimated to be 303,565 inhabitants (PCBS, 2014), with an area of 583Km^2. It serves as a major agricultural center for the surrounding governate. Jenin governorate location is shown in Figure 1.1

1.4.2 Climate

Jenin has Mediterranean climate which is described as warm to hot, dry summers and mild to cold, wet winters. The maximum and minimum average temperature are 26.6^{o}C and 16.6^{o}C respectively as recorded by the Palestinian Meteorology department, with relative humidity about 66% as recorded at Beit Qad weather station which located 5Km east of the treatment plant. In winter the average amount of annual rainfall is 480 mm distributed in about 40 rainy days. The directions of the wind are usually between southwest and northwest, with an average wind speed of 6.85 km\h in 2014 (PCBS, 2014).

1.4.3 Climate change

One of the major issues in the present century is global warming and its effects on climatic change. Due to Global climate change around the Mediterranean basin in general, and according to climate models for the region, there would be changes in rainfall amount and distribution combined with an increase in temperature (Abu-Madi et al., 2015). It is predicted that the increase in the temperature might range from 2 to 6^{o}C and the decrease in the amount of precipitation might reach up to 16% (Mizyed, 2009).

There are many indicators from Palestine that confirm climate change issue such as: the increase in the number of droughts, the average rainfall during the period from 2003-2010 were less than the historical average, another aspect is that the increase in the frequency of extreme events, finally as it was recorded in General Administration of Meteorology in Palestine the maximum and minimum temperature in summer are increased while the winter temperatures have declined (Palestinian team, 2014).

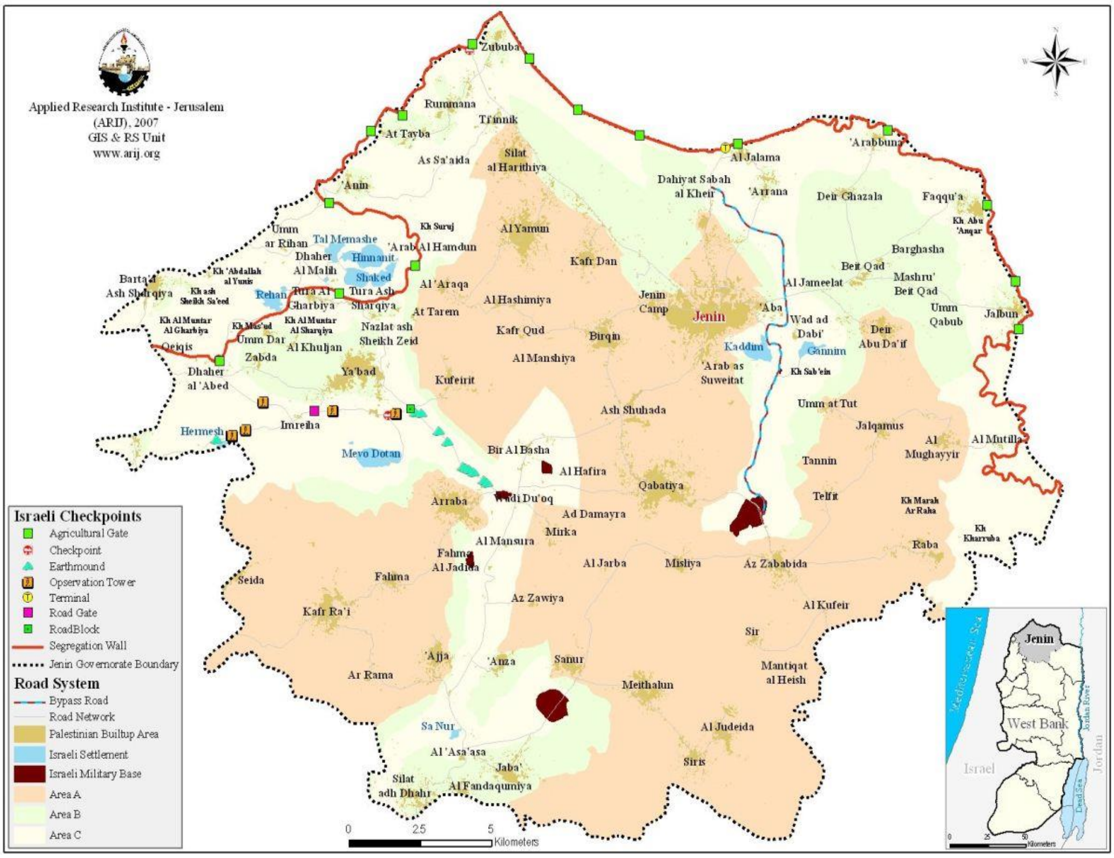


Figure 1.1: Jenin governate and location.

Resource: Applied research institute – Jerusalem, 2007

1.5 Thesis outline

This thesis is divided into seven chapters:

Chapter One: introduction about J-WWTP and its technology, Research Objectives, research motivation and Study area.

Chapter Two: overview about wastewater treatment, appropriate technology concepts, Sustainability aspects of appropriate technology, Popular technology processes used in wastewater treatment, modeling of wastewater treatment processes, wastewater reuse , benefits and risks of wastewater reuse in agriculture, guidelines for water reuse.

Chapter Three: overview about Jenin wastewater treatment plant (case study).

Chapter Four: describes the methodology used in this study.

Chapter Five: represents the results, analysis and the discussions.

Chapter Six: provides sustainable development for Jenin wastewater treatment plant (environmental, economic and social aspects).

Chapter seven: provides the overall conclusions and recommendations.

Chapter Two

Literature Review

2.1 Wastewater treatment principles

Treatment plants are designed at different stages with different technologies based on environmental, socio-economic and the uses of the treated water in order to support the local authorities to follow up with urban growth and the increased volume of wastewater; (Muga and Mihelcic, 2007).

Wastewater treatment levels:

The conventional main stages of wastewater treatment are: preliminary, primary, secondary, and tertiary, which consist of physical, biological or chemical processes.

- Preliminary treatment: this stage is used to remove coarse materials; these materials may cause damage to the plant, moreover; the influent can be stabilized by adding chemicals (Weiner and Matthews, 2003).
- Primary treatment: in this stage settleable material can be removed by sedimentation, these materials are: total suspended solids (SS), oil and grease, some organic nitrogen, organic phosphorus and heavy metals (Weiner and Matthews, 2003).
- Secondary treatment: in this stage the residual suspended and colloidal solids can be removed. Aerobic biological treatment processes are used (Weiner and Matthews, 2003)
- Tertiary or advanced treatment: it is any system which comes after the secondary treatment, it is used to remove more contaminants, and a certain standards for specific purpose are met(Weiner and Matthews, 2003)

2.2 Wastewater treatment in developing countries

In some developing countries, wastewater has been used for irrigation without treatment, and it is used as a source of crop nutrients over many decades. Some of their treatment plants are defected or no longer being used. This problem is due to lack of funds and expertise to operate these plants. Developing countries are generally suffering from un-sustainable wastewater treatment; they can't afford high tech, high cost and complex technology. Many studies show that the treatment plants in developing countries which depend on complex technology are usually out of service after a short time of installation, this is due to high operation cost and/or lack of expertise to operate them properly (Libhaber and Orozco-Jrramil, 2012 and Jiménez and Asano, 2008).

2.3 Appropriate technology concepts

It is important to choose appropriate technologies for wastewater treatment. Appropriate technology means simple treatment process with low costs, not complex to operate and can achieve required effluent quality. In developing countries, the appropriate technology processes is sometimes ignored, this is may be due to lack of understanding of environmental authorities, lack of expertise and lack of alternative mechanical parts of the units. Not all the treatment technologies achieve the same effluent quality, each technology produces different quality. This quality depends on the standards and the reuse of the effluent. The required effluent quality can be reached by using one basic unit process or a combination of two units or more. Finally using the appropriate technology process will reduce the investment cost and give more sustainable solution (Libhaber and Orozco-Jrramil, 2012).

2.4 Sustainability aspects of appropriate technology

Sustainability of the technology process is one of the problems in developing countries, using appropriate technology to enhance the sustainability of the plant and this can be done by enhancing economic sustainability; the investment cost, operation and maintenance cost, enhancing technical sustainability of the plant; by using technology which is simple to operate, and can be locally maintained in order to keep the plant functioning as long as possible. Wastewater has some resources which can be reused and recovered; those include nutrients which can be reused as fertilizers and the treated wastewater can be reused for agricultural purposes (Libhaber and Orozco-Jrramil, 2012).

2.5 Popular Technology processes used in wastewater treatment

2.5.1 Aerated lagoon process

Aerated lagoon is a process used to treat wastewater; its name comes from its function which provides aeration by mechanical surface aerators as shown in figure 2.1, or submerged diffused aeration systems, and this means mechanical or diffused aeration are used to supply oxygen (EPA, 2002).

In general, aerated lagoon is simple treatment process; its ponds receive and hold wastewater for a period of time to treat it naturally. In order to prevent the holed wastewater in ponds to reach the groundwater below; the ponds are lined with impermeable material like clay (National Small Flows Clearinghouse, 1997).

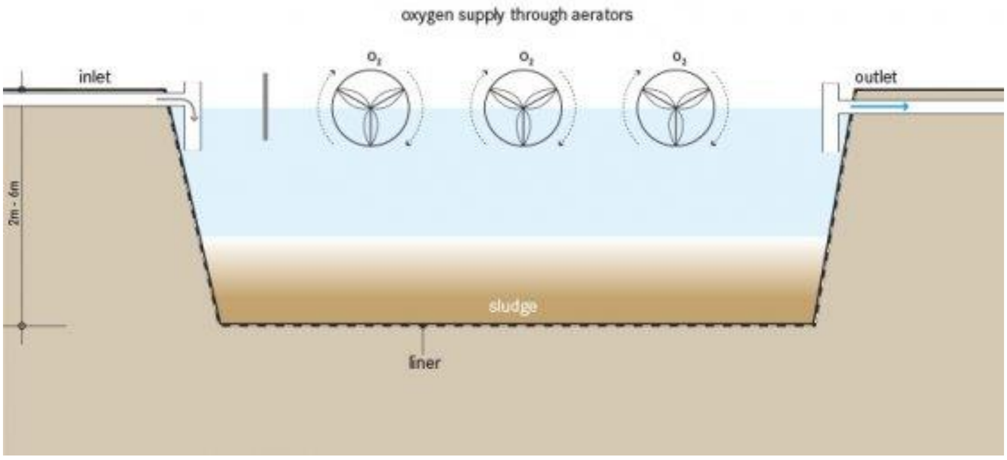


Figure 2.1:Schematic representation of AL.

Source: (sustainable sanitation and water management, 2014).

2.5.2 Waste stabilization ponds (WSP)

One of the effective natural treatment processes is Waste Stabilization ponds as shown in figure 2.2. WSP can meet high demand with large pathogenic organisms removal, low energy consumption, low cost (capital and maintenance), robustness, and sustainability. WSP system contains anaerobic, facultative and maturation ponds in series or several such series in parallel (Kayombo et al., 1998).

Anaerobic ponds do not contain dissolved oxygen or algae. In these ponds a large amount of BOD removal about (40-60%) can be achieved, for nutrient organic nitrogen is hydrolyzed to ammonia.

Facultative ponds have two types: Primary and secondary; primary receive raw wastewater, whereas secondary receive particle-free wastewater. They are frequently used to treat municipal and industrial wastewater, the layer of water near the surface contains dissolved oxygen due to atmospheric re-aeration and algal respiration that supports aerobic and facultative organisms. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organisms (EPA, 2002).

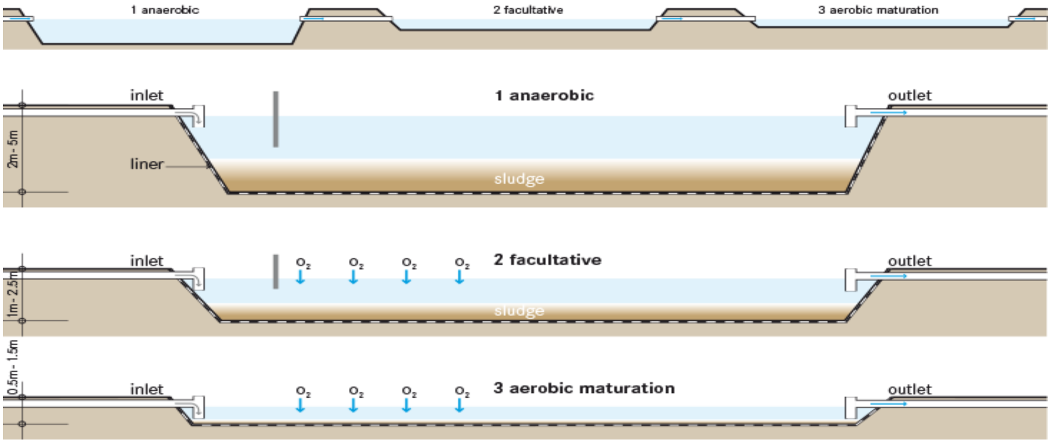


Figure2.2: Schematic representation of WSP

Source: (sustainable sanitation and water management, 2014).

2.5.3 Up-flow anaerobic sludge blanket (UASB)

It is an anaerobic process for the treatment of wastewater. it is a good choice to use in developing countries due to its simplicity. It works in both high and low temperatures; it may be used for high amounts of organic materials in wastewater (Gómez, 2011).

(UASB) reactor is a tank with a bed of sludge in the bottom to collect the organic material, after this zone there is a blanket zone to separate the suspended solids from the treated water which is flowing up. As a result of the digestion a biogas is produced and goes up to leave, the effluent of treated water goes up to leave too but in a different outlet (Gómez, 2011). The Schematic representation of a UASB reactors is shown in Figure 2.3.

This technology produces amount of sludge which is approximately~0.2 kg/kg of BOD removed. This amount is less than the amount produced by activated sludge which is (~0.8 kg/kg),and it is still less than the amount produced by anaerobic ponds, and this amount should be disposed (Haandel and Lettinga, 1994).

A UASB is not appropriate for small or rural communities. The system requires a continuous and stable water flow and energy, any sudden changes in wastewater characteristics, flow or environmental conditions will impose stress on microbial species which are located in the sludge bed (Tilley, 2014)

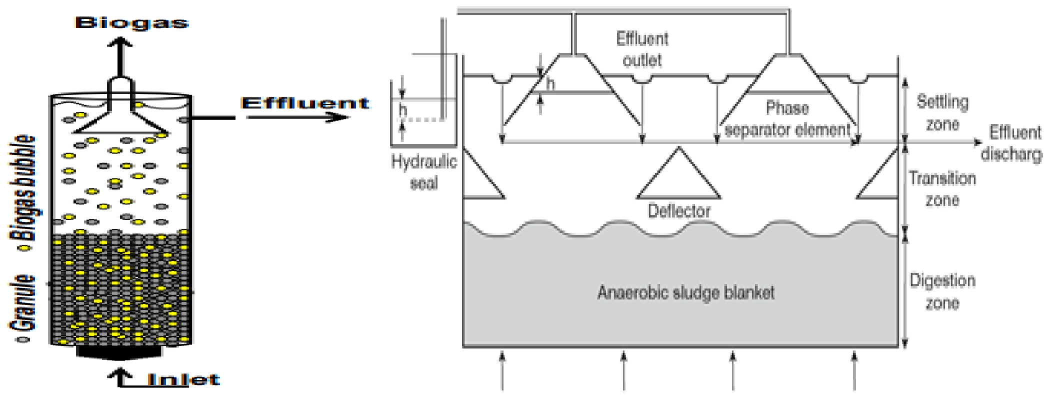


Figure2.3: Schematic representation of a UASB reactor

Source: (Gómez, 2011) and (Haandel and Lettinga , 1994).

2.5.4 Activated sludge

Activated sludge is a biological process when use organisms like bacteria, fungi and protozoa, keep them in suspension using mixing and aeration for treatment which convert wastes(organic and inorganic) into cell mass. These converted wastes are then separated from the treated wastewater to be returned or wasted. Activated sludge process have many advantages; it is very effective with low installation cost, and the area required for AS can be saved as the process it does not require a large space. The disadvantages are: AS can't deal with any sudden changes in flow or influent characteristics, high operational cost and large amounts of sludge production which should be disposed. Activated sludge process may or may not follow primary treatment. All activated sludge systems include a settling tank following the aeration tank (Marx et al., 2010). Schematic representation of AS is shown in figure 2.4.

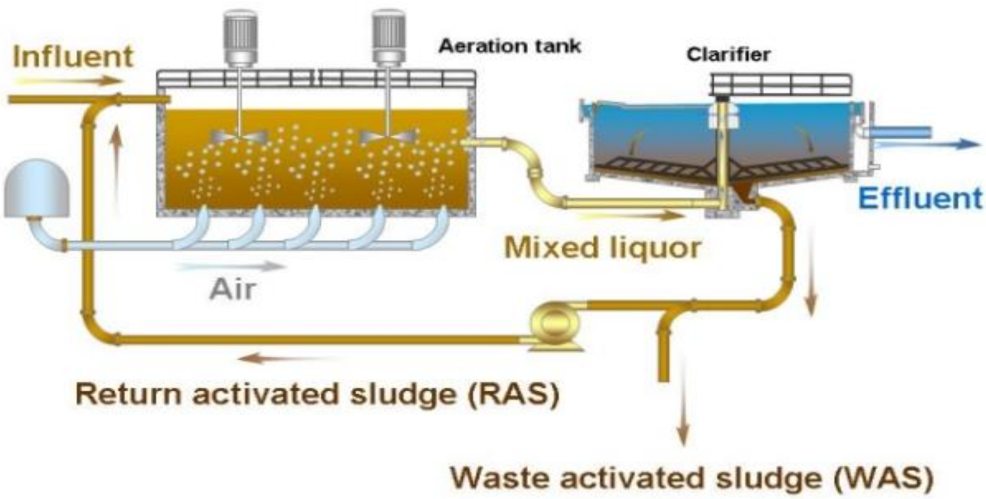


Figure2.4: Schematic representation of AS.

Source: water Institute of Southern Africa (2002).

2.6 Modeling of Wastewater treatment processes

It is interesting to advance the knowledge of the behavior of these treatment systems in order to use them at the best efficient way. A tool increasingly used to design, analyze, optimize and control systems of wastewater treatment is to simulate and model them in a software program.

The Model is a tool which is used to understand the reality and predict the behavior of the system under different scenarios. The main purpose of modeling is to simulate a system in order to investigate proposed development (Meijer, 2004).

The definition of wastewater treatment process modeling is the use of mathematical and physical models to represent the treatment process under assumptions and limitations (Shaw, 2013).

2.6.1 Simulator versus Model

Model is a set of equations that are solved within the simulator. But simulator is a software package on which model is run.

Schematic process units are represented together in a simulator, a model of each unit is made up of a set of equations that may be linked in series, parallel or unlinked (Shaw, 2013).

2.6.2 Static versus Dynamic Modeling

Steady state or static models are used to represent average conditions over a relatively long period of time (when the relationship between the model variables reaches equilibrium state independent of time). Static models depend on the type of process which could be fast such as chemical reaction or slow such as bacterial growth; steady state modeling is useful for system design (Shaw, 2013).

Dynamic modeling is using differential equations as a function of time. It is used with time-varying inputs or changing in process operation, and is useful for diurnal or daily variations and in prediction of the behavior of biological systems under wet weather conditions (Shaw, 2013).

2.6.3 Aerated and Facultative Lagoon Model

Aerated and Fluctuated lagoons can be simulated in GPS-X program, empirical model is used; which is empirical in nature; meanings it simulates the behavior and the rate of change which is observed in existing ponds.

- Facultative Ponds:

  The empirical BOD removal model used for facultative ponds is Thirumurthi , 1974.

  $BOD_{EFF} = BOD_{INF} * K_S * C_{TEMP} * C_O$

  Where:

  BOD_{EFF} = effluent BOD (g/m^3)

  BOD_{INF} = influent BOD (g/m^3)

  K_S = first order BOD removal rate coefficient (1/d) at 20°C

  C_{TEMP} = correction factor for temperature

  C_O = correction factor for organic loading

  And:

  $C_{TEMP} = \theta^{(Temp-20)}$

  $C_O = (1- 0.083*\log(\frac{SLR}{LR}))$

  Where :

TEMP = wastewater temperature, °C

θ = temperature correction constant

SLR = standard loading rate (kg/ha/d)

LR = current loading rate (kg BOD/ha/d)

For TSS removal:

$Removal_{TSS} = (A_{TSS} * \ln(n) + B_{TSS}) * (\frac{hrt}{Khrt+hrt})$

Where:

A_{TSS}, A_{BOD}, B_{TSS}, B_{BOD}, K_{hrt} = calibration parameters

n = number of ponds in series

Oxygen is determined by assuming that the dissolved oxygen (DO) is saturated in the aerobic zone, and zero in the anaerobic zone. The concentration of So is determined from the following equation:

So= SOST*AERDEPTH

Where

So=concentration of oxygen (gO_2/m^3).

SOST = saturated oxygen concentration (gO_2/m^3)

AERDEPTH = fraction of depth that is aerobic (unitless)

- Aerated Ponds:

The aerated pond uses the same empirical BOD and TSS reduction models as the facultative pond model. However, the default value for the BOD removal rate coefficient has been changed to reflect aerated conditions (Eckenfelder, 1980). Oxygen is assumed to be saturated at the effluent point of the aerated pond.

Modeling of the aerated lagoon allows investigating the behavior of such systems under different scenarios without compromising the effluent quality at full-scale.

In the scope of AL simulation, there are very few studies published on the scientific literature (Stropky et al., 2007). This problem motivated the simulation of aerated lagoon technology . The goal is to determine by using different simulations if aerated lagoon technology has the ability to remove TSS, Nitrate, TP and Ammonia, and how.

2.7 Reuse of treated wastewater

The treated water will have a good potential to be used in many sectors like agricultural, urban, industrial and environment if there is a good planning, selection and design of wastewater treatment processes, with enough public realization about the meaning of treatment and its effluent quality (Mizyad, 2012).

In order to deal with the scarcity of water problems in Arab countries, non-conventional water resources are used such as desalination in the Gulf Cooperation Council (GCC)countries and reuse of treated water in Jordan and United Arab Emirates(UAE) (UNESCO, 2012).

Some Arab countries treat relatively large amounts of wastewater as shown in table 2.1, like Saudi Arabia, Kuwait, Jordan and UAE ranging from (1-10%) of total water withdrawal in 2005 (FAO,2011). TWW can be used in food and non-food production (UNESCO, 2012).

Table 2.1: Wastewater reuse for irrigation in Arab countries

Country	**Wastewater used for irrigation (m^3/d)**
Egypt	1,918,000
Syria	1,182,000
Saudi Arabia	595,000
Kuwait	432,000
Jordan	225,000
UAE	200,000
Tunisia	118,000
Libya	110,000
Qatar	80,000

Source: Jimenez & Asano, 2008,

Agriculture has been playing major role in Palestine (Mizyed, 2012), so the quality of water used in irrigation is very important issue because of high rates of evaporation in summer. If the treated water is used in irrigation we may have many challenges and constraints (Pescod, 1992).

The amount of water needed for irrigation is different from one place to another due to differences in rainfall, evaporation, type of crop grown in the land, type of soil and type of irrigation etc. Ministry of agriculture (MoA) recommends using an average value of $600m^3$/year/ dunum for overall planning purposes in West Bank (Ministry of agriculture, 2014).

2.8 Effluent quality standards

The most important issue in water reuse is the quality of treated water; restricted urban reuse requires a secondary treatment followed by disinfection at minimum(EPA, 2002). The wastewater quality can be determined by BOD, TSS and fecal coliforms which determine the degree of disinfection needed, and the parameter that determines the performance of the treatment which is turbidity (EPA, 2004).

From one country to another there are variations in the criteria of water reuse because of different environmental and public health risks.

In Palestine; cooperation among Palestinian ministries, universities, Palestine Standards Institution (PSI) and Environment Quality Authority resulted in adopting Palestinian technical guidelines and standards for TWW reuse as shown in table 2.2.

Table2.2: Effluent quality limits for reuse in accordance with Palestinian technical guidelines (PSI 34-2012).

Effluent parameters mg/ml	Fodder irrigation		Gardens playground	Industrial crops	Groundwater recharge	Landscape
	Wet	Dry				
BOD5	60	45	40	60	40	60
COD	200	150	150	200	150	200
DO	>0.5	>0.5	>0.5	>0.5	>1.0	>0.5
TDS	1500	1500	1200	1500	1500	1500
TSS	50	40	30	50	50	50
PH	6-9	6-9	6-9	6-9	6-9	6-9
NO3-N	50	50	50	50	15	50

To avoid using treated wastewater for drinking or domestic purposes intentional or by accident, all pipes which used for conveying the treated wastewater to gardens or fields should be marked and painted by distinctive shining color (Pescod, 1992).

2.9 Effects of reusing treated waste water on soil and plant (nutrients and heavy metals)

Wastewater contains a significant load of organic material (carbon and nitrogen) as well as most of the mineral macronutrients (e.g. phosphorous, potassium, magnesium and boron) and micronutrients (e.g. molybdenum, selenium and copper) which are necessary for the growth of crops. Reusing wastewater in agriculture is considered a deleterious practice since it may introduce pollutants to the environment. Too much organic and inorganic matter especially nitrogen can delay maturity and cause excessive vegetative growth at the expense of grain yield (Bengtson, 2004). So it is important to study the impact of reusing treated wastewater in the soil. For nitrogen; it can be found in different forms, so it is important to study nitrogen cycle in soil.

2.9.1 Nitrogen cycle in soil

Nitrogen (N) is essential for the growth of crops, nitrogen can be found in the soil in different forms and from different process, these forms are described by the nitrogen cycle as shown in figure 2.5. Bacteria fixed molecular nitrogen from different ways like atmosphere or inorganic nitrogen of NH_x or NO_Y from anthropogenic sources mainly because all habitats depended on it. A few species of bacteria have the ability to fix atmospheric nitrogen; this process needs a lot of energy. The presence of nitrogen in any form in soil is highly dependent on the activities of microorganisms (Bengtson, 2004).

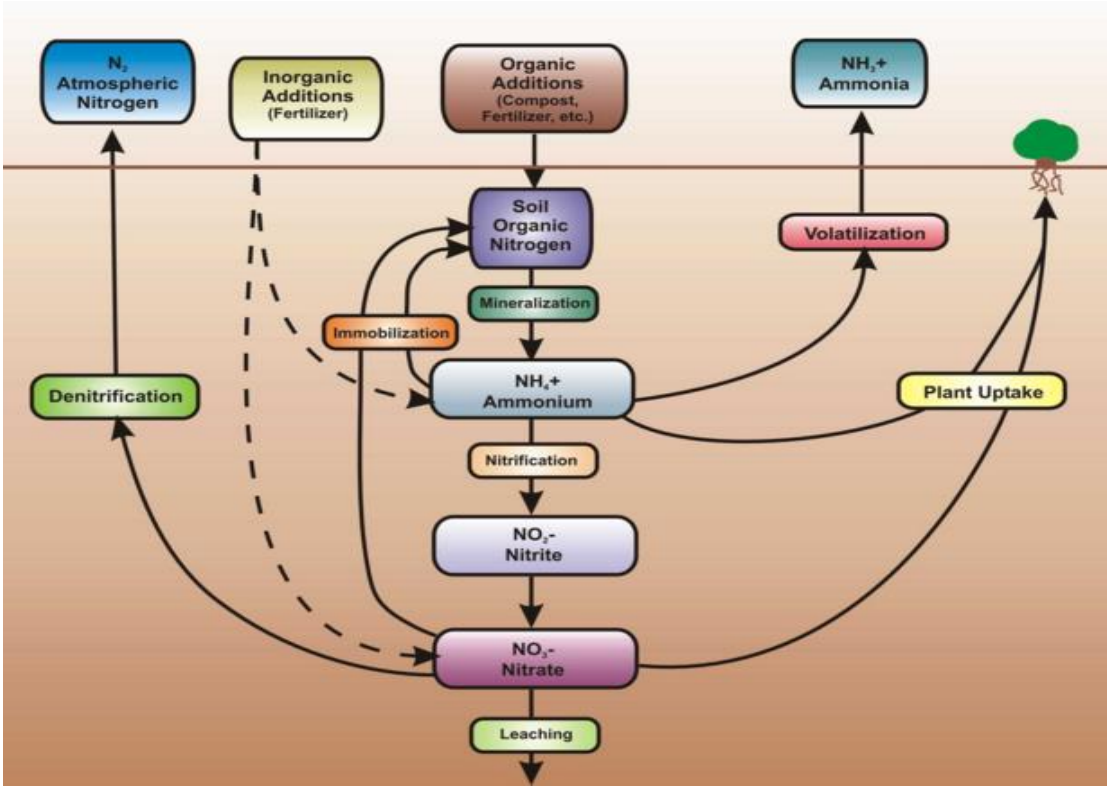


Figure 2.5: Nitrogen Cycle in Soil.

Source: Low Impact Development (LID) Center non-profit organization balancing growth and environmental integrity, 2015.

Modeling of nitrogen cycle has been used for more than 20 years, it is used for different purposes and under different assumptions to estimate nitrogen leaching, soil residual, the required amount of fertilizer, gases emissions and more (Shaffer, 2002).

- **Nitrogen fixation (N_{fixing})**

  This process is defined as the change of Nitrogen Gas to usable form like ammonia; this process can be done by some types of bacteria living in a symbiotic relation with plants, these plants have nodules like legumes.

  Perennial and forage legumes such as alfalfa may fix 110-225 Kg of nitrogen per acre. Approximately all of the fixed nitrogen is used by the plant and there is a little portion of the fixed nitrogen which leaks into the soil (Lindemann and Glover, 2003).

$$\underset{\text{Nitrogen gas}}{N_2} \longrightarrow \underset{\text{Ammonia}}{NH_3} \longrightarrow \underset{\text{Organic N}}{R\text{-}NH_2}$$

- **Mineralization (MIN)**

It is a process of converting organic Nitrogen into inorganic form that can be uptaken by plants. Nitrogen will be accumulated in the soil until the steady state condition is reached (Crohn, 2004).

The simplest representation of non-idealized steady-state conditions of mineralization assuming that all added organic N becomes available at the same mineralization rate (Benbi and Richter, 2002)

$MIN = N_o\,(1 - e^{-K*\Delta t})$

No ($M\ L^{-3}\ T^{-1}$) is the initial organic soil N, k (d^{-1}) is the mineralization rate, and Δt (d) is the time period of interest (Crohn, 2004).

$$\underset{\text{Organic N}}{R\text{-}NH_2} \longrightarrow \underset{\text{Ammonia}}{NH_3} \longrightarrow \underset{\text{Ammonium}}{NH_4^+}$$

- **Nitrogen uptake by plants**

Nitrogen compounds are very important for plant growth; they are found extremely in all tissues. People think that the orchard crops require high amounts of nitrogen, but in reality the trees and crop use approximately less than 20% of applied nitrogen for growth and production (Joshua, 2012).

Table 2.3: Amount of utilization of nitrogen in (Kg/ha) by various crops

Utilization of Nitrogen by various crops		
Crop	**Yield per ha**	**Kg/ha**
Alfalfa	8000	484
Corn	180 bu	202
Soybeans	60 bu	330
Spring wheat	80 bu	197

Source: International Plant Nutrition Institute (IPNI).

- **Volatilization of NH_4 (VOL)**

  Volatilization is the process of losing Ammonia (NH3) to the atmosphere. This process depends mainly on type of fertilizer, storage and spreading technology of the manure, soil pH and cropping system. Based on these factors; the best estimation of NH_3 lost as percentage of $NH_4$is evaluated to be 14% for fertilizers and 23% for manure (Viers et al., 2012).

$$\underset{\text{Urea}}{H_2N\text{-}\overset{\overset{O}{\|}}{C}\text{-}NH_2} \longrightarrow \underset{\text{Ammonium}}{NH_4} \longrightarrow \underset{\text{Ammonia}}{NH_3}$$

- **Denitrification**

  Denitrification is the conversion of nitrate into nitrogen gas like (nitric oxide, nitrous oxide, dinitrogen) by anaerobic bacteria in saturated soil, as shown in table 2.4 (Viers et al., 2012)..

$$\underset{\text{Nitrate}}{NO_3^-} \longrightarrow \underset{\text{Nitrite}}{NO_2^-} \longrightarrow \underset{\text{Nitric Oxide}}{NO} \longrightarrow \underset{\text{Nitrous oxidegas}}{N_2O} \longrightarrow \underset{\text{dinitrogen}}{N_2}$$

Table 2.4: Illustrates the % of nitrogen lost from denitrification with the effect of time and temperature.

Denitrification rates from saturated soil		
Time	temperature	Nitrogen loss
Days	Degree F	Percent
3	75-80	6
5	55-60	10
10	55-60	25

Source: Plant and soil sciences e library.

- **Leaching (LE)**

  Leaching is the ability of nitrogen to move downward through soil pores, Nitrate move more easily than ammonia through soil facilities, so the nitrate is the most susceptible to leaching. It leaches below the root zone until reaching a saturated zone; it is unrecoverable except for some crops like alfalfa with deep roots. This process depends mainly on plant uptake, the amount of entered water through precipitation or irrigation and the soil texture (coarse or fine).The time of Leaching differs according to type of soil and location of aquifer, it is ranging from months in sandy coarse texture over shallow aquifer to 25 years in silt clays with deep aquifer (Viers et al., 2012). .

2.9.2 Phosphorus

Phosphorus is an important nutrient for the plants; it has an ability to move within the plant from older to younger leaves. When P enters the plant it is rapidly converted to organic compounds, and it is used in some essential reactions; for example in Alfalfa P is important for phospholipids, and ATP and used in reactions like photosynthesis, nitrogenase activity and protein formation (Mikkelsen1, 2004).

High rates of nutrients don't mean high yields, the amount of extra needed phosphorus for alfalfa depends mainly on the soil current nutrient and yield expectations. A Study at Purdue for seven years starting out with low concentration of P (8 ppm). Showed that the highest yields were routinely obtained with applications of 50 pounds of P_2O_5 per acre per year (Lissbrant et al., 2009).

2.9.3 Heavy metals:

Trace elements included as lead (Pb), copper (Cu), cobalt (Co), molybdenum (Mo), boron (B), chromium (Cr), zinc (Zn), arsenic (As), and manganese (Mn).In disposed wastewater, these elements are toxic if they exist in high concentrations (Ensink et al., 2004). Pre-treatment of wastewater is always recommended. The order of metal uptake in crops is: Fe>Mn>Zn>Cu>Pb>Ni>Cr>Cd (Khan et al., 2004).

Moreover, Lone et al. (2003)showed that the high uptake of Ni by plant is determined by initially high concentration of Ni in soil and wastewater (Khan et al., 2004).

2.10 Cases studies -Local and global experience

Alvarado et al. (2012) developed Computational Fluid Dynamic CFD modeling of aerated lagoons in Ucubamba WSP system, which consists of pre-treatment steps followed by splitter into two lines; each line consists of an aerated lagoons (using 10 mechanical aerators), facultative lagoon and maturation ponds. The aerators were modeled by external momentum (velocity vector). Different aeration schemes with different number of aerator in operation were studied, the first 2 h of simulation represented almost the same curve when using 6, 8 and 10 aerators. It was concluded that the aeration scheme using 4 from 10 aerators provided a mixing condition similar to that with the 10aerators, this strategy can be used to save energy.

Saleh (2009) showed that the reuse of treated wastewater in irrigation has many positive impacts in environment, soil, crops productivity and ground water. His research was in Tubas city, he wanted to study the idea of constructing new WWTP with appropriate technology, and reusing its effluent in irrigation. Toevaluate the public acceptance of TWW reuse in irrigation, questionnaires were distributed and analyzed. For the treatment plant; there were three different technology units' choices, In order to decide the appropriate technology systems, benefit-cost analysis between these choices were carried out. These technologies were: activated sludge (AS), trickling filter (TF) and aerated lagoons (AL).

Elamin& Saeed, 2008 studied the impact of reusing treated wastewater for irrigation purposes in Al-Khartoum. Two stages were studied one of them was treated wastewater with River Nile water, and the other one was treated waste water with River Nile water in combination with three different tillage operations. Soil samples were taken and analyzed from different points and different depths; forage sorghum was also analyzed and used as an indicator plant.

The study showed that significant increase in many elements in the soil was due to the use of the TWW in irrigation; these elements are OC, N, Na, Ca, Mg, K, Cl, Cu, Zn, Fe, Mn, Pb, Co and P. the plant growth was also affected by the irrigation. They found that the tillage operations affected the concentration and distribution of the elements in the soil.

Ahmed Abu-Awwad, (2015) explained the Jordan experience with wastewater reuse for agriculture in Wadi Musa as shown in figure 2.6. It is considered as one of the successful reuse projects in Jordan, it was started in 2004.Thetreated wastewater was planned for use in agriculture, landscaping, and industrial purposes (Tetra Tech, 2015).

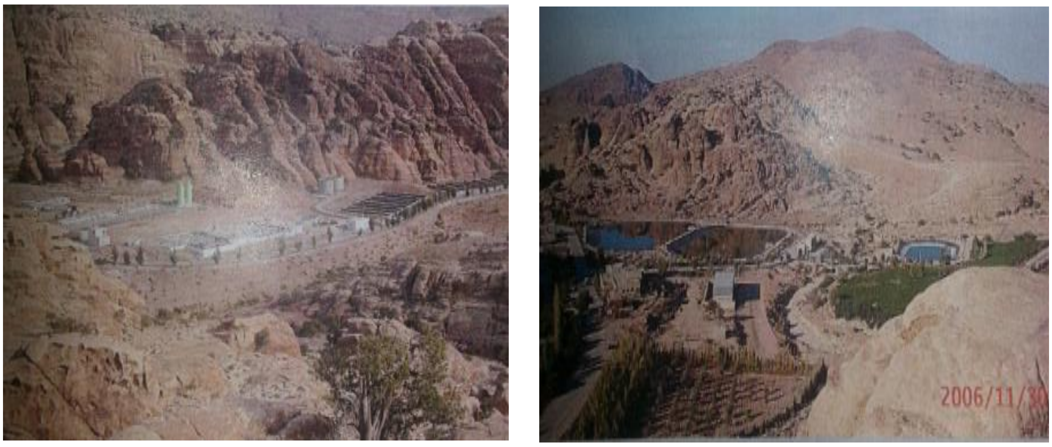


Figure2.6: Wadi Musa wastewater treatment plant scheme (2004, 2006)

Source: Ahmed Abu-Awwad, 2015.

Alfalfa is a very desired crop used to support sheep and goats, In Jordan alfalfa is imported from Saudi Arabia, so one of the objectives of the Wadi Musa project was to use the TWW to irrigate crops like alfalfa, trees and fodder.Using the TWW in irrigation will increase the production of the crops, thisis because of the increase in the available amount of water with low cost (The farmers pay low fees, to get treated wastewater) (Tetra Tech International Development, 2015).

as shown in figure 2.7, the production of alfalfa increased from 78 ton/ha in 2005 to 173 ton/ha in 2006 and this increased the income from 3274$/ha to 6722 $/ha (Tetra Tech International Development, 2015).

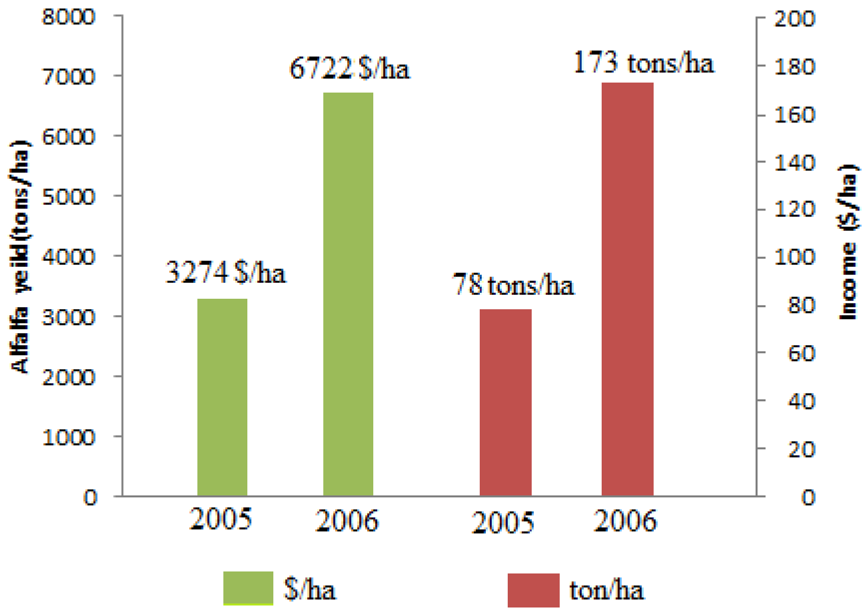


Figure2.7: Alfalfa yield in 2005 and 2006 and the income per ha.

Source: Ahmed Abu-Awwad, 2015

For research purposes and in order to test the health risks of using TWW in irrigation, the TWW was used for irrigation in the campus of Jordan University of Science and Technology, in order to test the TWW, soil and crops (Tetra Tech International Development, 2015).

Chapter Three

Jenin wastewater treatment plant

3.1 Over view of J-WWTP

Jenin wastewater treatment plant is one of the 5 largest plants in the West Bank. It serves about 40% of Jenin city population and 100% of the Jenin Refugee camp's population (UNEP, 2003), it was constructed in 1970, and is now over 46 years old. It has a total land area of 23,000 m^2, and it is considered as simple WWTP, which mainly consists of two aerated lagoons connected in series, in each lagoon the natural oxygenation is enhanced using surface aerators, these lagoons are followed by a polishing pond. The lagoons and pond have trapezoidal shapes with total surface area of 10,500 m^2 and volume of 2926, 2700 and 5082 m^3 respectively. To prevent the seep of wastewater and the contamination of the groundwater, the lagoons and the pond were lined (J-WWTP operator, 2015).

The plant was rehabilitated many times during the last 20 years, in year 2000; 750000 NIS was allocated for its rehabilitation. The rehabilitation included: cleaning the plant and de-sludging 80 cm of accumulative sludge in the polishing pond and supply sludge recirculation pump station and replaced the broken aerators. Unfortunately all the surface aerators and cables were damaged during the political instability around that time (UNEP, 2003).

After that time the plant was destroyed and used as temporary solid waste dumping site. All the untreated wastewater was left to flow into the near wadi of Al- Muqatta (UNEP, 2003). The treatment plant was rehabilitated again during the previous years. Nowadays; the treatment plant is divided into two lines each one has two aerated lagoons and one polishing pond. The first lagoon has3 surface aerators, and 4 surface aerators in the second lagoon as shown in figure 3.1.

The plant is designed for an average capacity of 7,600m^3/d, and peak instantaneous flow of 18,800 m^3/d, the plant influent consists of a municipal and industrial wastewater with BOD_5 loading about 5716 kg/d.

As a matter of fact J-WWTP was designed for a capacity of 7600m^3/d to treat BOD and COD only. Now it receives approximately about 3500m^3/d (J-WWTP operator, 2015). the developments are needed to achieve effluent quality for (BOD, COD, TSS and nutrients) which is match Palestinian standards to reuse it in irrigation.

3.2 Operation and Performance of J-WWTP

J-WWTP is under the authority of Jenin municipality. It has one supervising engineer, two operator technicians and 4 labors; the plant is working 24hr /day.

Each aerator has a mechanical power of 35hp consisting of an electric motor flexibly coupled to a solid rotating shaft (plant operator, 2015).

The Energy required for the aeration devices depends on the intensity of mixing desired (EPA, 2002).

$E = 6598\ (hp)^{1.026}$

E: Energy required for the aeration devices

hp: horse power

The performance of aerated lagoon can be described to be approximately completely mixed design by first order kinetics using the equation (Mara, 2003):

$$= \frac{1 \quad Ci}{1+K\Phi Co}$$

Where:

C_i: influent concentration of BOD(mg/l)

C_o: effluent concentration of BOD(mg/l)

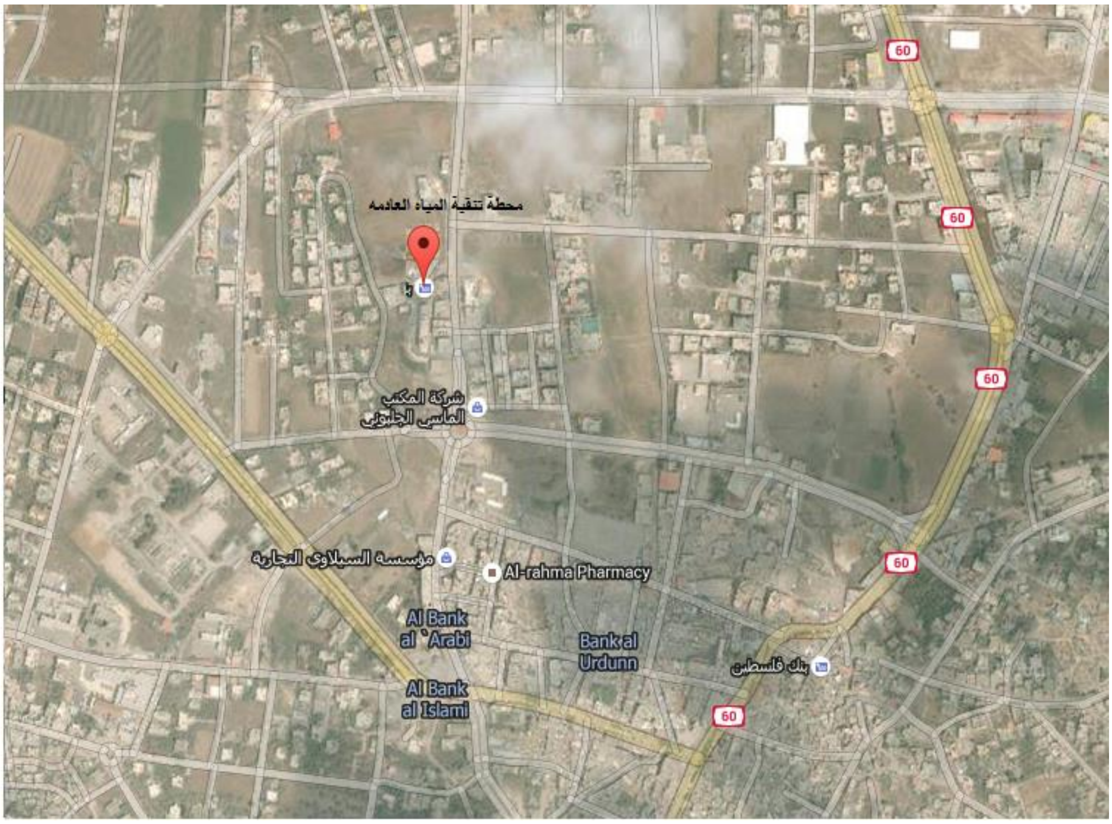
K: the overall first order BOD removal rate (d^{-1})

Φ: Hydraulic retention time (d);

$\Phi = V/Q$,

V: is the volume in (m^3)

Q: is the flow rate in (m^3/d)



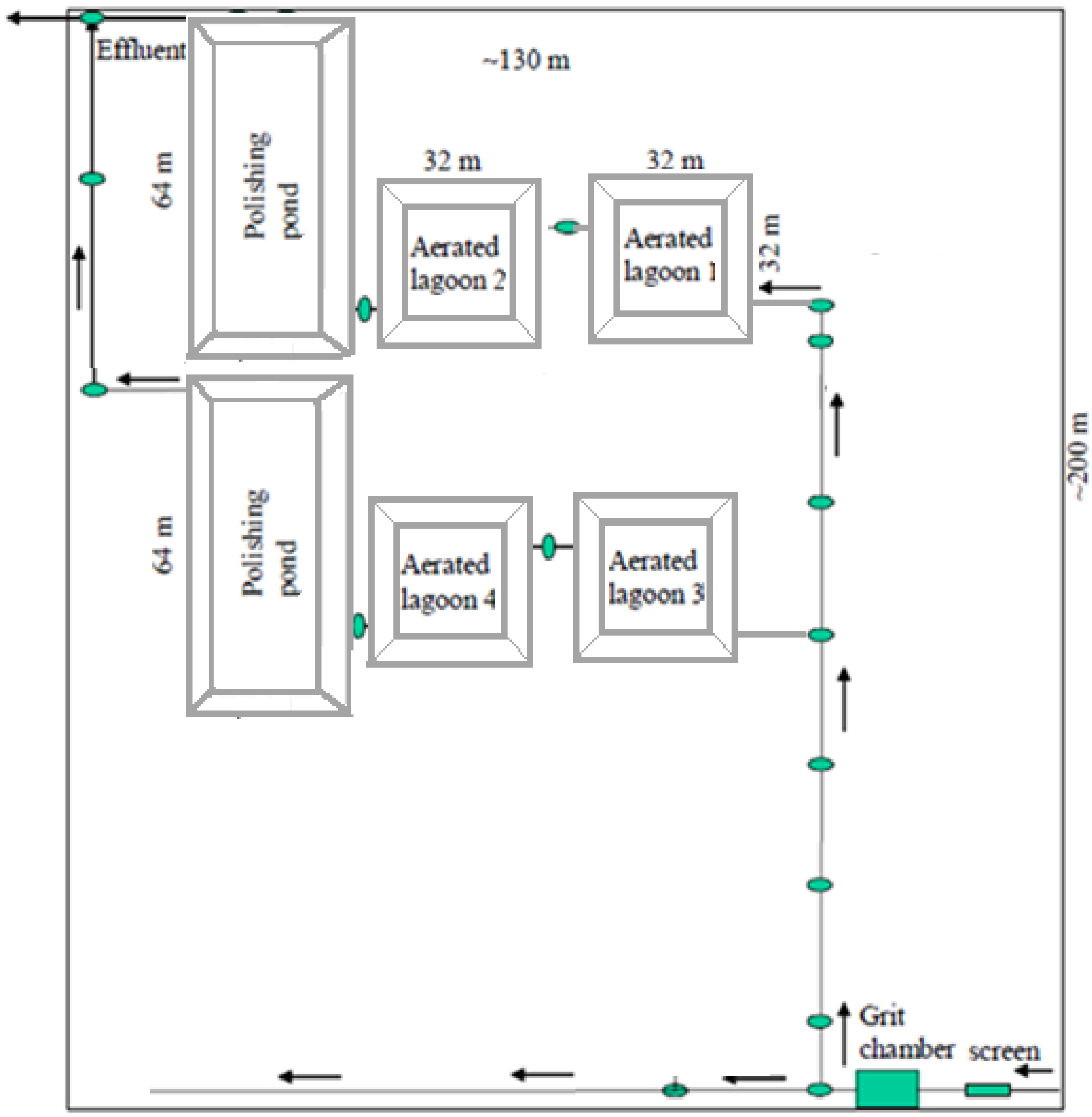


Figure3.1:J-WWTP location and Layout.

Chapter Four

Research Methodology

4.1 Historical Data collection

In order to simulate J-WWTP to upgrade its performance, needed data was collected from several sources and places including previous studies, reports, researches, field visits and government authorities.

- Existing situation: location of the waste water treatment plant, dimensions of the plant, flow measurements and specification of mechanical parts.
- Data base includes several process variables like Quantity and quality of water and wastewater in Jenin.
- Palestinian Standards of effluent from WWTP.
- Scientific data like definitions, process design, and process parameters.

After the historical data was collected the flow chart in figure 4.1 was used.

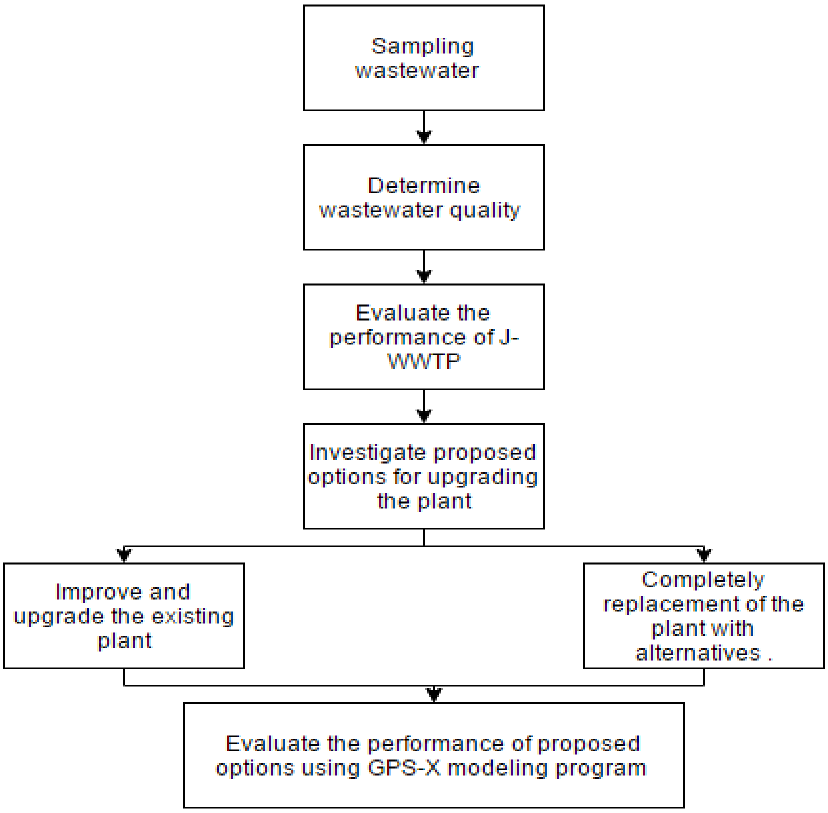


Figure 4.1: Research methodology

4.2 Sampling of Wastewater

The performance of J-WWTP was studied through evaluating of the characteristic of influent and effluent wastewater from the plant. On May and July /2015 wastewater samples were collected from different locations of the plant in order to analyze them.

- Site Selection for Wastewater Sampling:
    - Influent: to ensure a good mixing for the sample from the influent; grab sample was collected from a highly turbulent flow.
    - Pond and Lagoon Sampling: composite sampling is essential for pond or lagoon to be more representative.

- Effluent: it was preferred to collect the grab sample from downstream because it is at the most representative site.

The collected wastewater samples were reserved in clean and dried glass bottles.

4.3 Determining wastewater quality

After the samples were collected, they were analyzed in Poison Control & Chemical / biological Center laboratory at An-Najah National University, and the characteristics of the wastewater were determined. The analyses of the samples were according to the Standard methods for the examination of wastewater (APHA, 2003).

The samples were analyzed for chemical, physical and biological parameters

- **Chemical Analysis:**

  Chemical Oxygen Demand (COD) using UV-VIS Spectrophotometer (UV-2550) , Biological Oxygen Demand (BOD_5) using B.O.D Sensor VELP SCIENIFICA ,Total Kjeldahl Nitrogen (TKN) Using Raupa Trade (DNP- 1500) ,Ammonia ($NH4^+$ -N) using HANNA (HI96715) and Total phosphorus using UV-VIS Spectrophotometer (UV-2550) .

- **Physical Analysis:**

  Total suspended Solids (TSS), pH was measured in the field using HANNA (HI9124) pH meter, Electrical conductivity (EC) was measured in the field using ADWA (AD-204) EC meter and Wastewater temperature.

- **Biological Analysis:**

  Total and Fecal Coliform (TC/FC).

4.4 Evaluating the performance of J-WWTP

The performance of J-WWTP was evaluated depending on the results of the samples. The results of influent were used to determine the strength of Jenin wastewater, and the results of effluent were compared with Palestinian Standards to evaluate the performance of the plant.

The evaluation of existing plant was essential to investigate the proposed options for upgrading of the plant.

4.5 Investigations about proposed options

Many different systems and methods of treating municipal wastewater exist; the choice mainly depends on the water quality required at the effluent and the initial investment, operating and maintenance costs. The proposed options here are divided into two main categories which are:

- **upgrading the existing plant:**
  - Using Floating Baffle System.
  - Using Activated Sludge (AS) at the end of the existing treatment plant.
  - Using Upflow Anaerobic Sludge Blanket (UASB) at the beginning of the plant.
  - Using Sand Filter (SF) at the end of the plant.
- **Complete replacement the plant:**
  - Using Integrated Film Activated Sludge (IFAS).

- Using Combination between Activated sludge (AS) and Upflow Anaerobic Sludge Blanket (UASB).
- Using Land treatment Waste Stabilization Pond (WSP).

The chosen options can be appropriate where high removal of organic pollution is required. These options have efficient removal of BOD, COD, TSS and nutrients to meet specific requirements. And at the same time they are not complex. So these options can be used in Palestine which is considered as developing country.

In order to save time, effort and cost; computer modeling software can be used. Several scenarios of improving the operation of the existing J-WWTP can be evaluated, and different alternatives for complete replacement of the plant can be designed.

4.5.1 Software selection

J-WWTP was simulated by using GPS-X software (Hydromantis 1999). It is a valuable software application from Hydromantis manufacture that can be used for modeling WWTPs; it is one of advanced tool available for the mathematical modeling.

4.5.2 Building J-WWTP in GPS-X

- Selection of the library:

  It is essential to select suited library before proceeding to the physical characterization of each unit. GPS-X has six libraries; each library has its default parameter values which are used in program calculation. The Carbon, Nitrogen, Phosphorus (cnplib) library was chosen for this study, since there was an interest in modeling carbon, nitrogen and phosphorus.

- Construction of J-WWTP layout:

  The first step of simulation J-WWTP was to build it in a graphical form. Process unit icons were chosen from the process table in GPS-X and connected together through flow paths as it shown in figure 4.2.

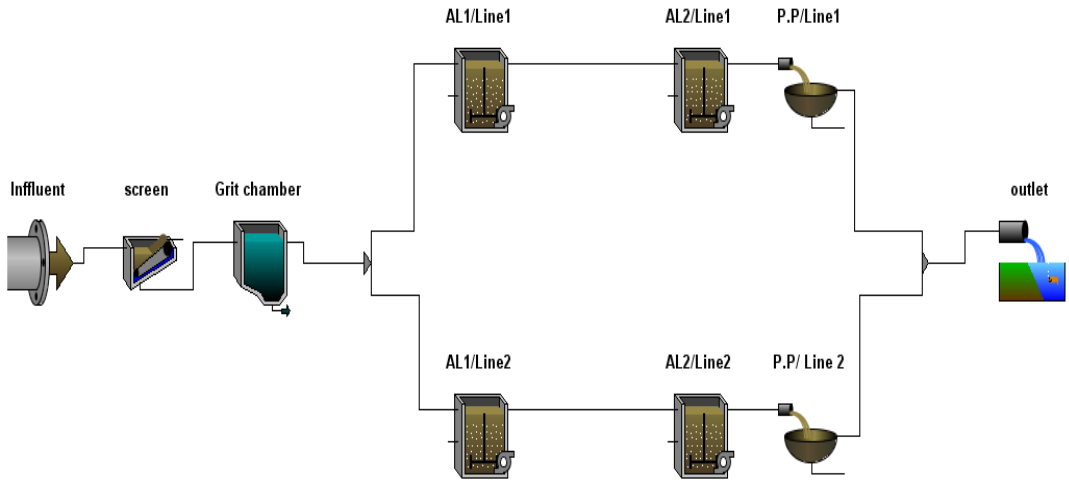


Figure 4.2: Layout of J-WWTP in GPS-X

- Selection of the model for each process unit

  To describe the behavior of any entered process unit, a set of models are available. The choice of any model is based on the available input information that is necessary for calculation.

The main models used to represent the existing plant are:

- Influent: six different models are available in GPS-X for the influent, which are: **bodbased, codfractions, codstates, sludge, states and tsscod.** From the available data (wastewater characteristics) which are mainly COD, TKN and TP; codstates model was used. GPS-X program has default values for COD fractions which are used to calculate the variables which are not entered by user. Any of these variables can be changed in order to calibrate the model.

- Aerated lagoon: empirical model; this model simulates the mixing, transformation and dilution in the pond. The empirical model can simulate 3 types of lagoons which are: aerated, facultative, and anaerobic (Eckenfelder, 1980).
- Completely mixed tank: The models employed for this process was newgeneral which is ASM1 extended to biological P removal (Dold, 1997).
- Aeration tank: Model No. 1 (ASM1) for the suspended biomass (Henze et al. 2000)
- Upflow Anaerobic Sludge blanket: The Mantis2 model is used to model the biological-chemical reactions in the reactor (hydromantis , 2013).

- Influent characterization

The characterization of the influent was one of the most important steps in the modeling, since codstates model was used; the main input parameters were COD,TP,TKN, Nitrate and Ammonia; other characteristics of wastewater like TSS and BOD can be determined by changing some COD fractions (calibrate the composite variable for influent characterization), table 4.1 below shows the COD fractions.

Table 4.1: input of influent, organic and nitrogen fractions which were changed.

Influent fraction	Fbod	BOD5/ BOD ultimate ratio	.84
	Ivt	VSS/ TSS ratio	0.526
Organic fraction	Frss	Readily biodegradable fraction	0.4
Nitrogen fraction	Frsnh	Ammonia fraction of soluble TKN	1.0

- Physical parameters for each unit is also entered as required: volume, depth, surface areas, etc.(see Annex A1)
- Model calibration:

  Calibration is a very important step in any modeling program. One of the collected samples from the plant (Annex A2.1) was used for calibration of the simulation.

  In GPS-X program, Simulations were initially run with the GPS-X model default values. As shown in figure 4.3, the resulted data were compared with measured data. If there were high differences, this means the obtained predictions were inaccurate, and the model required further calibration to obtain a better approximation to the reality of the treatment process. Consequently, the model parameters were manually adjusted by trial and error (Pereira, 2014).

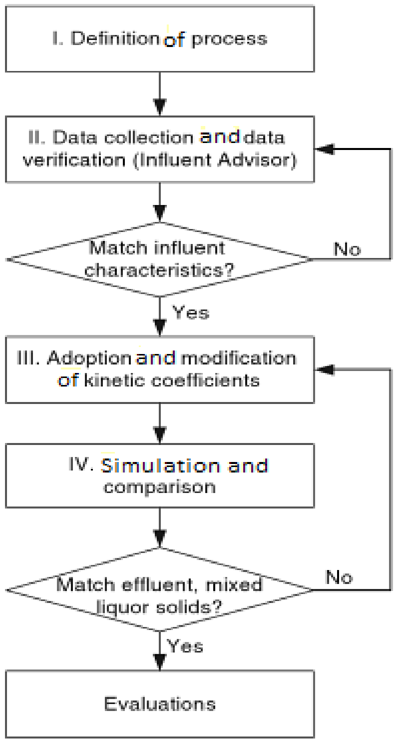


Figure 4.3: Model calibration protocol of GPS-X.

In order to calibrate the aerated lagoon model there are some model parameters that should be modified as shown in table 4.2.

Table 4.2: Modified empirical model constants

kinetic coefficients	Unit	Modified value
BOD removal rate constant for the first aerated lagoon	d^{-1}	0.329
BOD removal rate constant for the second aerated lagoon	d^{-1}	0.689
BOD removal rate constant for the polishing pond	d^{-1}	0.885
Empirical TSS constant B for the polishing pond	-	75

*See Annex B1, B2.

After the model was calibrated and to insure the reliability of the model, the data in Annex A2.2 was entered to the simulation, and the simulation results were compared with the laboratory data as shown in the figure below.

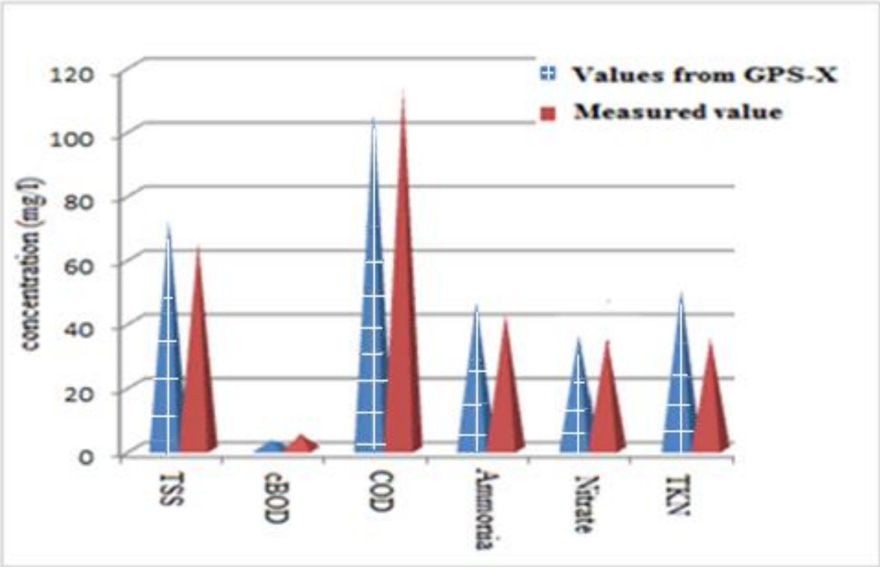


Figure 4.4: Comparison between the measured values in Lab and GPS-X model values.

When these samples were collected two surface aerators were turned on in the first lagoon and four surface aerators were turned on in the second lagoon.

Figure 4.4 shows that the output concentrations of the new simulation fitted J-WWTP results in a good way; this means the calibration of the model was considered complete.

Lastly, cases study of the plant were conducted and series of simulations were done in order to upgrade the plant.

4.6 Evaluate the performance of the proposed designs

After the proposed designs were simulated in GPS-X program, the results from each design were compared with Palestinian guidelines RT 34-2012 in order evaluate the designs.

Chapter Five

Results and Discussion

5.1 General

In order to evaluate the performance of Jenin's existing wastewater treatment plant, different data were collected from different agencies. This data is listed in Appendix (A):

1. Jenin wastewater treatment plant dimensions (Annex A1).
2. Laboratory results for different characteristic of influent and effluent for Jenin WWTP (Annex A2).
3. Characteristics of soil for some lands which will be irrigated by the treated wastewater (Annex A3).
4. Parameters which were needed for design.
5. Palestinian guidelines for treated wastewater used in irrigation (Annex A4).

5.2 Evaluation of the performance of J-WWTP

The collected samples were tested for different parameters, table 5.1 shows the results of these samples.

Table 5.1:Wastewater characteristics from inlet and outlet of J-WWTP

Test	Unit	Inlet	Outlet	Ref
BOD	ppm	742	5	SMWW*
COD	ppm	1025	113	SMWW*
TSS	ppm	660	60	SMWW*
Ammonia	ppm	92.5	42.7	SMWW*

SMWW:* standard method for water and wastewater

When the laboratory results were compared with (Henze and Comeau, 2008) of the composition of typical domestic/ municipal, Jenin wastewater is characterized as concentrated wastewater (high strength) (BOD>560, TSS>600 and COD around 1200); this problem is due to low water consumption in Jenin area which is estimated of 70l/c.d which is 30l/c.d below the minimum consumption that recommended by the World Health Organization which is 100l/c.d (Negotiations Affairs Department, 2014).

The ratio of BOD/COD is 0.73, which is a high ratio; it is due to the presence of high portion of biodegradable matter.

The recorded flow at the time of measurement in summer was 1700 m^3/d which is less than half of influent wastewater, the rest of the influent was drained to the wadi, and one of surface aerators was turned off in the first lagoon.

At this small flow and the aeration condition; the treatment plant has high efficiency to remove BOD, COD and TSS.

BOD removal $=\frac{BODi-BODe}{BODi}$

BOD removal = 99.1%

COD removal $=\frac{CODi-CODe}{CODi}$

COD removal=88.7%

The effluent BOD = 5mg/l is less than the TR34-2012 which is 60 mg/l, and the effluent COD =113mg/l is less than the TR 34-2012 which is 150mg/l.

The effluent TSS =60 mg/l and it is less than TR34-2012 which is 90mg/l.

For total Nitrogen; the measured values=82.57 mg/l exceeds the maximum allowable values from TR34 -2012 which is 60mg/l.

5.3 Simulation using GPS-X program

5.3.1 Simulation of the existing plant

J-WWTP consists of two aerated lagoons and one polishing pond with three surface aerators in the first lagoon and four surface aerators in the second lagoon. Recently; two lines are operation this means four aerated lagoons and two polishing ponds in two parallel lines as shown in figure 5.1.

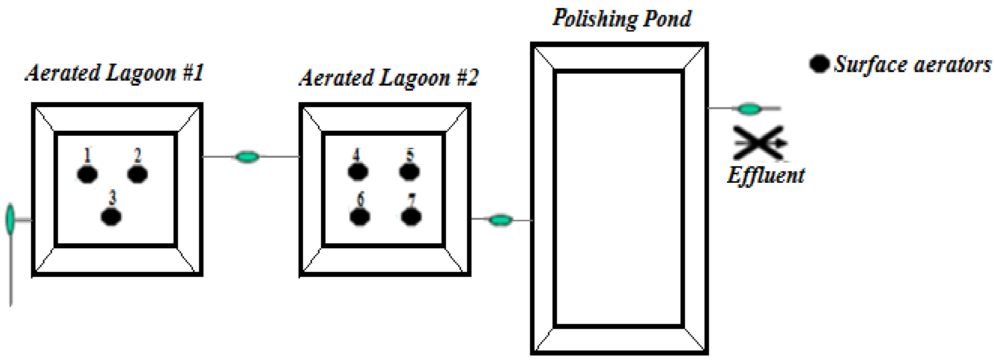


Figure 5.1: Schematic of one line of J-WWTP

In order to predict when the plant will fail due to BOD, COD and TSS; GPS-X simulation for the existing plant will be used. In this simulation all surface aerators are turned on, figure 5.2 shown the predicted value of maximum allowable flow that can be treated in the existing plant limited by Palestinian standards.

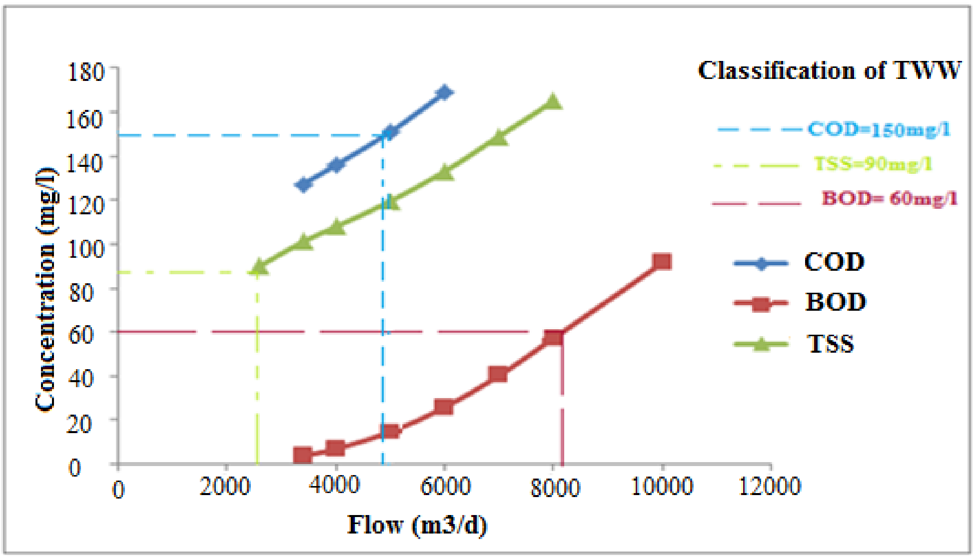


Figure5.2: Maximum allowable Flow limited by (BOD, COD and TSS) predicted by GPS-X simulation.

Table 5.2: Maximum acceptable flow limited by BOD, COD and TSS

	BOD	COD	TSS
Max allowable flow (m^3/d)	8100	4800	2500

The plant can treat BOD and COD in with high efficiency but there is a problem in treating TSS. This problem is due to poor aeration management. When all aerators are turned on, there is a poor treatment for TSS in the aerated lagoons, so the maximum amount of wastewater the plant can treat is 2500 m^3/d, which is less than the amount of influent wastewater which is 3500 m^3/d.

Currently; and in order to improve the performance of the plant for removing TSS; shutting off surface aerator No.3 and the same aerator in the parallel line, will produce a region of low velocity with no mixing and serves the function of sedimentation of suspended solids, figure 5.3 shown the predicted value of maximum allowable flow that can be treated in the plant when shutting off some of the surface aerators limited by Palestinian standards, using GPS-X simulation.

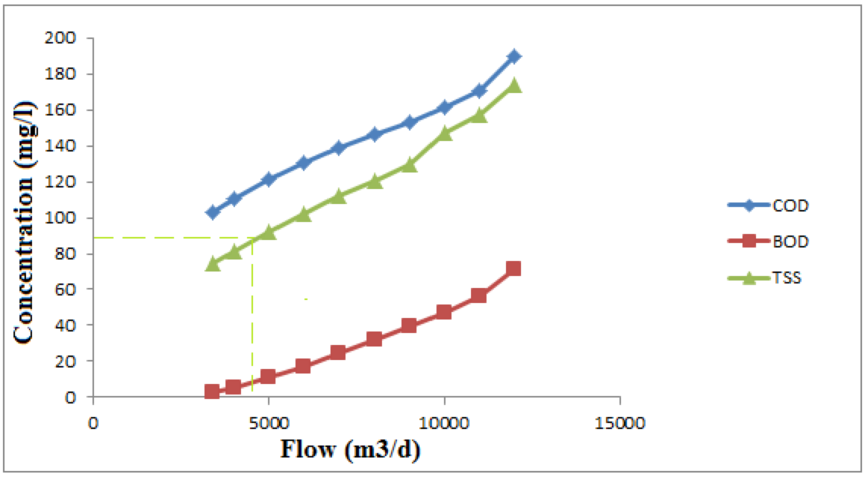


Figure 5.3: Predicted values of concentrations of BOD, COD and TSS in (mg/l) versus different values of Flow (m^3/d) when aeration management is used.

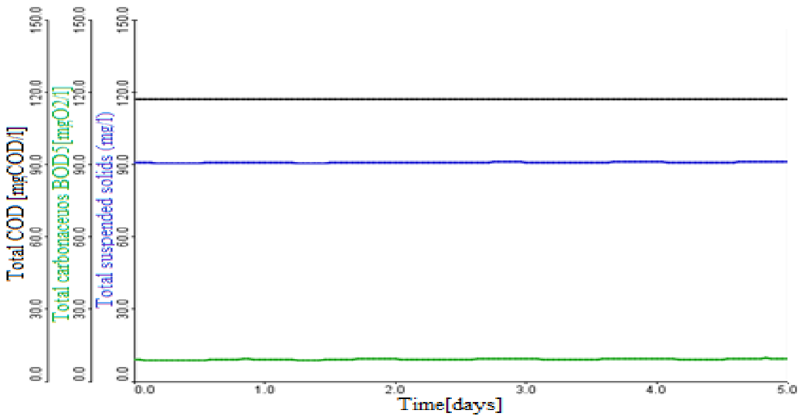


Figure 5.4:BOD, COD, and TSS, effluent concentrations diagram in (mg/l) at flow=4300m3/d, from GPS-X simulation for the proposed schemes of J-WWTP

From the above figures and by managing the aeration in the aerated lagoons; the plant can treat more influent with maximum value of 4300 m^3/d. Management the aeration in the plant by shutting off some surface aerators is considered a temporary solution at the current time. but in the coming few years, and due to increase in the number of population, more population will be connected to the plant, and more wastewater will be generated, so the plant will be over loaded and upgrading is needed.

5.3.2 Upgrade of the existing J-WWTP

5.3.2.1 Using Floating Baffle System

J-WWTP operators are using some operational scenarios of switching on/off number of aerators during the day in order to conserve energy, and to improve the performance of the plant. Floating baffle curtains can be used as shown in the figure 5.5 to divide the aerated lagoon into two cells, one of them is a completely mixed cell with working surface aerators, and the other cell is anoxic one with no surface aerators.

The used baffle increases the hydraulic retention time (HTR). it creates hydraulic flow patterns that guide wastewater through a serpentine route from the inlet to the outlet and this will increase the effective treatment area of a lagoon, this extended treatment time significantly reduces Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS).

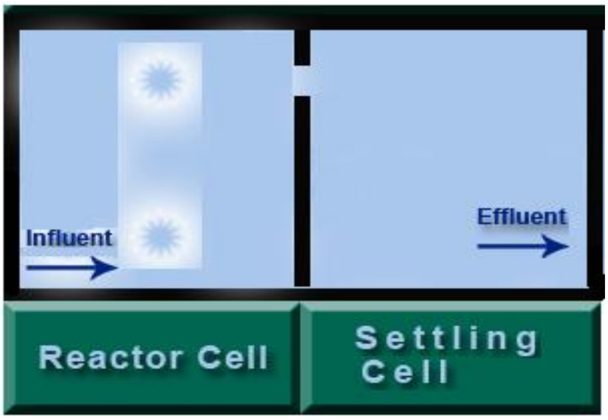


Figure 5.5:aerated lagoon after using baffle

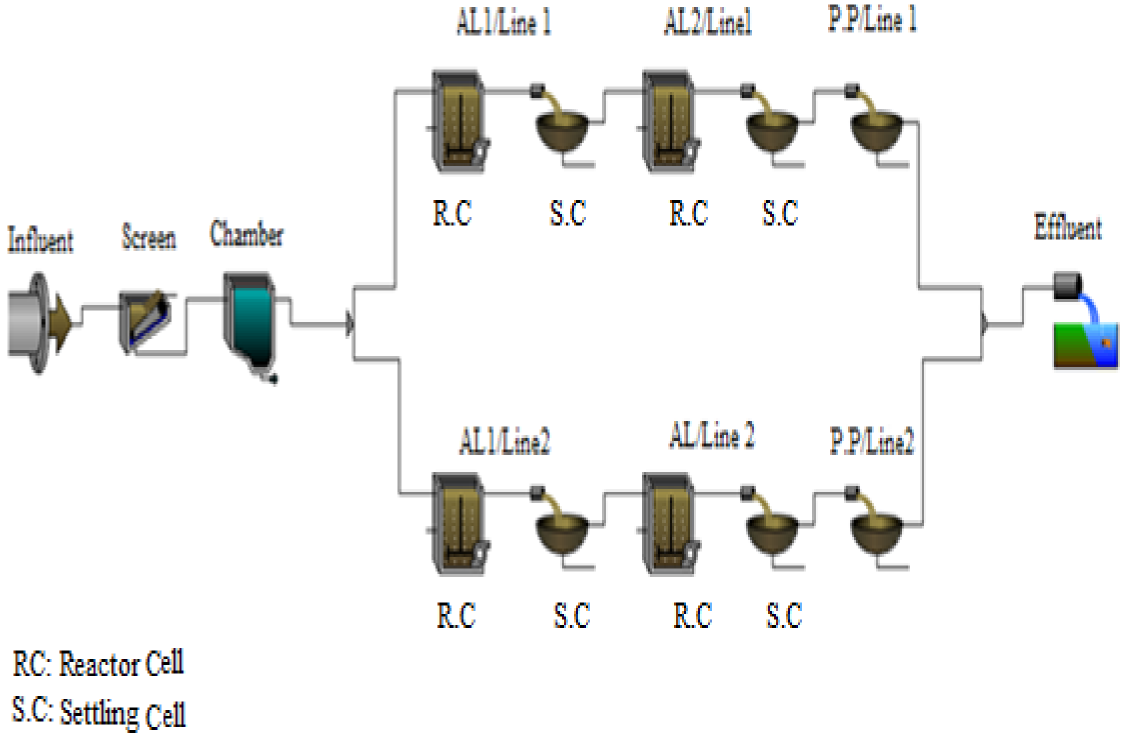


Figure 5.6: Schematic of proposed AL modeling in GPS-X.

Table 5.3: aeration scheme modeled in GPS-X.

Scheme	Active aerator
Case 1 existing plant (when all surface aerators working on with no baffle).	1,2,3,4,6,7
Case 2 (using baffle and half surface aerators are working on).	1, 2, 4, 5

The results of the two cases are summarized in figure5.7, which shown the comparison in the concentrations of BOD, COD, TSS, TN, Nitrate and Ammonia between the existing plant and the plant using floating baffle system:

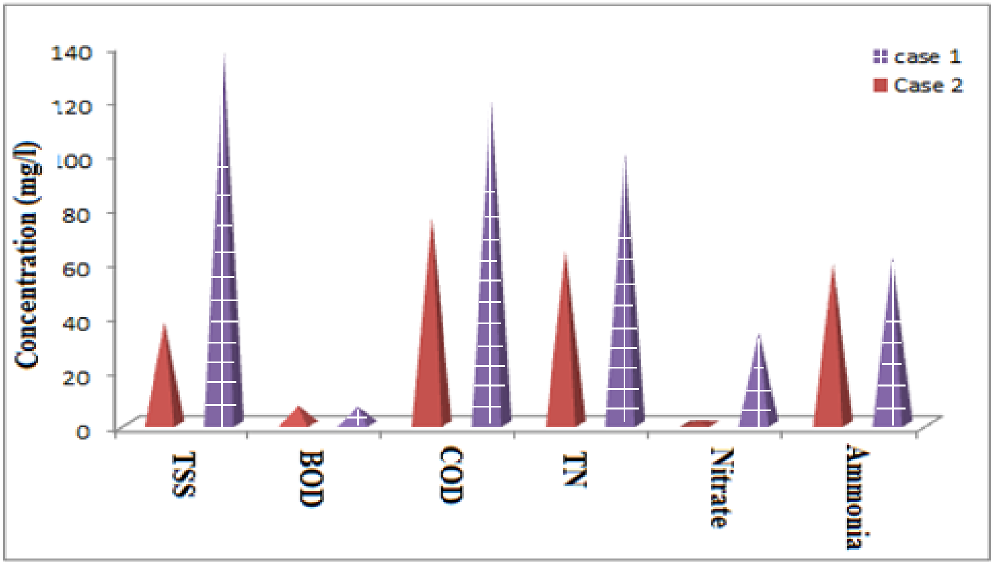


Figure 5.7: Comparison between the concentration values in the two cases using GPS-X simulations.

case 1, represents the existing plant condition when all surface aerators are working on; the best mixing conditions, on the other hand case 2 represents the same lagoons but using baffle to divide it into two cells; the first cell producing a good mixing condition, it provides sufficient oxygen needed for the conversion of the influent BOD to carbon dioxide and biomass, it maintains all solids in suspension. The other cell has anoxic condition, it maintains a thin aerobic layer at the top; it is a region of very low velocity and serves the function of sedimentation of suspended solids.

The used baffle increases the hydraulic retention time (HTR) and this will increase the effective treatment area of a lagoon, this extended treatment time significantly reduces Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS).

In this case there is an improvement in the performance of nitrogen removal; in the first cell (aeration zone); there is a growth of nitrifying bacteria which convert ammonia nitrogen to nitrate nitrogen (nitrification) this process mainly depends on the Carbonaceous Organic Matter, in the second cell there is an anoxic environment conditions, this will enhance the heterotrophic bacteria to denitrify the nitrate into nitrogen gas and reduce the value of nitrate.

It is observed from the above results that the nitrite oxidizers grow faster than ammonia oxidizers. This case is considered as a simple way to enhance the plant with less energy cost.

5.3.2.2 Separating the domestic wastewater from other types of wastewater.

In this case domestic wastewater is separated from other types of wastewater like industrial wastewater, and this will be done by choosing a city which is located near to Jenin city and having approximately the same economic activities and nearly the same domestic wastewater characteristics in which they separate between industrial and domestic wastewater; the city is Nablus. By entering the characteristics of Nablus wastewater to J-WWTP modeling figure 5.8 is achieved, the maximum allowable flow 5200 is greater than the maximum allowable flow for existing Jenin wastewater plant.

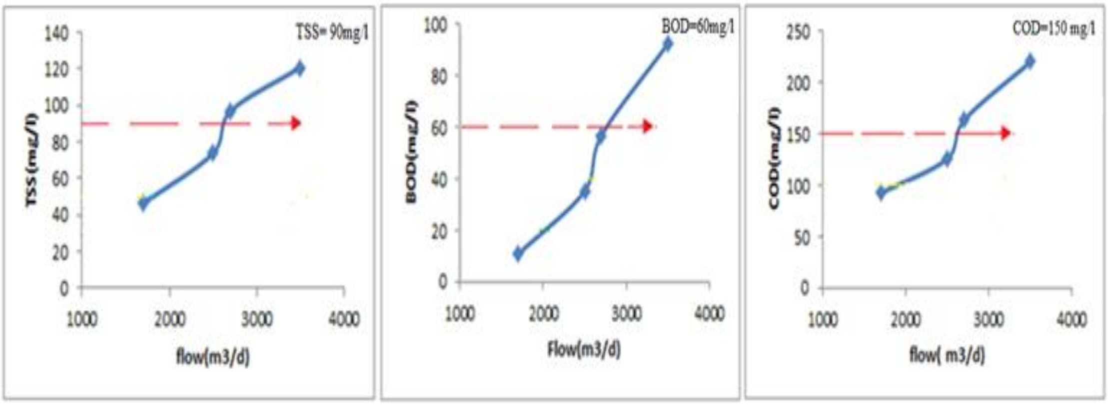


Figure 5.8: BOD, COD and TSS effluent concentrations in (mg/l) vs. flow in (m3/d) limited by TR34-2012classifications.

5.3.2.3 Using Activated Sludge at the end of the existing treatment plant

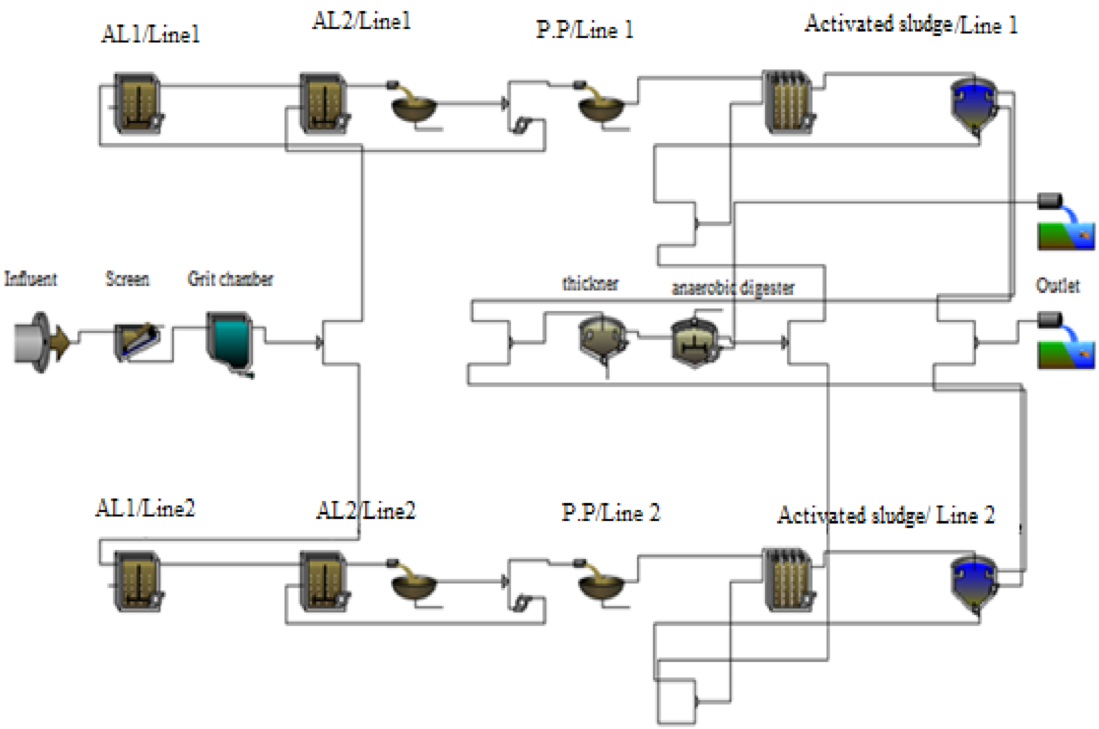


Figure 5.9: Schematic of proposed AS modeling in GPS-X.

In this design the existing plant is followed by two activated sludge in two parallel lines, each tank has volume of 1200m^3 (46m length, 6.5 width and 4 depth) with four reactors, the influent BOD into the activated sludge is equal to 107.4 mg/l; (BOD loading= 452 g BOD/m^3.d) it is within the range of conventional AS (320-640 g BOD/m^3.d)

As shown in figure 5.9, the activated sludge tanks are followed by 2 circular secondary sedimentation tanks with 133 m^2 surface area (Diameter =13m) and depth of 3 m.

Figure 5.10 and table 5.4 show summary of the effluent COD, BOD, TSS, TN, TP concentration. Food to mass ratio in activated sludge tank is 0.2217 g BOD5/g MLSS.d and the BOD removal efficiency is about 85% and 78% is the percent removal of TSS, the amount of produced sludge from AS is 508 Kg/d.

The concentration of TSS, BOD, COD, TN and TP are less than the RT 34-2012 values as represented above.

These results are in agreement with Ukpong, (2013) which showed that the activated sludge has high performance to remove organic maters, the microorganism oxidize them and form water, CO_2 and new cells. Activated sludge technology can removed high percent of TSS when the mixture enters the clarifier, a fraction of microorganisms also settling down and removed from the effluent, whereas the other part of them is recycled to the influent of aeration tank.

AS also has the ability to remove ammonia through nitrification.

Therefore using activated sludge for upgrading the plant has an important effect in the future, when the plant become over loaded or when stricter effluent standards are applied, the aeration tank can be easily improved without building a new tank by adding biofilm carriers into the aeration tank for growth and attached biofilm, this technology is defined as Integrated Fixed-film Activated Sludge (IFAS), this way in the aeration tank higher biomass concentration is obtained without significant increase of the load in the secondary clarifier (Sriwiriyarat et al., 2005).

Table 5.4: Summary table for AS simulation results of proposed plant effluent.

Simulation Results		
Characteristic	**Unit**	**Value**
TSS	mg/L	12.58
cBOD5	mg/L	4.51
COD	mg/L	68.52
TN	mg/L	53.03
NH4-N	mg/L	43.20
TP	mg/l	3.60

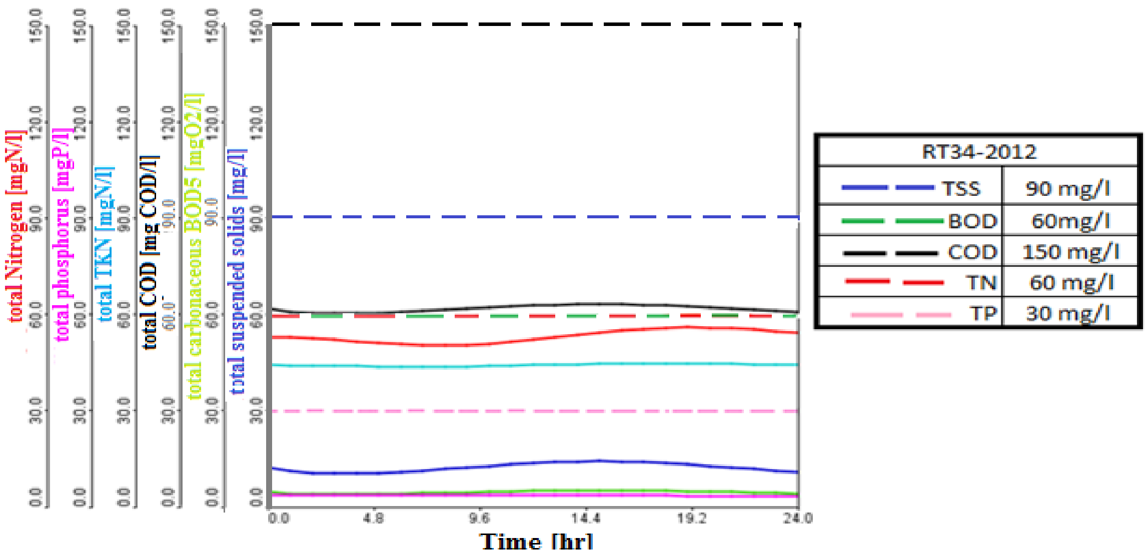


Figure 5.10: BOD, COD, TSS, TP and TN effluent concentrations diagram in (mg/l) from GPS-X program for the proposed conventional AS design.

5.3.2.4 Using Upflow Anaerobic Sludge Blanket at the beginning of the plant

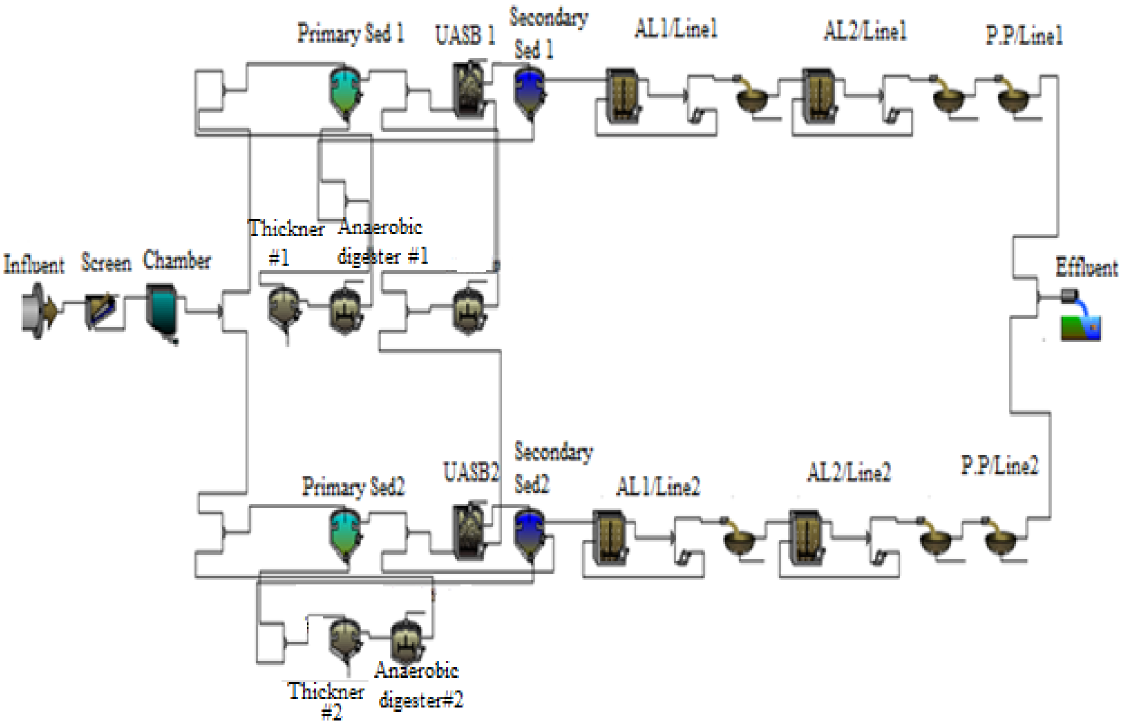


Figure 5.11: Schematic of proposed UASB modeling in GPS-X.

In this design UASB is used at the beginning of the existing plant as shown in figure 5.11, the design is divided into two lines each one has 1 primary sedimentation tank with 153.8m^2 surface area (Diameter= 14 m) and 3 m depth,1 UASB with volume of 1231m^{3,} and 8m depth of water and 1secondary sedimentation tank with area of 176.6m^2 (Diameter=16m) and depth of 3m.

When UASB is used before the existing plant, it has high efficiency in removing BOD, COD, TSS and nitrate, but for ammonia and TKN lower efficiency can be achieved as shown in figure 5.12.

UASB is attractive to use in high organic loading, high efficiency was achieved in removing COD and BOD, and converted them by anaerobic microorganisms in the reactor to biogas (CH_4), this biogas can be used for energy production. A study reported by Syutsubo et al., (1997) showed that the COD removal efficiency of UASB reactor can reach higher than 85 percent, Elmitvalli, (2005) showed that the BOD removal and TSS removal in UASB are up to 85%, whereas the Coliform removal from 70 - 90 % Helminthe eggs up to 100%.

The nitrate is reduced to 5.31 mg/l, this result is in agreement with de Sousa, et al (2008) when they showed that the UASB has the ability to remove nitrate by anaerobic bacteria in the reactor, and convert it to nitrogen gas in a process which called Denitrification.

Using UASB at the end of the plant can be a sustainable option to use due to the effluent quality which can be used in irrigation, low values of TSS, BOD, COD and Nitrate. From the design it needs a small area of land due to its small size and number of units.

Table 5.5: Summary table for UASB simulation results of proposed plant effluent.

Simulation Results		
TSS	mg/L	3.72
cBOD5	mg/L	8.11
COD	mg/L	15.70
Ammonia N	mgN/L	54.13
Nitrite/Nitrate N	mgN/L	5.11
TKN	mgN/L	54.15
TN	mgN/L	59.26

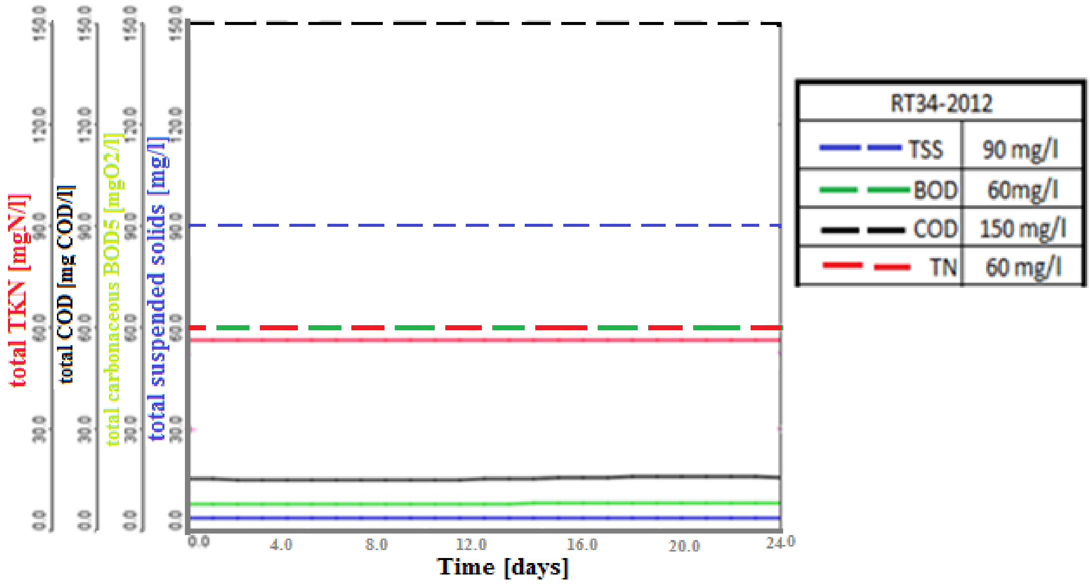


Figure 5.12:BOD, COD, TSS and TN effluent concentrations diagram in (mg/l) from GPS-X program for the proposed UASB design.

5.3.2.5 Using Sand Filter at the end of the plant

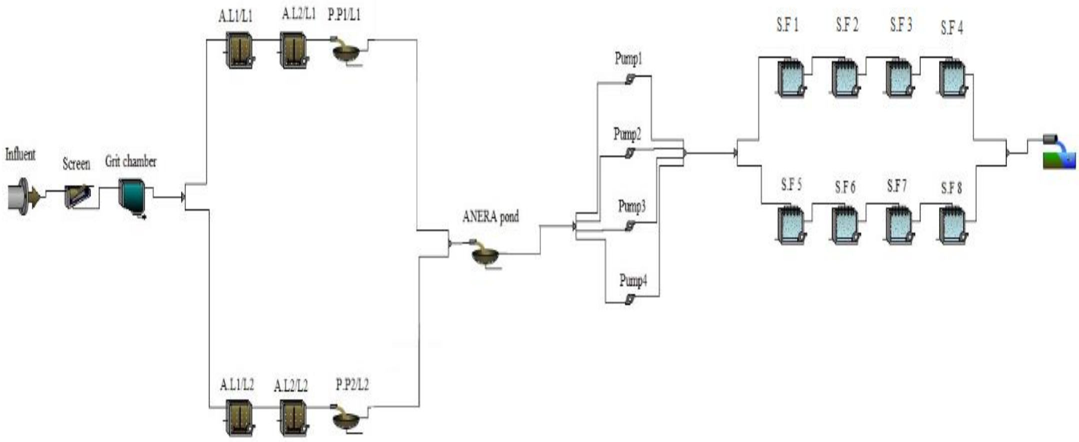


Figure 5.13: Schematic of proposed SF modeling in GPS-X.

In this design as shown from figure 5.13, eight sand filters are used at the end of the plant with four pumps to provide sufficient pressure to overcome the operating pressure of the system and to move treated wastewater from the pond to the sand filters, two pumps could work at the same time.

Figure 5.14 and table 5.6 represent summary of the effluent COD, BOD, TSS, TN, NO_3 and ammonia, Sand filters produce a high quality effluent with TSS concentration of 0.05 mg/l and significant fecal coliform bacteria reductions can be achieved. BOD and COD values are within Palestinian standards.

This design produce a high quality effluent that can be used for drip irrigation or can be surface discharged after disinfection.

Table 5.6: Summary table for SF simulation results of proposed plant effluent.

Simulation Results		
TSS	mg/L	0.05
cBOD5	mg/L	39.11
COD	mg/L	110.53
Ammonia N	mgN/L	67.74
Nitrite/Nitrate N	mgN/L	7.24
TKN	mgN/L	67.74
TN	mgN/L	74.98
TP	mgP/L	28.29

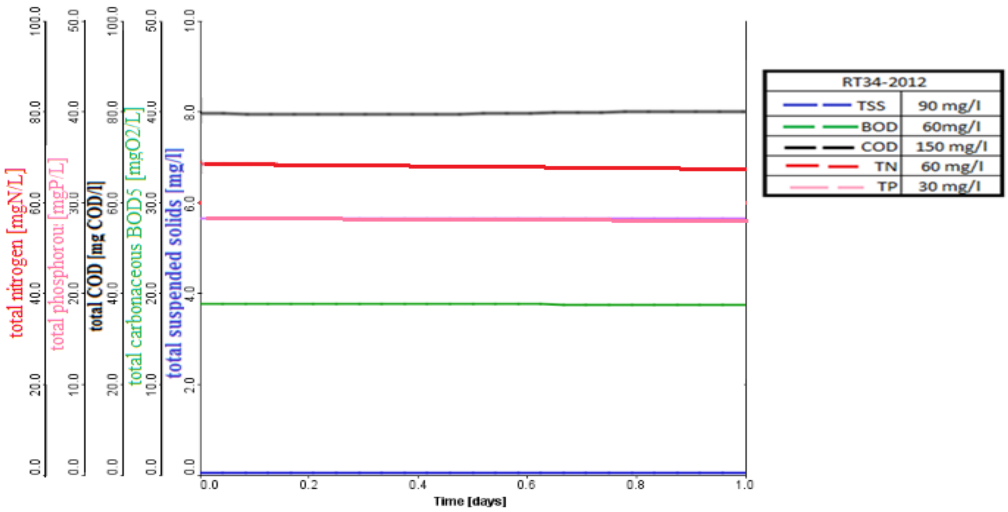


Figure 5.14: BOD, COD, TSS, TP and TN effluent concentrations diagram in (mg/l) from GPS-X program for the proposed SF design.

Recently; this technology is added to the plant, in order to reduce the value of TSS.

5.3.3 Complete replacement the plant

5.3.3.1 Integrated fixed film activated

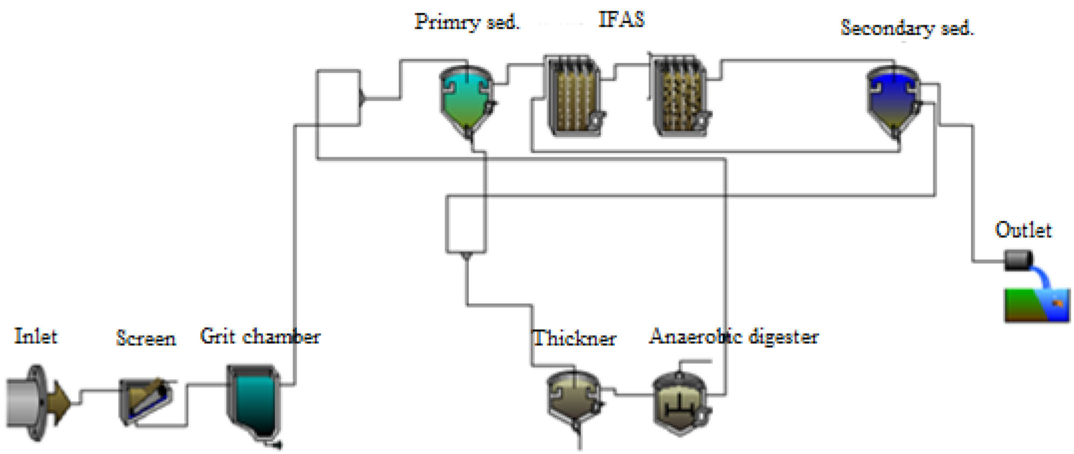


Figure 5.15: Schematic of proposed IFAS modeling in GPS-X.

Integrated fixed film activated sludge IFAS (anaerobic and anoxic, aerobic)treatment process is used as shown in figure 5.15, it consists of one primary sedimentation tank Diameter= 14m, depth= 2.5m, followed by Anaerobic/ Anoxic with volume of 1500m^3,and aerobic tank 1400m^3, followed by secondary sedimentation tank with Diameter=18m and 2.5m depth.

Figure 5.16 and table 5.7 represent summary of the effluent COD, BOD, TSS, TN, $NO_3$and ammonia, all the concentrations are within Palestinian standards.

This new technique is very useful for lower total nitrogen (TN) level required by the PSI-standard. The added biomass enhances nitrification process by improving nitrifying plants to nitrify; using this technology the amount of TN decreased. This result is in agreement with several previous studies which demonstrated that IFAS process can be an alternative design for biological nitrogen removal(Sriwiriyarat et al., 2005).

Table 5.7: Summary table for IFAS simulation results of proposed plant effluent.

Simulation Results		
TSS	mg/L	**29.77**
cBOD5	mg/L	**10.78**
COD	mg/L	**76.46**
Ammonia N	mg/L	**33.95**
Nitrate N	mg/L	**2.62**
TKN	mg/L	**38.39**
TN	mg/L	**42.55**
TP	mg/l	**23.24**

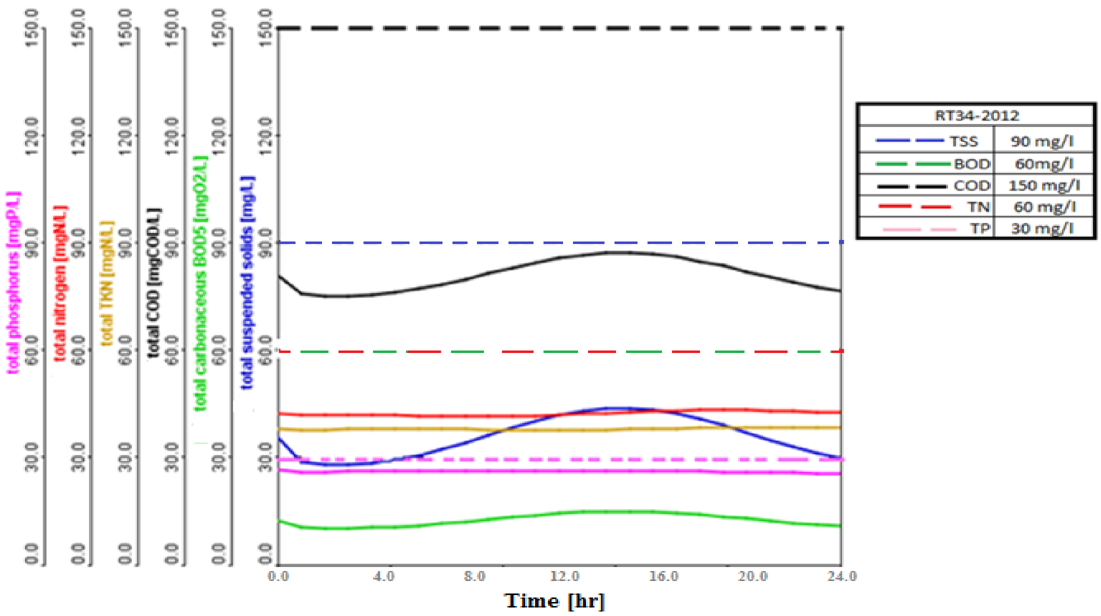


Figure 5.16: BOD, COD, TSS, TP and TN effluent concentrations diagram in (mg/l) from GPS-X program for the proposed IFAS design.

5.3.3.2 Up-flow Anaerobic Sludge Blanket with Activated sludge

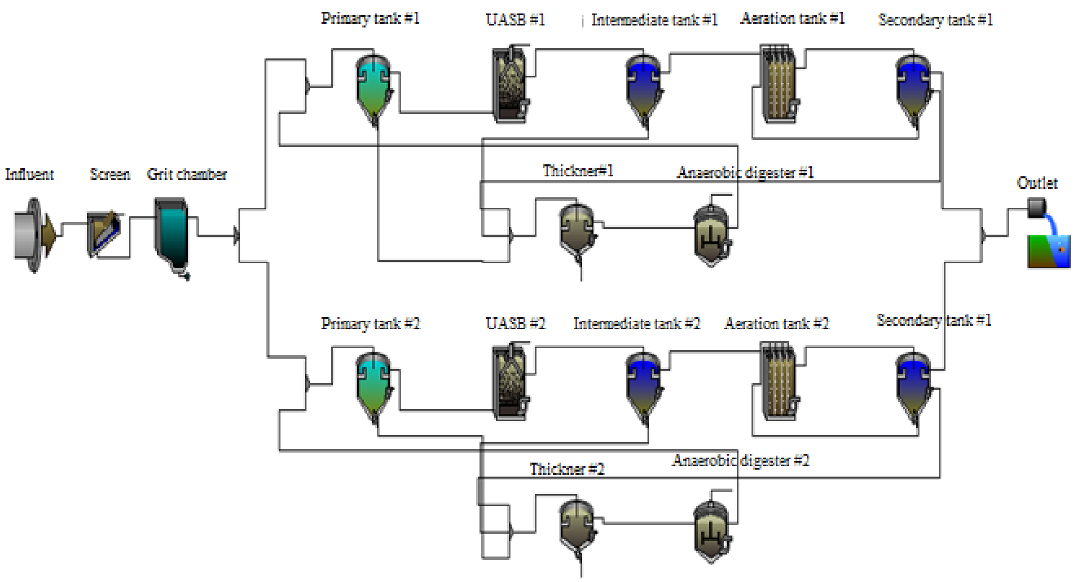


Figure 5.17: Schematic of proposed UASB with AS modeling in GPS-X.

In this case 2 primary sedimentation tanks are used with Diameter =13m and 2.5 m depth for each one, they are followed by 2 UASB each one has 1231m^3 volume and 8m depth of water; 2 intermediate sedimentation tank with 13m diameter and 2.5m depth flowed by activated sludge of1000m^3 and height of 4 m, finally 2 secondary sedimentation tank 132.69 m^2 surface area.

From figure 5.18; all the values are within the standard values, this option has high efficiency in removing BOD, COD, TSS, TN and TP.

In this case all the effluent concentrations are less than the RT34-2012, this combination developed the effluent quality, TN at effluent has a value of 42.55, this result is in agreement with Descoinsa et al. (2012) study which presented that a combination between aerobic and anaerobic technologies (UASB, AS reactors) can enhance the carbon and nitrogen removal, heterotrophic and autotrophic micro-organisms biological activity in the reactors enhance nitrification and de-nitrification biochemical reactions.

Table 5.8: Summary table for the simulation results of combination between UASB and AS.

Simulation Results		
TSS	mg/L	23.36921
cBOD5	mg/L	8.707113
COD	mg/L	25.29786
Ammonia N	mgN/L	0.009687
Nitrite N	mgN/L	0.064281
TKN	mgN/L	1.585931
TN	mgN/L	58.2935
TP	mg/l	17.2

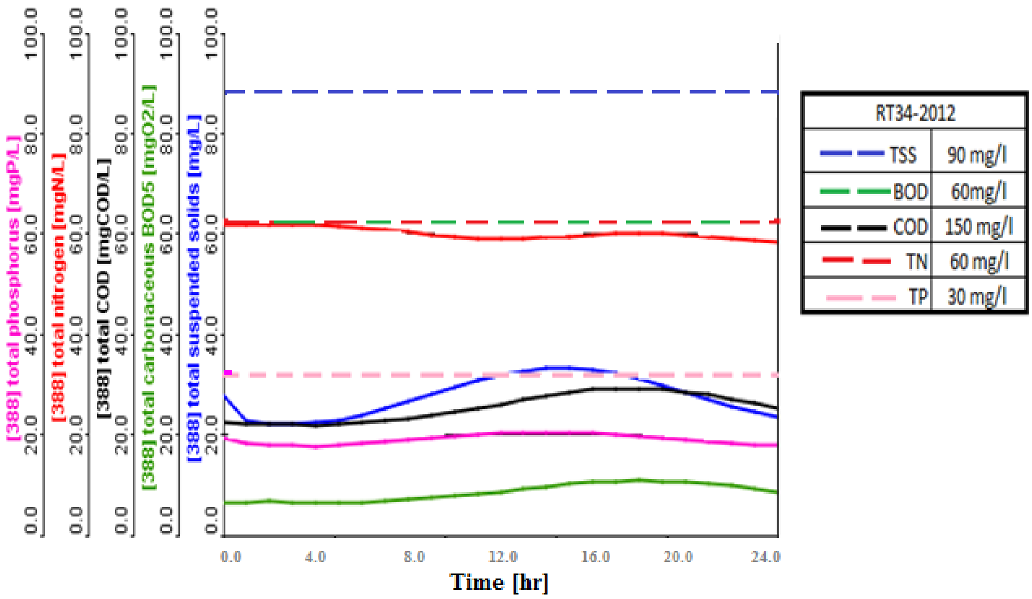


Figure 5.18: BOD, COD, TSS, TP and TN effluent concentrations diagram in (mg/l) from GPS-X program for the proposed UASB with AS design.

5.3.3.3 Land treatment -waste stabilization pond (WSP):

- Anaerobic pond:

	Value	**unit**
Area	3339	**m^2**
Depth	3	**m**
Time θ	3	**day**

The anaerobic pond is designed according to volumetric loading for BOD removal (WSP, 2007);the pond has a trapezoidal shape in order to prevent erosion of the banks of the pond, 2:1 breadth ratio was used in order to prevent the form of sludge around the inlet.

The pond has retention time of 3 days and this will reduce the BOD loading from 752mg/l to 300.8mg/l

- Design of secondary facultative pond

	Value	**Unit**
Area	94446	**m^2**
Depth	1.5	**m**
Time θ	14	**day**

The facultative pond is designed according to surface loading also used for BOD removal (WSP, 2007).

The facultative pond has a trapezoidal shape with 1:1 slope ratio for the pervious mentioned reason, the sludge is deposited and accumulated at the bottom of this pond, and 2:1 breadth ratio for length is used.

The pond has retention time of 14 days and this will reduce the BOD loading from 300.8 mg/l to 59.16mg/l; this meets the RT34-2012 standard which is 60mg/l.

- Maturation pond

	Value	Unit
Area (AM1)	28421.15	**m^2**
Depth	3	**m**
Q $_{eff}$ from Am1	9402.664	**m3/d**

	Value	Unit
Area (AM2)	27998.01	**m^2**
Depth	3	**M**
Q $_{eff}$ from Am2	9262.674	**m3/d**

E coli after first 3 days (Ne)	4027.18 2	per 100 ml	<10^5/100 ml the restricted values for irrigation
E coli after second 3 days (Ne)	205.326 4	per 100 ml	<1000/100 ml the unrestricted values for irrigation

The maturation pond is designed according to Marais method (1974) for faecal removal. The pond also has trapezoidal shape with 1:1 slope, and 1:5 breadth ratio for the length in order to give approximately plug flow condition. The retention time is 6 days and the fecal coliform is reduced to 205 per ml, which is less than 1000/100 ml the unrestricted values for irrigation, as shown in figure 5.19.

As represented; WSP needs large area of 161359 m^2 and long hydraulic retention time of 32 days.

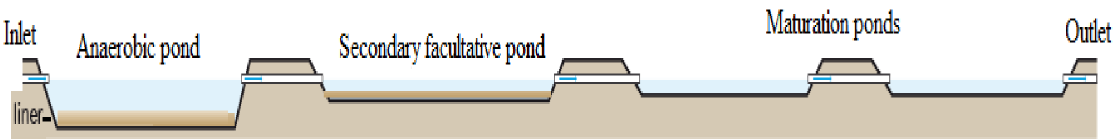


Figure 5.19: Schematic of proposed WSP

Chapter six

Sustainable Development of J-WWTP

6.1 Environmental aspects

6.1.1 Preliminary study about the impact of treated wastewater on the soil

The treated wastewater will be used in irrigation of Jenin agricultural land, this study was carried out as a background for other researcher to investigate the effect of TWW constituents such as nitrogen, phosphorus and heavy metals on irrigated soil.

6.1.1.1 Soil Sampling

Five agricultural lands around the treatment plant which will be irrigated with TWW were selected. Soil samples were taken randomly; each sample about 1Kg.

General Considerations for soil sampling:

- The samples were collected from dry soil because (soil conditions were dry in summer) too wet soil is very difficult to mix.
- The spots of soil were Chosen and cleaned of any residue of plants, mulch and leaf from the surface.
- To prevent the samples from contamination with metals of concern including copper, zinc, etc. the tools were free of metal, brass, bronze, or galvanized.

- To prevent inaccurate results; the buckets and sampling tools should be free of lime and fertilizer residues.
- From each agricultural land three samples were collected at a depth between 10 to15 cm.

6.1.1.2 Sample preparation

After the samples were collected, they were brought to Poison Control & Chemical / Biological Center laboratory at An-Najah National University in order to test and determine the characteristics of the soil.

Soil samples were weighed and stored in cardboard boxes and then dried in an oven with a fan at 36–40°C until constant weight was reached. Then they were disaggregated using a wood pestle, sieved at 2 mm, the volume was reduced by quartering and riffling and at the end the laboratory samples were milled at 90 µm to obtain the test samples. The samples were taken for trace metals analysis by ICP-MS.

6.1.1.3 Testing of soil samples

The samples were analyzed for parameters like: Heavy metals (As, Fe, Hg, Cd, Cr, Cu, Hg, Mo, Ni, Se, Pb and Zn) by Inductivity Coupled Plasma Mass Spectrometry (ICP-MS) using EPA method for testing soils (USEPA, 1986).

The soil samples were tested to set the base conditions for the soil to allow estimation of the future effects of TWW irrigation on.

6.1.1.4 Simple model for nitrogen cycle in soil

Pollutant and concentration in the soil of Jenin irrigated land were determined before the irrigation with TWW, but due to time constraints and delay in the implementation of the J-WWTP project, theoretical and simple model was built for nitrogen, this model demonstrated all forms of nitrogen in the soil. After the irrigation with TWW, soil samples from the same points must be collected and tested in order to calibrate the model.

This model may be used as a background for subsequent work dealing with the same subject.

For the impact of other parameters like heavy metals; mass balance is used.

General considerations:

❖ Ammonium $NH4^+$ can be obtained from:

- the degradation of organic nitrogen which is (mineralization), or
- From inorganic addition of fertilizers.

But, it can be lost through

- Plant uptake using plants or microorganisms.
- Volatile as NH_3 in (valorization).
- Converted to organic nitrogen (immobilization).
- And finally it can be lost through (nitrification).

❖ Nitrate NO_3^- can be obtained from:

- Nitrification.
- Directly added from inorganic fertilizers.

But, it can be lost through:

- converted to organic N by microorganisms (immobilization)
- Uptaken by plants.
- Reduced to gaseous N compounds by denitrifying bacteria (de-nitrification).
- Leaching

6.1.1.5 Nitrogen mathematical model

$$\frac{dN\ org}{dt} = N_{exis} + N_{fixing}$$

$$\frac{dN+}{dt} = \text{MIN} + \text{IF}^{+} + \text{IW} - \text{IMM}^{+} - \text{VOL} - \text{UP}^{+} - \text{NIT}$$

$$\frac{dN-}{dt} = \text{NIT} + \text{IF}^{-} + \text{IW} - \text{UP}^{-} - \text{LE}^{-} - \text{UP}^{-} - \text{IMM}^{-} - \text{DIN}$$

By adding the above two equations together:

$$\frac{dN\ tot}{dt} = MIN + IF^{+} + IF^{-} + IW^{+} + IW^{-} - VOL - UP^{+} - UP^{-} - LE - DIN$$

Where:

$N_{exis:}$ The amount of organic nitrogen existing in the soil.

N_{fixing}: The amount of atmospheric nitrogen which is fixed in the soil by the plant

MIN: Mineralization rate from applied manure organic N [$M\ L^{-3}\ T^{-1}$] .

IMM^{+}: Immobilization rate from NH_4 [$M\ L^{-3}\ T^{-1}$].

IMM^{-}: Immobilization rate from NO3 [$M\ L^{-3}\ T^{-1}$].

NIT: Nitrification rate.

UP^{+}: N uptake by plants from the NH_4 [$M\ L^{-3}\ T^{-1}$].

UP^{-} : N uptake by plants from the NO_3 [$M\ L^{-3}\ T^{-1}$].

LE^{+}: N flux from root zone towards groundwater from NH_4 [$M\ L^{-3}\ T^{-1}$]

LE^{-}: N flux from root zone towards groundwater NO_3 [$M\ L^{-3}\ T^{-1}$].

DIN: Di-nitrification of NO_3^{-}

IF+: Inorganic addition fertilizers of NH_4

IF^- : Inorganic addition fertilizers of NO_3

IW+: Addition NH_4 from treated water.

IW+: Addition NO_3 from treated water.

VOL: Volatilization of NH_4

AR: Addition of NO_3 from acid rain.

Assumptions:

- All organic nitrogen will be mineralized.
- No nitrogen accumulation in the soil (steady state conditions).
- There is a small amount of nitrogen in rain which can be neglected.
- Runoff and erosion will be neglected.

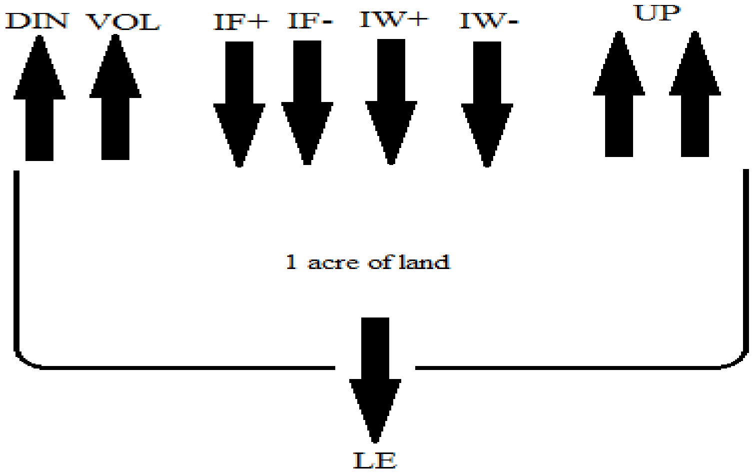


Figure 6.1:modeling of nitrogen in soil.

$$\frac{dN\ tot}{dt} = MIN + IF^{+} + IF^{-} + IW^{+} + IW^{-} - VOL - UP^{+} - UP^{-} - LE - DIN$$

If no fertilizers are used:

$$\frac{dN\ tot}{dt} = MIN + IW^{+} + IW^{-} - VOL - UP^{+} - UP^{-} - LE - DIN$$

In steady state condition $\frac{dN\ tot}{dt} = 0$

$$LE = MIN + IW^{+} + IW^{-} - VOL - UP^{+} - UP^{-} DIN$$

6.1.2 Sludge Disposal & Reuse

The produced sludge from the treatment of wastewater must be aerobically or anaerobically stabilized before disposal or reused. On February /2014 the PSI issued Technical Instructions for sludge reused in agriculture to be used as fertilizer; these instructions include concentrations of heavy metals (PSI, 2014).

This sludge can be used to produce higher quality of Composting of organic fraction, the sludge should be free or at minimum cost, this way is less costly than landfill the sludge or incinerates it.

6.2 Economic aspects

6.2.1 Cost Benefit Analysis:

It defines as the sum of all expected benefits minus the expected cost. Indicators which are used to evaluate the costs and benefits for the different actors involved in TWW (during supply, treatment, storage, distribution and the end users) are presented.

- Investment costs.
- Operation and maintenance (O&M) cost
- Benefits resulting from the reuse of treated wastewater for irrigation.

6.2.1.1 Evaluation of the cost

- **Capital, operation and maintenance cost**

  Initial Investment costs are the costs for construction or upgrading of the treatment plant and network, whereas the operation and maintenance

(O&M) costs are the cost for running the system, salaries and maintenance of the plant as shown in table 6.1 (EPA, 2015).

Table 6.1: Capital, operation and maintenance costs for the used technology processes (AS, UASB. AL, WSP and IFAS).

Technology process	Capital cost	Operating and maintenance cost
Waste stabilization pond (Varon, 2004)	• High/ low capital cost depending on the price of land especially large land area is required. • Expert design is required	• very low operation costs • No electrical energy required • De-sludging required (normally every few years) • low-tech infrastructure
Aerated lagoon (Tilley et al., 2014)	• Investment costs are moderate to high (Requires a large land area). • Expert design is required.	• large energy consumption • operation and maintenance is expensive • Skilled staff is required to maintain and repair aeration machinery. • must be de-sludging every 2 to 5 years • Not all parts and materials may be locally available
Upflow Anaerobic Sludge Blanket (Tilley et al., 2014)	• Capital costs for construction can be estimated as low to medium • Low land demand. • Needs professional for construction	• Operation costs are low, due to little energy consumption • A skilled operator is required to repair mechanical parts. • *De-sludging* is infrequent (every 2 to 3 years), due to small amount of sludge which is produced.

		• Not all parts and materials may be locally available.
Activated Sludge (WSP, 2008)	• Very high construction costs. • Costly mechanical parts. • Little land required. • Requires expert design and construction	• Very high operational cost due to high electricity consumption and the requirement of permanent professional operation. • Very high maintenance cost due to the requirement of constantly maintained the mechanical part (mixers, aerators and pumps). • Not all parts and materials may be locally available.
Integrated Film Activated Sludge (Brentwood, 2009)	• Very high construction cost (less capital cost than a conventional AS system). • For newly installation little land is required. • costly mechanical parts	• Very operation cost due to large energy requirements and permanent professional operation. • Very high maintenance cost due to the needs of expert knowledge and system mechanical parts are not locally available.

In order to estimate the investment cost and the annual O&M costs for a plant with secondary treatment technology using relevant costs of similar plant with different capacity, these equations can be used (Executing Agency Applied Research Institute, 2005).

Investment cost 2= investment cost 1*$\left(\frac{\text{capacity 2}}{\text{capacity 1}}\right)^{0.79}$

O&M Cost 2= O&M cost 1*$\left(\frac{\text{capacity 2}}{\text{capacity 1}}\right)^{0.6}$

- **Wastewater Storage**

  The treated wastewater flowing out of J-WWTP will be stored in a settling pond for 10 days before transferred to reuse, the investment cost for a settling pond is 0.26 $/ m3 (Palestinian Water Authority, 1999 b) with 3% inflation rate for each year (Executing Agency Applied Research Institute, 2005).

  Two storage ponds are needed with (60m length, 38m width and 20m depth) for the design period.

- **Wastewater Transport to Reuse Sites**

  Transmission lines will be installed for transporting the treated wastewater to the irrigation lands, the lengths of transmission lines required can be calculated using the Geographic Information System (GIS). This will result in addition investment cost. These lines must be painted purple to distinguish it from other pipes According to the Palestinian Specifications.

6.2.1.2 Evaluation of the economic benefits

Economic benefits are the benefits resulting from the reuse of treated wastewater in irrigation.

- **Economic benefits**

  The proper and safe reuse of treated wastewater in irrigation can have economic benefit; which means revenues can be generated. According to Palestinian authority $0.20 is the value of 1$m^3$ of treated wastewater reused for irrigation purposes (Palestinian Water Authority, 1999 b), with 3% inflation rate for each year (Executing Agency Applied Research Institute, 2005).

  But The Palestinians should benefit from Jordan experience in this field. Farmers do not pay for the treated water used for irrigation, they pay only for the facilities of conveyance and distribution, the treatment cost should be charged to the polluters.

- **Production Value of Irrigated Crops**

  The reused of TWW in irrigation will increase the area of irrigated agricultural lands as shown in figure 6.2, also the production of these lands will increase.

  This benefit can be calculated for 1 dunum by multiplying total dunums of irrigated lands by 1 dunum cultivated with any type of irrigated crops.

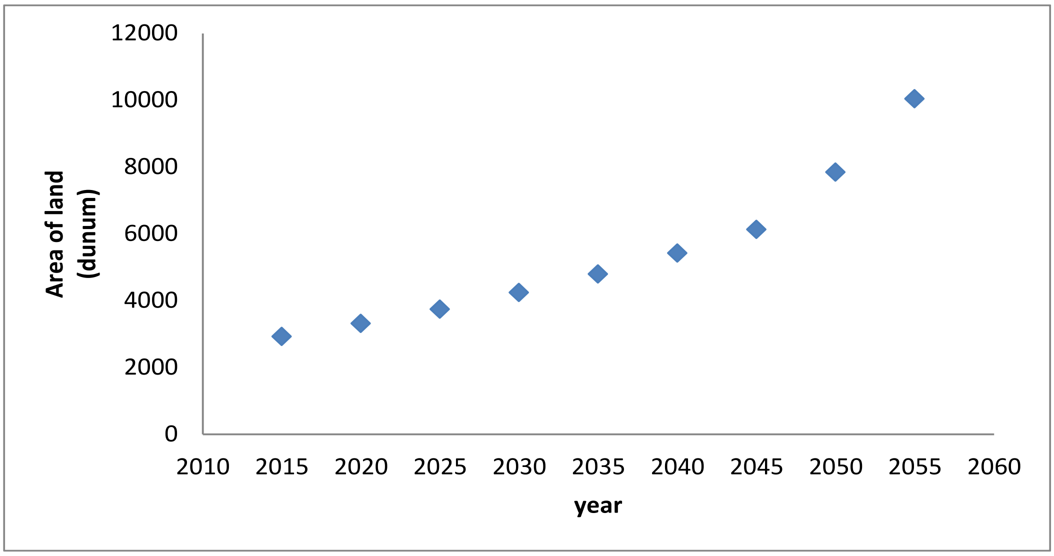


Figure 6.2: Area of lands in dunum can be irrigated by treated wastewater from Jenin plant.

6.3 Social aspects

The acceptable reused of TWW in irrigation has social benefits including the holding of wastewater-borne diseases spreading. The other benefit is the creation opportunities of new jobs in agricultural sector, it is due to increase irrigated agricultural lands, and this will increase the income of the farmer.

The farmers, technicians, operators and any person may be in contact with the TWW which used for irrigation should be trained about the safety requirements when dealing with TWW.

The acceptance of the farmer to use TWW in irrigation, and the acceptance of the people to buy crops which are irrigated with this water should be taken into account.

Chapter Seven

Conclusions and Recommendations

7.1 Conclusions

In General, according to the results obtained from this research, the following conclusions can be made.

- Jenin wastewater is concentrated with high concentration of BOD, COD, TSS and nutrients.
- The existing J-WWTP can effectively treat BOD and COD, the most restricting factor is treatment for TSS there is a problem. This restriction can be handled by managing turned on/off some surface aerators. The maximum allowable flow which can be treated is estimated of4300m^3/d. By this way; the concentration of TSS can be reduced to be within the Palestinian standard, at the same time the concentrations of BOD and COD are still less than the RT34-2012 values, this is considered as temporary solution.
- In few more years there will be an increase in the population in Jenin city. More people will be connected to the plant, more wastewater will be generated so the plant will be over loaded and upgrading is needed. Aerated lagoon can be combined with other technologies to achieve high effluent quality for the increased load to a level suitable for reuse in irrigation.
- some nitrification generally occurs in aerated lagoons. However, such nitrification is usually unpredictable and cannot be depended upon to

meet effluent limits. The reason is that the organisms responsible for nitrification are slow growers and more sensitive to environmental factors than are those that remove BOD5.

- A simple way to easily enhance J-WWTP without building new technology units is to use Floating Baffle curtains which divide the lagoon into to cells and separate reactor cells from settling cells; by this way less energy cost can be supplied.
- For upgrading the existing plant; using UASB at the beginning of the plant is considered as a sustainable way; it has high efficiency in removing BOD and COD and converted them into methane biogas which can be recovered as energy. It has high efficiency to reduce nitrate by denitrification and converting it to nitrogen gas.
- For economic aspects UASB is considered as an economic way. Capital costs for construction can be estimated as low to medium, Operation and maintenance costs are low too, due to little energy consumption.
- For environmental aspects, UASB produces amount of sludge which is approximately ~0.2 kg/kg of BOD removed. This amount is less than the amount produced by activated sludge which is (~0.8 kg/kg), and it is still less than the amount produced by anaerobic ponds.
- For complete replacement the plant; the WSP is useful and simple way for treating wastewater but it needs a very large area about 161359 m^2 and long hydraulic retention time 32 days.

7.2 Recommendations

- J-WWTP should have a laboratory inside the plant and periodic test should be carried out to monitor the quality of effluent and to ensure that it lies within the guideline limits.
- One of the important issues is to define the responsibility of monitoring the quality of treated wastewater before and after reaching the farmers in order to improve the confidence of the public to reuse the treated water.
- DO meter must be used in the aerated lagoons in order to insure the amount of DO in the lagoon.
- After treating the wastewater and before it is discharged to the farmer for irrigation, it must be stored in tanks above or underground, if the above ground is chosen, considerations have to take into account about algae growth, bacteria re-growth and evaporation losses. Using this tank is important especially when the withdrawal of TWW by framers is decreased for any reason.
- Municipality should monitor and strict regulations should be enacted to prevent illegal draining untreated wastewater into wadi Al-Muqatta.
- Municipality should monitor the working of surface aerators.
- The municipality should have the responsibility of de-sludging the accumulative sludge
- Technicians, operators, farmers and any person may be in contact with the treated water should be trained in order to be able to handle with this water.

- More research on long term impact of treated wastewater on the soil is needed.
- To limit the amount of nitrogen in soil and avoid leaching of nitrogen intercropping of alfalfa with other crops which have high nitrogen uptake is recommended, to reduce the potential for nitrate N Leaching losses.
- To plant mixed legume-grass, in this case the nitrogen fixed by legumes can be used by grass.

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Appendix (A)

Annex A1. Jenin wastewater treatment plant dimensions.

J-WWTP PROCESS			
Unit/ process	**Description**		**unit**
mechanical bar screen	number of units	1	
	Type	automatic cleaning	
	channel width	500	mm
	channel depth	1700	mm
grit chamber	number of unit	1	
Aerated lagoon (1)	number of units	2	
	Width	27	m
	Length	28.5	m
	Depth	3.8	m
	Surface area	770	m2
	Volume	2926	m3
	surface aerator number	3	
	power for each aerator	35	hp
Aerated lagoon (2)	number of units	2	
	Width	26	m
	Length	28.75	m
	Depth	3.6	m
	Surface area	750	m2
	Volume	2700	m3
	surface aerator number	4	
	power for each aerator	35	hp
polishing pond	number of units	2	
	Width	26.75	m
	Length	57.5	m
	Depth	3.3	m
	Surface area	1540	m2
	Volume	5082	m3

Annex A2. Wastewater characteristics in J-WWTP:

A2.1 Samples for calibration.
*The two lines were working
*The flow was 700m^3/d

Water characteristics								
	COD mg/l	**DO (mg/l)**	**TEMP (c^0)**	**Ammonia (mg/l)**	**TSS (mg/l)**	**BOD**	**TKN**	**TP**
Inlet	986	66.90%	13	50.5	572	680	80	39.7
AL1/Line 1	517	10.56	8.9	29.5	182	*	65.79	38.5
AL1/ Line 2	235	9.77	14	39	178	*	54.5	30.8
AL2/Line 1	157	9.53	10.3	18.5	72	*	20.07	40.6
AL2/Line2	182	11.52	10.2	7.9	69	22	22.9	31.4
P.P/Line 1	66	8.14	10.2	6.1	8	*	22.94	32.22
P.P/Line 2	*	8.62	12	5.4	18	12	19.32	34.01
inter to ANERA pond	62	**	**	3.1	15	12	28.67	20.9

A2.2 the samples used in simulation

Water characteristics		
parameters	**Inlet**	**Outlet**
Ph	7.2	6.8
BOD5 (mg/l)	742	5
COD (mg/l)	1025	113
TSS %	0.660	.06
TC (CFU/100ml	$4.6*10^5$	$2.3*10^2$
FC (CFU/100ml	$1.2*10^3$	$2.3*10^2$
E. Coli(CFU/100ml)	$1.1*10^2$	<30
Nitrate	181.3	47.4
Ammonia	92.6	42.7
TKN	76.2	35.17
EC	1027	

*One line was working
*The flow= 1700m^3/d

Annex A3 Soil samples characteristics.

المزروعات السابقة	درجة الحرارةC0	الوقت	التاريخ	اسم صاحب الأرض	رقم العينة
فجل	28.1	2:00 pm	4/5/2015	مصلح حسن مصلح	عينة 1#
شعير	34.6	2:20	4/5/2015	عماد مصلح	عينه 2#
برسيم	32.1	2:30	4/5/2015	علي ياسين صبح	عينة 3#
تبغ	30.3	2:40	4/5/2015	فاعور صبح	عينة 4#
حمضيات,سيله	29.1	2:50	4/5/2015	صلاح احمد عبيد	عينة 5#

Test	Unit	Results					Ref
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
Ag	ppm	0.96	0.46	0.54	0.57	0.81	ICP-MS*
Al	%	8.9	6.6	5.99	9.1	26.97	ICP-MS*
Ba^{-1}	ppm	183.7	137.21	127.15	155.55	846.61	ICP-MS*
Be	ppm	2.41	1.11	0.94	1.57	2.5	ICP-MS*
Bi	ppm	0.28	0.09	0.08	0.11	0.17	ICP-MS*
Ca	%	2.3	6.9	0.83	2.3	3.2	ICP-MS*
Cd	ppm	0.51	0.27	0.21	0.47	0.44	ICP-MS*
Co	ppm	25.13	15.58	8.39	16.84	26.37	ICP-MS*
Cr	ppm	168.9	51.04	68.29	104.02	96.51	ICP-MS*
Cs	ppm	1.07	1.07	0.84	1.48	2.04	ICP-MS*
Cu	ppm	32.25	22.06	11.39	17.56	27.87	ICP-MS*
Fe	%	14.1	7.1	5.3	9.4	13.7	ICP-MS*
Ga	ppm	31.51	18.05	17.04	22.55	33.5	ICP-MS*
In	ppm	0.07	0.03	0.03	0.04	0.06	ICP-MS*
K	%	0.76	0.88	0.44	0.57	0.92	ICP-MS*
Li	ppm	34.55	15.26	15.02	24.71	41.83	ICP-MS*
Mg	%	2.37	1.98	1.3	2.9	4.3	ICP-MS*
Mn	%	0.33	0.16	0.11	0.21	0.34	ICP-MS*
Mo	ppm	1.67	0.69	0.81	0.65	1.09	ICP-MS*
Na	%	0.35	0.16	0.18	0.17	0.29	ICP-MS*
Ni	ppm	54.53	29.83	18.45	36.13	55.61	ICP-MS*
Pb	ppm	14.1	11.39	6.49	9.95	15.89	ICP-MS*
Rb	ppm	19.62	31.86	22.85	33.61	48.31	ICP-MS*
Sr	ppm	214.38	108.31	53.22	95.94	127.46	ICP-MS*
V	ppm	116.73	53.31	59.78	78	115.43	ICP-MS*
Za	ppm	29.31	23.48	10.34	15.9	30.63	ICP-MS*
B	ppm	0.05	0.05	0.05	0.06	0.05	ICP-MS*

Annex A4. RT34-2012; Palestinian standards for treated wastewater reuse in irrigation.

34-2012 التعليمات الفنية الإلزامية المياه المعالجة للري الزراعي

(23/1/2012)

التعليمات الفنية الإلزامية 34-2012

المياه المعالجة للري الزراعي

(2012/1/23)

مقدمة

تهدف هذه التعليمات الفنية الإلزامية إلى ما يلي:

(1) وضع أسس لاستخدام المياه المعالجة للري الزراعي بشكل لا يضر بصحة الإنسان والحيوان وبالمزروعات.

(2) ضمان أن لا تشكل المياه المعالجة للري الزراعي ضررا على العناصر البيئية من تربة ومياه وهواء.

مادة (1)

المجال

تسري أحكام هذه التعليمات على المياه المعالجة الخارجة من محطات المعالجة بهدف استخدامها للري الزراعي.

مادة (2)

تعريفات

لغايات تطبيق أحكام هذه التعليمات يكون للكلمات والعبارات التالية المعاني المخصصة لها أدناه، ما لم تدل القرينة على خلاف ذلك:

2-1 الجهة المختصة: الجهة أو الجهات التي يحددها مجلس الوزراء لتنفيذ أحكام هذه التعليمات بموجب المادة (23) من قانون مؤسسة المواصفات والمقاييس والقوانين السارية الأخرى ذات الصلة.

2-2 المستخدم: شخص أو مقاول أو منشأة حكومية أو اهلية أو خاصة تستخدم أو تستفيد من المياه المعالجة للري الزراعي.

2-3 المياه العادمة: هي المياه الملوثة بمواد فيزيائية أو كيميائية أو بيولوجية أو إشعاعية ونتجت أو تخلفت عن استخدام المياه للأغراض المنزلية أو الصناعية أو التجارية أو الزراعية بحيث أصبحت تشكل خطورة عند إعادة استخدامها أو صرفها بشكل مخالف لأحكام القوانين السارية ذات الصلة.

صفحة (1) من (5)

2-4 الحدود القصوى: هو الحد الأقصى من تركيز المادة الملوثة المسموح بوجودها في المياه المعالجة وفقاً للحدود القصوى المذكورة في هذه التعليمات.

2-5 المياه المعالجة: هي المياه العادمة التي يتم التخلص من بعض أو جميع العوالق والرواسب والمواد المذابة فيها بالطرق الطبيعية أو الميكانيكية أو الكيميائية أو البيولوجية (الحيوية) سواء منفردة أو مجتمعة والتي لا تتجاوز مستوياتها الحدود القصوى المذكورة في هذه التعليمات.

2-6 محطة معالجة المياه العادمة: مجموعة المنشآت والأجهزة المعدة لمعالجة المياه العادمة بالطرق الطبيعية والميكانيكية والبيولوجية والكيميائية بهدف تحسين خواص المياه العادمة لإعادة استخدامها أو التخلص منها دون أيه أضرار صحية وبيئية.

مادة (3)

تصنف المياه المعالجة لأغراض الري الزراعي حسب جودتها إلى التصنيفات الواردة في ملحق (1).

مادة (4)

يشترط لاستخدام المياه المعالجة لأغراض الري الزراعي ما يلي:

(أ) مطابقتها لهذه التعليمات وخاصة الملحق (1).

(ب) موافقة الجهة المختصة بالري الزراعي على هذا الاستخدام وفق تعليمات صادرة عنها لهذه الغاية بما لا يتعارض مع اشتراطات هذه التعليمات.

مادة (5)

5-1 يجب أن تنقل المياه المعالجة لأغراض الري الزراعي بأنابيب ملائمة مغلقة ومميزة باللون البنفسجي ومطابقة للمواصفات الفلسطينية المعنية.

5-2 في حال نقل المياه المعالجة لأغراض الري الزراعي باستخدام مركبات الصهاريج، يجب أن تكون هذه الصهاريج مدهونة باللون البنفسجي ويكتب عليها عبارة "مياه معالجة للري الزراعي"، وذلك بخط مقروء وواضح من الجهتين.

مادة (6)

يجب على الجهة المختصة وضع تعليمات تشرح التدابير الوقائية الواجب اتخاذها داخل المزارع عند التعامل مع المياه المعالجة للري الزراعي.

مادة (7)

يجب على الجهة المختصة مراقبة جودة المياه المعالجة للري الزراعي من خلال تطبيق نظام المراقبة المذكور في المواصفة الفلسطينية رقم 742.

مادة (8)

يحظر استخدام المياه المعالجة للري الزراعي في:

(أ) سقاية المواشي والدواجن.

(ب) ري جميع أنواع الخضار.

(ت) تغذية المياه الجوفية عن طريق الحقن المباشر.

(ث) الاستزراع السمكي.

مادة (9)

لا يجوز للمستخدم التصرف في المياه المعالجة للري الزراعي في استخداماتٍ غير تلك التي حددتها الجهة المختصة بالري الزراعي.

مادة (10)

عند وجود تعارض مع وثائق رسمية صادرة عن جهات أخرى، يجب تعديل تلك الوثائق بما ينسجم مع هذه التعليمات.

مادة (11)

تسري هذه التعليمات اعتباراً من تاريخ المصادقة عليها والإعلان عنها.

مادة (12)

في حال ظهور أي خلاف في تفسير أحد نصوص هذه التعليمات، فإنه يجب اعتماد التفسير الصادر عن لجنة التعليمات الفنية الإلزامية.

مادة (13)

على الجهة المختصة أن تضع خطة لتطبيق جميع احكام هذه التعليمات بحيث تتضمن مراحل التطبيق والموارد المطلوبة لتنفيذها على أن لا تتجاوز مدة هذه الخطة عن ثلاث سنوات من سريان هذه التعليمات.

ملحق (1)

تصنيف المياه المعالجة حسب جودتها

الحدود القصوى للخصائص الكيميائية والبيولوجية (ملغم/لتر) ما لم يذكر غير ذلك	جودة المياه المعالجة			
	جودة عالية (A)	جودة جيدة (B)	جودة متوسطة (C)	جودة متدنية (D)
الأوكسجين الممتص حيوياً BOD_5	20	20	40	60
المواد العالقة الكلية TSS	30	30	50	90
بكتيريا قولونية برازية FC (مستعمرة/100مل)	200	1000	1000	1000
الأوكسجين الممتص كيميائياً COD	50	50	100	150
الأكسجين المذاب DO	1<	1<	1<	1<
المواد الذائبة الكلية TDS	1200	1500	1500	1500
الرقم الهيدروجيني pH	9-6	9-6	9-6	9-6
الدهون والزيوت والشحوم Fat, Oil & Grease	5	5	5	5
الفينول Phenol	0.002	0.002	0.002	0.002
المنظفات الصناعية MBAS	15	15	15	25
النترات- نيتروجين NO_3-N	20	20	30	40
الأمونيوم- نيتروجين NH_4-N	5	5	10	15
النيتروجين الكلي Total-N	30	30	45	60
الكلوريد Cl	400	400	400	400
الكبريتات SO_4	300	300	300	300
الصوديوم Na	200	200	200	200
المغنيسيوم Mg	60	60	60	60
الكالسيوم Ca	300	300	300	300
نسبة ادمصاص الصوديوم SAR	5.83	5.83	5.83	5.83
الفوسفات - فسفور PO_4-P	30	30	30	30
الألمنيوم Al	5	5	5	5
الزرنيخ As	0.1	0.1	0.1	0.1
النحاس Cu	0.2	0.2	0.2	0.2

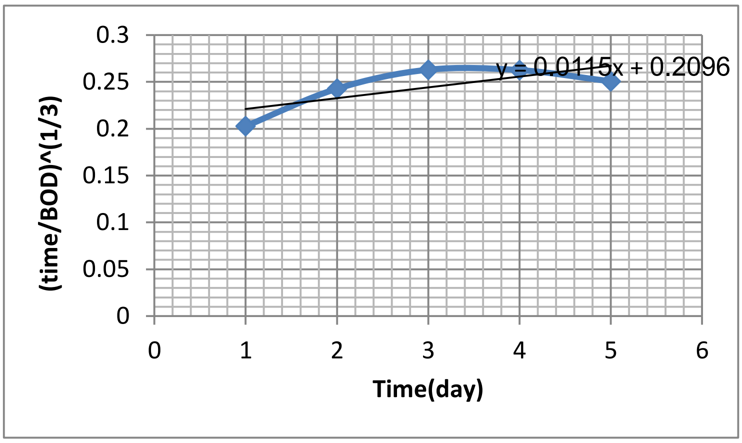
الحدود القصوى للخصائص الكيميائية والبيولوجية (ملغم/لتر) ما لم يذكر غير ذلك	جودة المياه المعالجة			
	جودة عالية (A)	جودة جيدة (B)	جودة متوسطة (C)	جودة متدنية (D)
الحديد Fe	5	5	5	5
المنغنيز Mn	0.2	0.2	0.2	0.2
النيكل Ni	0.2	0.2	0.2	0.2
الرصاص Pb	0.2	0.2	0.2	0.2
السيلينيوم Se	0.02	0.02	0.02	0.02
الكادميوم Cd	0.01	0.01	0.01	0.01
الزنك Zn	2	2	2	2
السيانيد CN	0.05	0.05	0.05	0.05
الكروم Cr	0.1	0.1	0.1	0.1
الزئبق Hg	0.001	0.001	0.001	0.001
كوبالت Co	0.05	0.05	0.05	0.05
البورون B	0.7	0.7	0.7	0.7
بكتيريا *E. coli* (مستعمرة/100مل)	100	1000	1000	1000
بيوض الديدان المعوية Nematodes (Eggs/L)	1≥	1≥	1≥	1≥

Appendix B

Annex B1. Decay factors for aerated lagoons.

❖ **For the first Aerated Lagoon**:

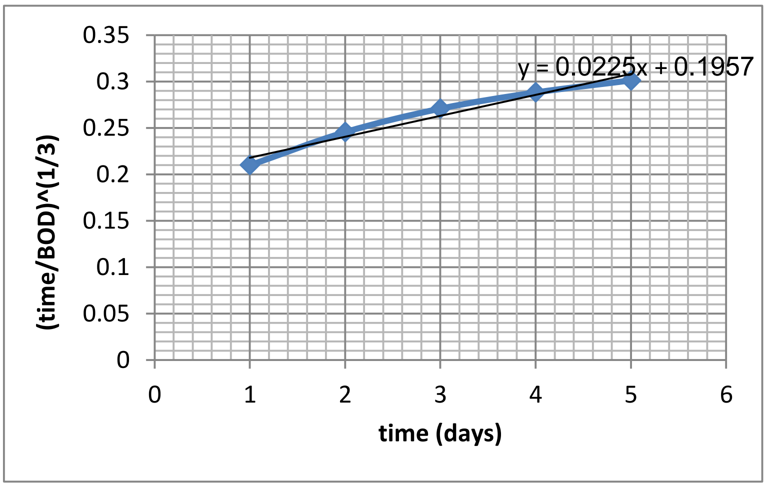
Time	BOD
1	120
2	140
3	165
4	221
5	318



BOD removal rate for the AL#1=0.329198473

❖ **For the second Aerated Lagoon:**

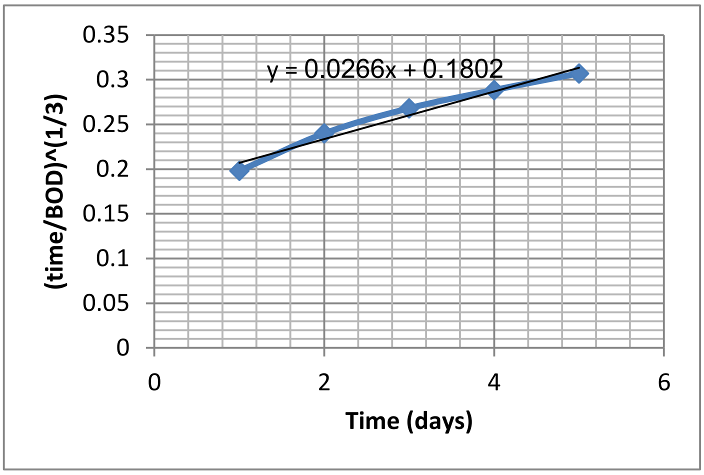
Time(day)	BOD
1	180
2	135
3	151
4	167
5	183



BOD removal rate for thefor AL#2= 0.689831375

- **For the polishing pond:**

Time	BOD
0	0
1	129
2	145
3	156
4	167
5	173



BOD removal rate for

polishing pond =0.885682575

Annex B2. Adjusted model parameters:

Completely mixed tank	Heterotrophic max specific growth	5.0	1/d
	Ammonia (as nutrient) half saturation coefficient	0	mgN/l
	Nitrate half saturationcoefficient	1.0	mgN/l
	Heterotrophic decay rate	1.0	1/d
	Ammonia as substrate half-saturation coefficient	0.1	mgN/l

Annex B3. Design calculation.

UASB with the existing plant			
Process type	**Design**		**unit**
Primary sedimentation tank	Number of unit	2	
	Area	153.86	m^2
	Diameter	14	m
	Depth	2.5	m
	HRT	1.7	h
	Surface over flow rate	38.68	$m^3/m^2.d$
UASB	Volume	1231	m^3
	Depth	8	m
	HRT	5.8	h
	Size of granulated sludge particles	2	mm
	Volumetric loading	3.56	Kg $COD/m^3.d$
Secondary sedimentation tank	Number of unit	2	
	Area	176.68	m^2
	Diameter	16	m
	Depth	3	m
	Surface over flow rate	28.47	$m^3/m^2.d$
thickener	Number of unit	1	
	Surface area	120	m^2
	Depth	3	m
Anaerobic digester	Number of unit	1	
	Volume	2000	m^3
	Head space volume	20	m^3
	Depth	3.5	days
AS with the existing plant			
Process type	Design		unit
AS	AS tank	2	
	Volume	1200	m^2
	Depth	4	m
	F/M	0.233	hr.
	Recycle ratio	61%	$m^3/m^2.d$
	Number	2	
	Area	132.6	m^2

Secondary sedimentation tank	Depth	3	m
	HRT	2	hr.
IFAS			
process type	Design		unit
Primary sedimentation tank	Number of unit	1	
	Area	200.96	m^2
	Diameter	16	m
	Depth	2.5	m
	HRT=	1.4	hr.
	Surface over flow rate	48.2	$m^3/m^2.d$
Anaerobic/ anoxic tank	Volume	1500	
	F/M	1.2	
	Recycle %	200	%
Aerobic tank	Volume	1400	m^3
	Total air	11660	$m^3/hr.$
	OTR	181.3	g/m^3
	F/M	0.2	
Secondary sedimentation tank	Number of unit	1	
	Area	254	m^2
	Diameter	18	m
	Depth	3	m
	Surface over flow rate	41.2	$m^3/m^2.d$
thickener	Number of unit	1	
	Surface area	20	m^2
	Depth	3	m
Anaerobic digester	Number of unit	1	
	Volume	500	m^3
	Head space volume	20	m^3
	HRT	10	days
UASB with AS			
process type	Design		unit
Primary sedimentation tank	Number of unit	2	
	Area	132.66	m^2
	Diameter	13	m
	Depth	2.5	m
	HRT=	1.5	hr.
	Surface over flow rate	39.45	$m^3/m^2.d$

UASB	Number of unit	2	
	Volume	1231	m^3
	Depth	10	m
	HRT	5.8	h
	Size of granulated sludge particles	2	mm
	Volumetric loading	3.56	Kg $COD/m^3.d$
intermediate sedimentation tank	Number of unit	2	
	Area	132.68	m^2
	Diameter	13	m
	Depth	2.5	m
	Surface over flow rate	38.02	$m^3/m^2.d$
	HRT	1.51	h
Aeration tank	Number of unit	2	
	Volume	1000	m^3
	Depth	4	m
	F/M	0.21	
	Total air flow	1929	m^3/h
	Recycle	39.64	%
Secondary sedimentation tank	Area	132.68	m^2
	Depth	2.5	m
	HRT	1.13	h
	Over flow rate	37.73	$m^3/m^2.d$
	RAS flow	2000	m^3/d
	WAS flow	40	m^3/d
thickener	Number of unit	2	
	Surface area	40	m2
	Depth	3	m
	Hydraulic loading rate	40	$m^3/m^2.d$
Anaerobic digester	Number of unit	2	
	Volume	2000	m3
	Head space volume	20	m3
	Depth	3.5	m

Comparison between different technology systems which are used in the research.

<table>
<tr><th colspan="3">UASB technology</th></tr>
<tr><td rowspan="2">Working mechanism</td><td>Description</td><td>Results from design</td></tr>
<tr><td>The wastewater is flow to the bottom part of UASB tank. The anaerobic microorganism which lives in granules degrades the organic pollutants under anaerobic conditions. The suspended sludge blanket formed gas bubbles; this gas is separated at the top and used biogas for energy production . The accumulation of Sludge is low.</td><td>Two tanks each with volume of 1230m^3, connected in parallel. UASB convert the organic component into methane gas; the main components of this gas are: nitrogen, methane and CO2.</td></tr>
<tr><td>Performance</td><td>▪ It has high efficiency in remove BOD approximately from 60 -90 % , efficiency in removed COD 60 – 80% And approximately 60 to 85 % of TSS
▪ It has minimum of phosphorus and nitrogen.
▪ Hydraulic retention time is from 4-20 hrs .</td><td>The % removal in UASB
• % BOD = 82.5%
• %COD = 73%
• High % removal of nitrate
• But for ammonia, TKN and phosphor the % is low.
• Gas production from each UASB in proposed design=712.3 m^3/d
• HRT=5.9hr</td></tr>
<tr><td>Main advantages</td><td colspan="2">from simulation of UASB for JWWTP the main advantages which observed, based on the influent characteristics of J-WWTP :
• High efficiency removal of BOD, COD and nitrate.
• Small amount of sludge is produced.
• UASB produces amount of gas which can be recovered as energy.</td></tr>
<tr><td>Main Disadvantages</td><td colspan="2">Low efficiency in P, TKN and ammonia removal.</td></tr>
</table>

<table>
<tr><th colspan="3">Integrated Film Activate Sludge</th></tr>
<tr><td rowspan="2">Working mechanism</td><td>Description</td><td>Results from design</td></tr>
<tr><td>It is process like activated sludge with some differences like the fixed biomass joins three zones: aerobic, anaerobic and anoxic.
this combination well increase sludge retention time</td><td>Two tanks linked together one of them are anaerobic /anoxic and the other one is aerobic tank
The volume of each one is 1000m^3, followed by sedimentation tank with recycle fraction=2.</td></tr>
<tr><td>Performance</td><td>It is a high technology and used for extensive removal of nitrogen</td><td>• It can remove approximately 70 % of ammonia and 68.2% of TKN nitrogen.</td></tr>
<tr><td>Main advantages</td><td colspan="2">from simulation of IFAS for J-WWTP the main advantages which observed are:
• High efficiency of nitrogen removal.
• High efficiency of BOD, COD, TSS removal.
• Small area of land is needed.</td></tr>
</table>

Conventional Activated sludge		
	Description	**Results from design**
Working mechanism	In this process wastewater is mixed with active bacteria. In order to dispose the pollutants from wastewater used them as food and produce new cells. Nitrification and Denitrification processes are used to remove nitrogen; phosphorus is removed biologically, chemically or disposed in the sludge.	• Volume= 1200m^3 • 4 reactors, depth= 4m • MLSS =2538mg/l within the range of conventional AS (1500-3500) mg / L • F/M=0.22 within the range of (0.2-0.5)
Performance	It has high efficiency to remove TSS and BOD approximately from 80-100% It has ability to remove nitrogen	% removed of: • %TSS=78 • %BOD= 85 • %ammonia= 92% • %TKN=51%
Main advantages	from simulation of AS for JWWTP the main advantages which observed are • High efficiency in removed of BOD, COD, Nitrogen. • It is a good to use in highly polluted areas.	
Main disadvantages	• It cannot use directly when high loading of BOD. • Large amount of sludge is produced. • Low % removal of nitrate.	

Aerated lagoon		
	Description	**Results from design**
Working mechanism	It is a pond using surface aerators to enhance the mixing of the air with water and increase the efficiency of the treatment, with high pathogen removal	Two aerated lagoon with 3 surface aerator in the first one and 4 surface aerators in the second each surface aerator has a power = 35 hp
Performance	• Reliable in BOD removal approximately 70 to 90 % BOD • HRT: 2 to 4 day	• BOD removal= 87% • HRT= 5days
Main advantages	from simulation of AL main advantages which observed are : • High efficiency removal of BOD, and COD. • simple process. From laboratory results AL is effective in remove fecal coliform. • The growth of microalgae gives additional treatment.	
Main disadvantages	• Less effective in remove P and N • Consume energy.	

<table>
<tr><th colspan="3">Waste Stabilization pond</th></tr>
<tr><td rowspan="2">Working mechanism</td><td>Description</td><td>Result from design</td></tr>
<tr><td>It consists three types of ponds:
Anaerobic pond: in this pond sludge is formed in bottom of the pond due to anaerobic microorganism
The second type is facultative pond, this pond depends on microalgae cultures growing on its surface this algae using nutrients for growth
The third pond is aerobic pond using solar light for disinfection.</td><td>Three ponds
A1= 3339m^2
A2=94446 m^2
Am1=28421 m^2
Am2=27998 m^2
Total area= 161359 m^2</td></tr>
<tr><td>Performance</td><td>• It has high efficiency in removed BOD approximately 90%, for TSS and pathogen.
• Less efficiency in removed nutrient like ammonia and phosphorus
• HRT: 20 to 60 days</td><td>Effluent E coli = 205.3264</td></tr>
<tr><td>Main advantages</td><td colspan="2">• Very simple process
• High efficiency in remove BOD, TSS and pathogens</td></tr>
<tr><td>Main disadvantages</td><td colspan="2">• Large surface areas
• Long total hydraulic retention time
• Not very suitable for concentrated wastewater</td></tr>
</table>

جامعة النجاح الوطنية
كلية الدراسات العليا

التحسينات المستدامة لمحطة معالجة مياه الصرف الصحي في جنين

إعداد
لمى قاسم أسمه

إشراف
د.عبد الفتاح حسن
د. نعمان مزيد

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس – فلسطين.
2016

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الملخص

محطة تنقية المياة العادمة في مدينة جنين هي واحدة من أكبر خمس محطات في الضفة الغربية، تم انشاؤها عام 1970،وتم ترميمها عدة مرات حتى الان، تحوي على تقنيات بسيطة وهي البرك الهوائية تحوي على هوايات وبالاضافة الى برك ترسيب.

الهدف من هذا البحث هو تقييم اداء محطة جنين لمعالجة المياة العادمة في مدينة جنين عن طريق جمع عينات منفصلة ومركبة من مناطق مختلفة داخل المحطة، وتحليلها في المختبر فيزيائيا وكميائيا وبيولوجيا، من أجل البحث في الخيارات المستدامة لتحسين نوعية مياه الصرف وامكانية استخدامها في الري .

بينت نتائج فحص العينات ان مياة الصرف الصحي في جنين تحوي تراكيز عالية من طلب الأكسجين البيوكيميائيBOD، طلب الأكسجين الكميائي COD , والمواد الصلبة العالقة TSS .

تم استخدام برنامج الحاسوب GPS-X لنمذجة وحدات المحطة، نتائج العينات تم استخدامها في بناء نموذج المحطة ومعايرته.عندما تم الانتهاء من معايرة النموذج، أجريت دراسات لسيناريوهات مختلفة.

محطة تنقية جنين تستطيع معالجة BOD and COD بطريقة جيدة وكفاءة عالية، لكن يتم معالجة TSS بكفاءة أقل وذلك بسبب تشغيل هوايات البرك الهوائية بشكل عشوائي. لكن اذا تم ادارة التهوية داخل البرك بالشكل الصحيح فان المحطة تستطيع معالجة كمية اكبر من الماء حوالي 4300م^3/يوم, وهذا يعتبر حل مؤقت للمحطة، لأن المحطة سوف تستقبل كمية ميا صرف صحي اكبر خلال السنوات القليلة القادمة وذلك نظرا لزيادة عدد سكان محافظة جنين، بالتالي ربط عدد اكبر من الناس على المحطة، فستستقبل المحطة كمية مياة صرف صحي اكبر من قدرتها, وبالتالي فان هناك حاجة لتطوير المحطة.

وهذا التحسين يمكن ان يتم بطريقتين :

اما تحسين المحطة نفسها باضافة بعض وحدات التنقية الهوائية او الغير هوائية لها مثل

Upflow Anaerobic Sludge Blanket or Activated sludge

او ان يتم استبدال المحطة كليا باحدى التقنيات التاليه :

Waste stabilization ponds, integrated fixed film activated sludge or combination between Upflow Anaerobic Sludge Blanket and Activated sludge.

تعتبر UASB طريقة اقتصادية لتطوير المحطة ، لها قدرة عاليه للتخلص من BOD and COD والنيترات, بينما AS مع المحطة الحالية سوف يحفز ازالة النيتروجين وCOD .

يمكن استبدا المحطة كاملة ب Waste Stabilization Pond وهي طريقة سهلة ومفيدة لمعالجة المياة العادمة، لكن مشكلتها انها بحاجة الى مساحة ارض واسعة ووقت احتجاز هيدروليك طويل.