An-Najah National University

Faculty of Graduate Studies

Exploratory Study on the Performance of Newly Constructed Nablus West Wastewater Treatment Plant under Different Load Conditions

By

Mohammed Abdul-Fattah Ibrahim Saleh

Supervisors

Dr. Abdel Fattah Hasan

Prof. Marwan Haddad

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This Thesis was defended successfully on 30 / 4 /2014 and approved by:

Defense Committee Members		**Signature**
–Dr. Abdel Fattah Hasan	(Supervisor)	....
–Prof.Dr. Marwan Haddad	(Co-supervisor)	....
–Dr. Fathi Anayah	(External examiner)	....
–Dr. Hafez Shaheen	(Internal examiner)	....

اقرار

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Student's Name: **اسم الطالب:**

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List of Abbreviations

AS	Activated Sludge
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
Hrs.	hours
MAX	Maximum
MCRT	Mean Cell Residence Time
MIN	Minimum
NW-WWTP	Nablus-West Wastewater Treatment Plant
PCBS	Palestinian Central Bureau of Statistics
PWA	Palestinian Water Authority
RAS	Recirculated Activated Sludge
SS	Suspended Solids
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant

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Abstract

Nablus is the largest city in the north of West Bank. It consists of two catchments; western and eastern. therefore. Two wastewater treatment plants were proposed to treat Nablus wastewater. The western plant were constructed and operated, while the eastern plant is still under planning.

Nablus-West Wastewater Treatment Plant (NW-WWTP) was designed to treat 3 million cubic meter of wastewater, where the produced effluent is planned to be reused in agricultural activities.

Two challenges face treatment plant operators in Palestine: Lack of Information and skills in operation and maintenance of treatment plants, and the wide range variability of wastewater characteristics which received by the treatment plants.

This thesis aims at studying the performance of Nablus-West Wastewater Treatment Plant (NW-WWTP) under different load conditions. This research depended on a computer model to simulate the operation of treatment plant. All input data such as influent characteristics, treatment plant processes,..etc. were collected from the concerned agencies. The computer program STOAT (WRC, 2010) was used to achieve research goals.

One of simulation problems is the initial conditions of the treatment plant. Dynamic simulation was used to ignore those effects. The simulation period required 63 days (1512 hours) to reach the dynamic equilibrium.

The modeled and studied cases were: performance of NW-WWTP based on the designer values, cases of some hydraulic equipment's malfunctioning such as malfunctions of return activated sludge pumps, wastage activated sludge pumps, and completely one line malfunctioning. In addition, effects of variable pollutant loads from the most industrial activities in Nablus city on the treatment plant performance, were simulated and studied.

The model was calibrated based on data received from the treatment plant laboratory.

In case of exploring the performance of NW-WWTP by applying the design values for wastewater influents, the treatment plant expected to achieve about 98% COD removal, Nitrification to occur and 81% for ammonia were nitrified., total phosphorous in the effluent reached a value of 20mg/l without any changes on influent concentration.

The treatment plant efficiency under the effect of malfunctioning cases varied from case to another. The worst case scenario expected to decrease to 61% COD removal.

The efficiency of the treatment plant will varied from 63% during the olive oil season to 74.3% in the off seasons.

Finally, a list of problems and their remedial actions were set in management plan to be employed for solving the problems that can occur due to the studied cases. One of the studied problems is foaming in activated sludge tanks that results in presence of scum on the surface of the aeration tank. One of the possible causes is the highly content of foaming agents and/or oils and greases in the incoming wastewater. The suggested remedial actions are: foam removal through water sprinkling and/or chlorine dosage.

Another studied problem is the elevated concentration of suspended solids in the secondary clarifier effluent. The possible causes of this phenomena are: bad sludge settling characteristics, high overflow rate, or not properly functioning of the scraper. The suggested remedial actions are: to enhance the weir layout and eventually place some screen wind, or increase the sludge extraction and sludge recycle flow to aeration tanks.

Chapter One

Introduction

1.1 Background

The traditional aim of wastewater treatment is to enable wastewater to be disposed safely, without being a danger to public health and without polluting watercourses or causing other nuisance. Increasingly another important aim of wastewater treatment is to recover energy, nutrients, water, and other valuable resources from wastewater (Michael and Butler, 2011).

Decision makers should concern the construction and improvements of wastewater treatment plants, and sewerage systems in the region. Currently the Percentage of households in Palestine connected to sewer networks is approximately 55% while cesspits and septic tanks receive the rest (PCBS, 2012).

Nowadays, approximately 50% of water used in the West Bank (90 million cubic meter per year) is used for agricultural activities, all of which fit for drinking purposes (Ben Ari, 2012). Treated wastewater reuse can substitute the fresh water for agriculture and industrial uses in addition to groundwater aquifer recharge.

Palestinian Water Authority (PWA), as a regulatory body for water in Palestine, planned to operate and build 6 wastewater treatment plants in Al Bireh, Hebron, Salfit, Nablus, and Gaza Northern Governorate. Almost all of those plants are to be activated sludge.

There is a significant interest in using process models for WWTP design to verify if designed processes can match the standard guidelines, and effluents meet the standards (Corominas et al., 2010). Moreover, WWTP models are used for continuous improvement of treatment processes and its alternatives through optimization and to solve treatment malfunctions for plants robust operation.

This research is to explore the performance of the Nablus-West wastewater treatment plant (NW-WWTP) under different hydraulic and pollutant loadings.

To achieve this, a model for Nablus wastewater treatment plant had been built and different scenarios were modeled.

The importance of this research comes from the Lack of knowledge and skills in operation and maintenance of treatment plants in Palestine, and particularly Nablus city.

1.2 Objectives

Objectives of this research are:

1. To develop a model for the recently constructed wastewater treatment plant in the West of Nablus (NW-WWTP).
2. To check if the designed processes of NW-WWTP can produce effluent that meets the Palestinian Guidelines for wastewater reuse (Mizyed, 2013; Appendix A6).
3. To detect the effect of different sudden hydraulic and pollutant loads on the performance of NW-WWTP

4. To propose a management plan to deal with treatment processes' malfunctions that may occur due to different sudden loads.

1.3 Study Area

Nablus is one of the largest cities in the West Bank, featuring also industrial and commercial activities. It is embedded in the saddle of Nablus Valley which forms the watershed between the Mediterranean and the Dead Sea in respect of both, surface and subsurface streams. The western part of the city drains via Wadi Zeimar to the Alexander River and from there to the Mediterranean Sea, the eastern part via Wadi Sajour to the Jordan Valley. Within the Zeimar Basin, stretching from Nablus to Tulkarem are two groundwater horizons encountered: The Eocene Aquifer (upper horizon) contributing to the Northern Mountain Aquifer and the Western Cenomanian (lower horizon) contributing to the Western Mountain Aquifer. The Sajour Basin forms part of the catchment area of the Eastern Cenomanian Aquifer, which contributes to the Eastern Mountain Aquifer.

Nablus (presently 198,000 inhabitants including 4 refugee camps) is the largest urban center of the northern West Bank. The city center is located in the valley between the hills of north Eibal (940 m) and south Gerizim (881 m) mountains. The difference in topographical elevation within the city limits exceeds 300 m (Nablus Municipality, 2008).

The sewerage network of Nablus was constructed in the past 50 years and has a total length of almost 160 km. The connection rate is estimated as 95 %. The remaining population uses cesspits or discharges the sewage directly to nearby wadis. In general, the wastewater effluent from Nablus city is heavily contaminated with pollutants because of the industrial activates wastes, and can be classified as high strength municipal wastewater (Metcalf and Eddy, 1922). Table (1) shows general wastewater characteristics for Nablus.

Table 1: Raw wastewater characteristics for Nablus city (Khalili,2007).

Parameter	Concentration (mg/l)
BOD (Biochemical Oxygen Demand)	600
COD (Chemical Oxygen Demand)	1400
TSS (Total Suspended Solids)	800
Chloride	2000-9000
Total Phosphorus	60
Total Nitrogen	150

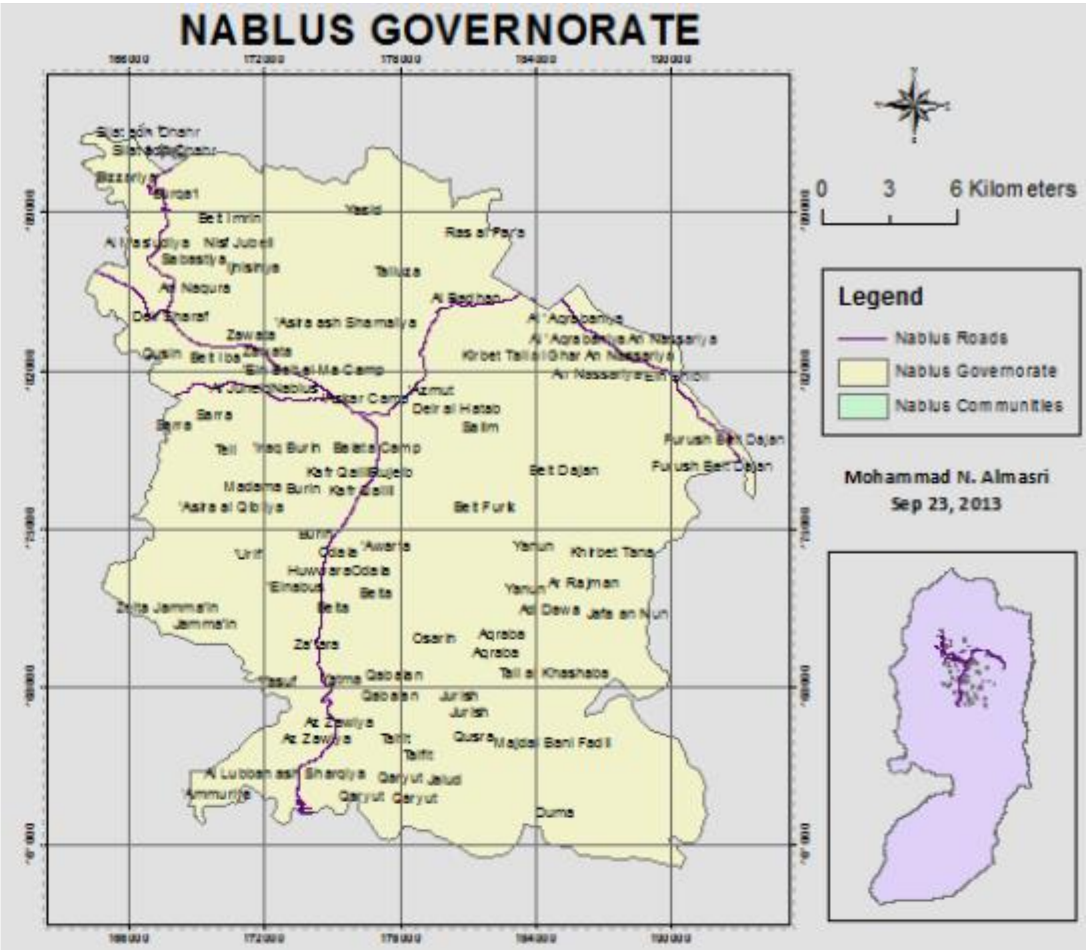

Figure 1:Nablus Governorate

1.4 Overview of Nablus-West Wastewater Treatment Plant (NW-WWTP)

Nablus city has two catchments, so wastewater flows by gravity into wadis in the West and East parts of the city.

For the Western area, the construction of a wastewater treatment plant (WWTP) had begun under the German-Palestinian Financial Cooperation project "Nablus West Sewerage in Dir Sharaf' village” and planned to treat three million cubic meters of raw sewage, where effluent is to be reused for agricultural purposes.

The project also deals with the connection of villages in the upper Wadi Zeimar namely:

- Beit Wazan, and Zawata which connected to the Nablus West sewerage system;
- Beit Eba, Qusin, and Deir Sharaf which connected to the western inceptor up to the plant (Nablus Municipality, 2008).

Three construction stages have been planned for the Nablus-West WWTP to meet design flow in 2020, 2025 and 2035, and to include physical, biological and sludge treatment stages.

The design values of influent and effluent of wastewater characteristics are presented in Tables 2 and 3 (Nablus Municipality, 2011).

The process units have been arranged in a modular way to easily allow future extensions of the WWTP in order to cope with the predicted extension of the treatment capacity as well as with changes of designed effluent concentrations (Figure2).

Table 2. Design influent wastewater characteristics for Nablus WWTP.

Loads and concentration	2020	2025	2035
BOD_5 (kg BOD_5 /d) / (mg/l)	8,350 / 562	12,375 / 628	16,700 /610
COD (kg COD/d) / (mg/l)	16,500/1,110	24,750/1,256	33,000 / 1,205
SS (kg SS/d) / (mg/l)	9,625 / 648	14,438 / 733	19,250 / 703
Total Nitrogen (kg TKN/d) /(mg/l)	1,654 / 111	2,081 / 106	3,310 / 121
P Total (kg P/d) / (mg/l)	269 / 18	341 / 17	538 / 20

Table 3. Nablus WWTP designed effluent concentrations.

Loads and concentration	2020	2025	2035
BOD_5 (mg/l)	≤ 20 mg/l	≤ 10 mg/l	≤ 10 mg/l
COD (mg/l)	--	≤ 70 mg/l	≤ 70 mg/l
SS (mg/l)	≤ 30 mg/l	≤ 10 mg/l	≤ 10 mg/l
Total Nitrogen (mg/l)	--	≤ 25 mg/l	≤ 25 mg/l
Fecal Coliform	--	≤ 10 /100ml	≤ 10 /100ml

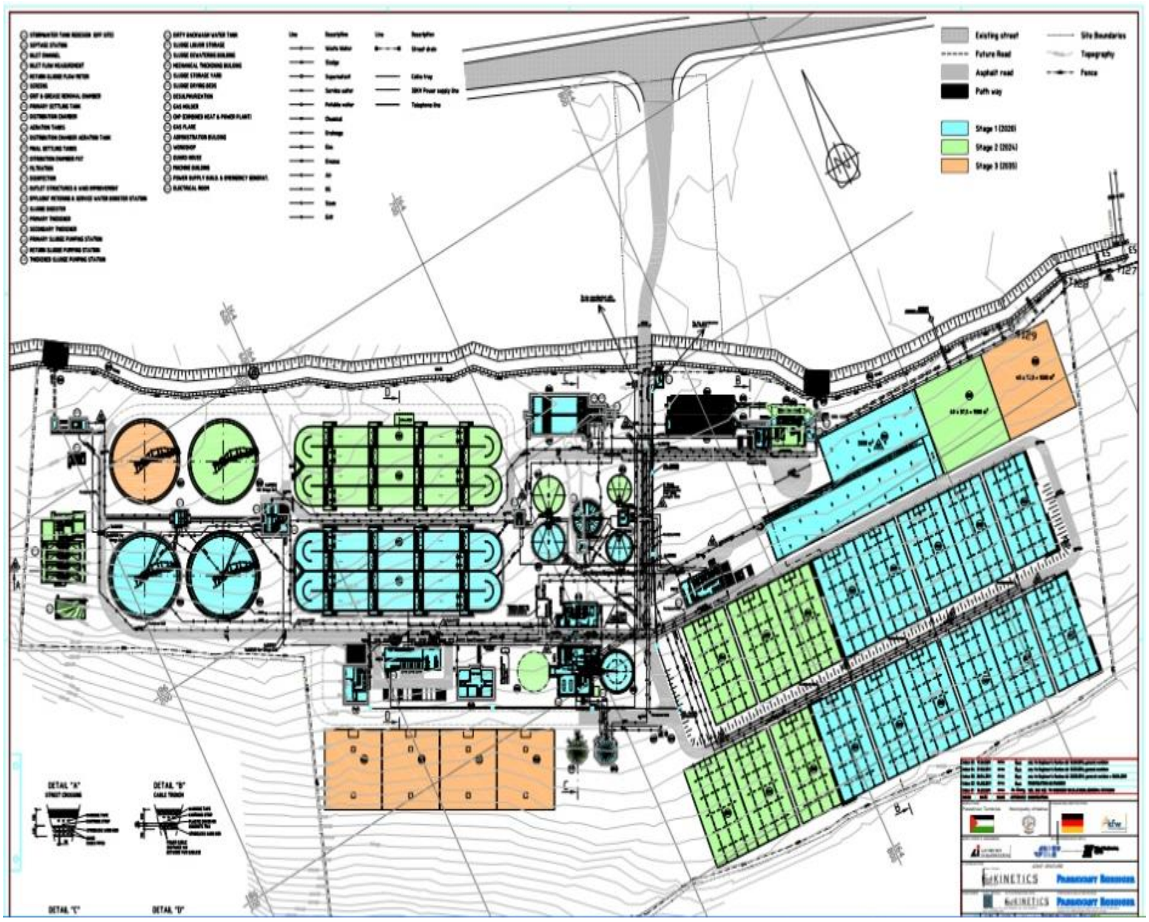

Figure 2: Layout of Nablus-West WWTP

The feasibility study for the construction of Nablus- East wastewater treatment plant had already done, and the bidding documents for pant design were tendered.

Chapter Two
Methodology

2.1 General

Wastewater Treatment Plant modeling is a useful tool for performing plant capacity assessments and improving plant operations; therefore, saving energy and chemical costs (Tijerina and Chiang, 2005).

This research tried to model Nablus-West wastewater treatment plant (NW-WWTP) and to study the treatment plant performance under different sudden loads and scenarios and to suggest operation plan to deal with each modeled case.

2.2 Research Methodology

In order to achieve the objectives of this work, the following research methodology has been adapted:

2.2.1 Data collection

- Data needed to complete this research such as: influent flow, expected effluent, treatment plant processes…etc. were collected from relevant agencies such as: PWA, Nablus Municipality, and the staff in the NW-WWTP. The collected data
- Scientific data such as: definition of process parameters were collected from literature.

2.2.2 Wastewater Quality Determination

Quality parameters needed as inputs to the model have been determined by collecting the data from NW-WWTP laboratory. Samples were collected daily from the the plant’s influent and effluent and analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2003) for:

- BOD_5.
- COD.
- TS/TSS.
- Ammonia.
- Total Phosphorus.

2.2.3 Software selection

Many programs are dealing with wastewater treatment plant modeling(Table 4). STOAT program was chosen because it is free, and capable to achieve the objectives of this research. STOAT can deal with two sides: wastewater and sludge treatment.

2.2.4 Modeling by STOAT

The wastewater treatment plant modeling is a critical point in this research, so the following points were considered:

2.2.4.1 Treatment plant modeling steps:

1. Determining model goals.

   The goal is to model NW-WWTP and to study the proposed treatment plant performance under different loads.

2. Data analysis.

   The collected data that are relevant to the treatment plant were analyzed, and the missing data were identified from literature or from laboratory experiments.

3. Model setup and calibration.

The treatment plant was being represented using STOAT program tool. Also the model type options were chosen (ASAL1) which meets NW-WWTP properties. ASAL1 requires sewage retention time greater than 2-4 hours, and the modeling effort is directed at effluent quality . This model incorporates oxidation, nitrification and denitrification processes.

In addition to that, all input parameters were being entered, which could be classified into:

1. Name and dimension of the processes including: name, model, volume….etc.
2. Connectivity, that shows the stream connected to the operation.
3. Operation order for a specific process.
4. Initial condition that shows the amount of soluble BOD; Ammonia; Nitrate; Soluble phosphate; Dissolved oxygen; Total solids; Viable autotrophs; Nonviable autotrophs; Viable heterotrophs; Nonviable heterotrophs and other constituents.
5. Sewage calibration data that shows sewage calibration parameters for the model such as: nitrification rate.
6. Process calibration data that depend on the process type, sludge specific gravity value as an example of those which enclose to primary sedimentation tank.
7. Model Simulations, where after entering data step the model had been run several times.

2.2.4.2 Modeling Scenarios:

Cases modeled in this research can be classified as follows:

1. Modeling of NW-WWTP based on the plant designer data.
2. Modeling of NW-WWTP based on the measured values from treatment plant laboratory.
3. Hydraulic loads include:
   - Flow under dry weather conditions.
   - Flow under wet weather conditions.
   - Low flows.
   - Malfunction of hydraulic equipment and machines inside the plant, such as failure of pumps that's include (RAS, WAS pump failure, digester line failure, and completely one line failure).
4. Pollution Loads include:
   - Intermittent discharge of wastewater ahead of treatment plant by tankers.
   - Daily and seasonal variations of pollution loads.
   - Expected peaks of pollution loads during certain conditions, such as high BOD, COD, SS or inert materials that may occur during feasts, or as a result of industrial maintenances or illegal discharge of pollutants such as olive mills wastewater.

2.2.5 Data Management.

The results obtained from the simulation and modeling of NW-WWTP were discussed, and finally management plan were recommended to deal with the simulated cases.

The methodology of the research is divided into 3 main steps as summarized in the following flowchart (Figure 3).

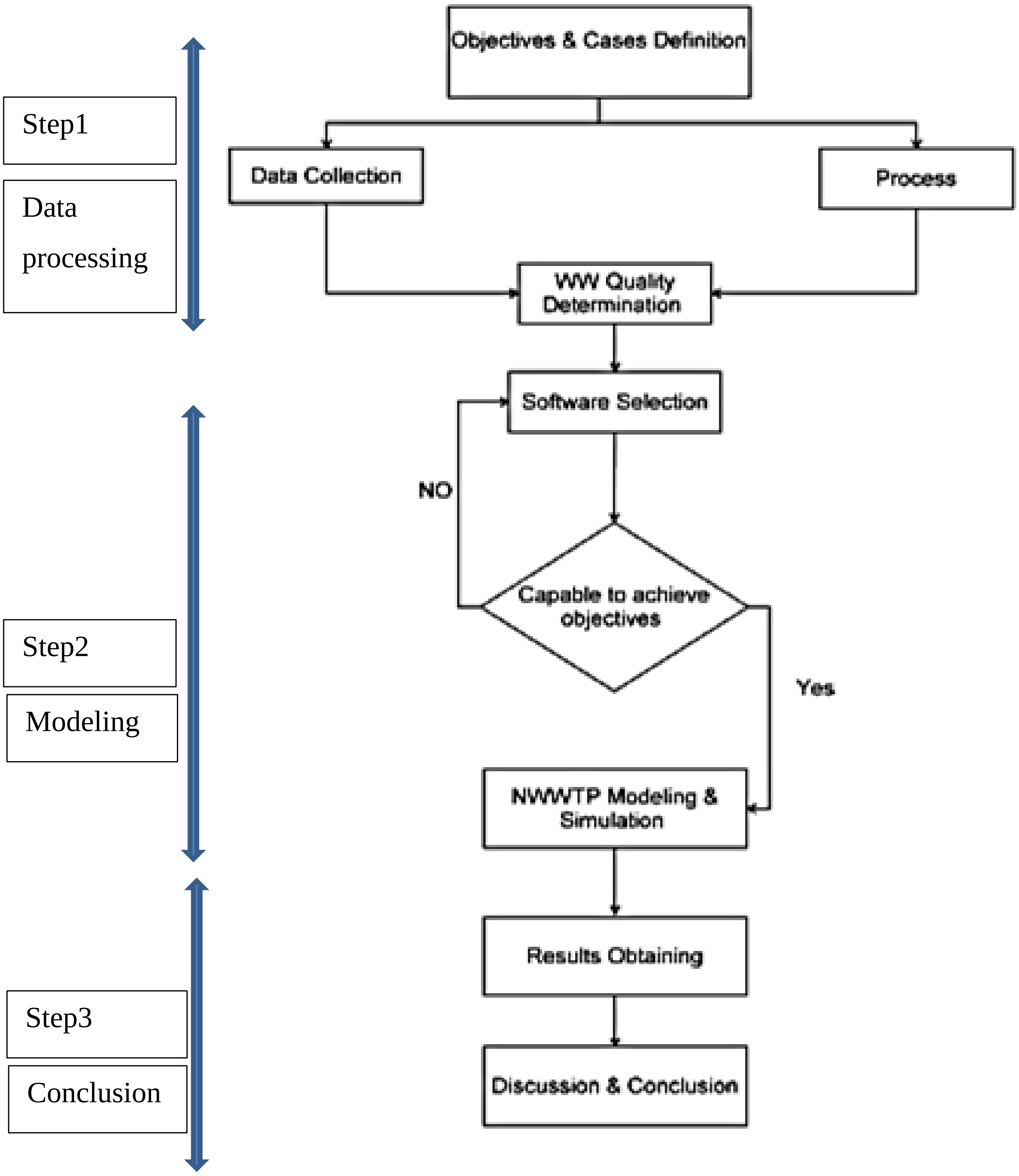

Figure 3: Research Methodology Flowchart

Chapter Three

Literature Review

3.1 Wastewater Origin and Characteristics

Every community produces both liquid and solid wastes. The liquid portion -wastewater- is essentially the water supply of the community after it has been fouled by a variety of uses. From the standpoint of sources of generation, wastewater may be defined as a combination of liquid -or water- carried wastes removed from residences, institutions, commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present.

The part of wastewater that comes from residences, business buildings, and institutions can be referred as domestic or sanitary wastewater. The part from manufacturing is the industrial wastewater.

The definition of domestic septage is either liquid or solid material removed from a septic tank, cesspool, or portable toilet, Type III marine sanitation devices, or similar treatment works that receives only domestic sewage (Hethnawy, 2004).

Wastewater is mostly water by mass (99.9%) and the (0.1%) is the contaminants which include: suspended solids, biodegradable dissolved organic compounds, and refractory organics, inorganic solids, salts, nutrients, metals, and pathogenic microorganisms (Michael and Butler, 2011).

Wastewater characteristics can be possibly determined by several laboratory experiments such as: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), temperature, pH, alkalinity, ammonia, phosphorus, color, grease, and presence of heavy metals. These characteristics can be classified to three main categories that are: physical, chemical, and biological characteristics.

BOD is the oxygen used in meeting the metabolic needs of aerobic microorganisms in water rich of organic matter. And the meaning of Chemical oxygen demand (COD) is the amount of chemically oxidizable materials present in the wastewater (Spellman, 2003).

BOD measurements are used for:

- Determination of the approximate quantity of oxygen required to react with organic matter.
- Determination of the sizing of the wastewater treatment works.
- Measurements of the efficiency of aerobic treatment processes.
- Determination of compliance with wastewater discharge permits or consents.

COD is used to measure the organic matter in industrial and municipal wastes containing chemical compounds that are toxic to biological life and/or not readily biodegraded (Michael and Butler, 2011).

COD or Chemical Oxygen Demand is the total measurement of all chemicals in the water that can be oxidized, BOD- Biochemical Oxygen Demand is supposed to measure the amount of food (or organic carbons) that bacteria can oxidize.

The organic matters can be measured either by BOD or by COD and expressed in mg/l. COD is preferable to the BOD because it is rapidly measurable parameter for river, streams and industrial waste studies and control of water treatment plants.

SS is a measure of suspended solids content of wastewater and also expressed in mg/l.

The main task in treating the wastewater is simply to remove most or all of this 0.1% of solids (that includes suspended solids, salts, BOD, COD, .etc).

3.2 Wastewater Treatment.

3.2.1 Wastewater Treatment Levels.

Wastewater treatment methods are several. The methods that the physical forces predominate are known as a unit operation. Also the methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions are known as unit processes (Techobanoglous et al., 2003).

Nowadays, unit processes and unit operation are grouped together to improve treatment efficiency and to provide various levels of treatment known as preliminary, primary, advanced primary, secondary (with or without nutrient removal), and advanced (or tertiary) treatment (Techobanoglous et al., 2003).

- Preliminary treatment: to remove the wastewater material that may cause damage to treatment plant and extra cost due to maintenance and operation problems, such as: rags, sticks, floatable grit, and grease (Weiner and Matthews, 2003).
- Primary treatment: to remove settleable, floatable solids, and organic matter from the wastewater (Weiner and Matthews, 2003).

- Advanced primary: Enhanced removal of suspended solids and organic matter from wastewater. Typically accomplished by chemical addition or filtration (Dar Lin, 2007).
- Secondary treatment: to remove BOD, dissolved solid, colloidal suspended organic matter by biological action. Secondary treatment also includes disinfection process (Dar Lin, 2007).
- Secondary treatment with nutrients removal: in addition to the above constituents this type removes nutrients e.g. nitrogen, phosphorus (Weiner and Matthews, 2003).
- Tertiary: the next wastewater treatment process after secondary treatment and it aims of removing residual suspended solids (Techobanoglous et al., 2003).
- Advanced wastewater treatment: this process is applied after normal biological treatment and used to remove additional amount of BOD, solids, and nutrients (Techobanoglous et al., 2003).

3.2.2 Considerations for Plant Design.

A basic schematic diagram positioning fundamental design consideration relative to the boundary of the treatment plant is shown in Figure 4.

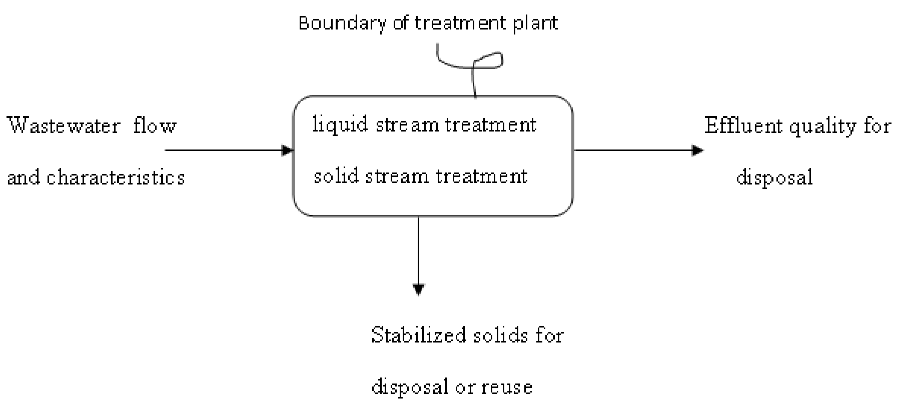

Figure 4: Design Consideration Schematic

The desired effluent quality is specified for the design engineer by a government pollution control authority. Because designed effluent concentrations are specific for each receiving water, they must be established for each receiving water, they must be established for each treatment plant based on location of discharge. Based on the input of raw wastewater flow and characteristics and the output of the required effluent quality, the design engineer can recommend alternative wastewater treatment systems (Hammer and Hammer, 2008).

3.2.3 Wastewater treatment techniques:

There are many techniques used in wastewater treatment such as wetlands, waste stabilization ponds Trickling filter, anaerobic filter, and so on, this research focus on Activated Sludge (AS). That because AS is the system that used in NW-WWTP.

3.2.4 Activated Sludge Process

Activated sludge process derives its name from the biological mass formed when air is continuously injected into the wastewater. In this process, microorganisms are mixed thoroughly with the organic compounds contained in wastewater under conditions that stimulate their growth through use of the organic compounds as substrate. As the microorganisms grow and are mixed by the agitation of the air, the individual organisms flocculate to form an active mass of microbes (biologic floc) called activated sludge (Davis, 2010).

3.3 Modeling of Activated Sludge WWTP System.

3.3.1 Models Building in General.

The model is a tool that describes the reality, used to understand and predict certain aspects of reality (Meijer, 2004).

In building a model, there is a fact should be noticed, that the perfect model never been built and it is only a simplification of reality.

A simulation model can be physical, conceptual, mathematical, or combination between all of them.

Physical modeling can be defined as the process of project rescaling (smaller or larger). Usually, the scale on the geometry and the importance factors. It also includes bench and pilot scale processes (Gall, 1999).

Conceptual models represent the understanding of the cause-effect relationships –that can be described qualitatively and/or quantitatively- between the system components (USEPA, 1993).

Mathematical models are used to quantitatively describe certain aspects of a system, such as effectiveness, performance or technical attributes, and cost (USEPA, 1993).

In general the usefulness of any model depends on a number of criteria that should be fulfilled. These criteria related to the following areas:

- Model validation: that mean the appearance of the correlation between the result and the true system, and it has a three stages (Kops et al, 1999):

3 Replicative: the model is able to reproduce the input/output behavior of the system.

4 Predictive: the model is able to be synchronized with the system into a state, from which unique prediction of future behavior is possible.

5 Structural: the model can be shown to uniquely represent the internal (structural) workings of the system

- Model verification: the state variables of it must in some way be comparable to measurable conditions (directly or indirectly) of the true process. This implies that the complexity of a model should be related to the amount of reliable measurements available from the physical process (Jeppson, 1993).

3.3.2 AS Modeling Development.

Wastewater treatment plant modeling is a useful tool for performing plant capacity assessments and improving plant operations; therefore, saving energy and chemical costs (Tijerina and Chiang, 2005).

The modeling of activated sludge had been developed through three stages:

1. first period – empirical criteria.
2. second period – steady-state relationships of microbial growth and organic substrate utilization.
3. third period – complex dynamic models. (Makinia, 2010). the first period- empirical criteria lasting from the process discovery until the early 1950s can be called “*empirical design, piloting and guesswork*” (Johnson, 2009).

One of the first parameters used was a period of aeration and it was dependent upon “*the strength of the sewage treated and the degree of purification required*” (Ardern and Lockett, 1914) and “*the greater the* *degree of oxidation of the organic matter required, the longer must be the period of aeration*" (Metcalf and Eddy, 1922).

Gould (1953) defined the term "sludge age" as the ratio of the mixed liquor suspended solids to the daily load of suspended solids (SS) in the influent wastewater. Lawrence and McCarthy (1970) established the term mean cell residence time (MCRT) that is synonymous to sludge age term. Eckenfelder and O'Connor (1954) noted that "*the efficiency of the activated sludge process for the treatment of organic wastes is a function of the aeration time, the activated sludge solids concentration, and the BOD loading*". Finally, Echenfelder and Porges (1957) proposed simple, empirical equation to estimate the amount of excess sludge produced and oxygen demand in the tank. This equation summarizes this stage effort (Makinia, 2010).

The second phase - steady-state relationships of microbial growth and organic substrate utilization can be characterized as a formal application of chemical reaction type kinetics to relate (at steady-state) microbial growth and organic substrate utilization under aerobic conditions (Wanner, 1998).

Monod (1942) studied the relationship between the growth rate and substrate (carbohydrate) concentration for strains of Escherichia coli and Bacillus subtilis.

The steady state model was developed through conducting a mass balance for the substrate and the biomass in the activated sludge process .

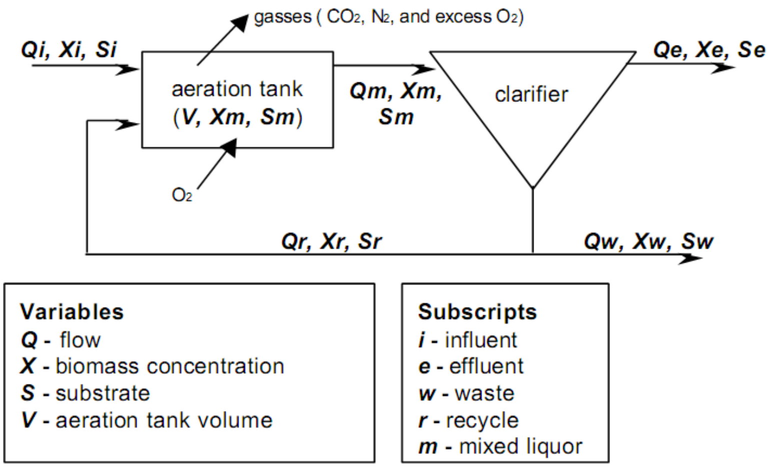

Figure 5: Activated Sludge Model (Mulas,2006)

The mass balance for the process can be written based on Figure5 , and it is important to write two mass balance equations; one for biomass and the other for substrate.

$$\text{Biomass in influent} + \text{Net biomass growth} = \text{Biomass in effluent} + \text{Biomass wasted} \qquad (3.1)$$

By assuming the aeration tank is completely mixed reactor (CSTR), then the mass balance for biomass using a single substrate can be represented symbolically as (Techobanoglous et al., 2003):

$$\frac{dXm}{dt} V = Q_i . X_i - [Q_w . X_w + Q_e . X_e] + r_x . V \qquad (3.2)$$

The term for net growth rate "r_x" is often represented as a combination of biomass growth and biomass decay:

$$r_x = r_{xg} - r_{xd} \qquad (3.3)$$

Biomass growth is typically represented by the Monod equation:

$$rxg = \frac{\mu m.S}{Ke+S} X \qquad (3.4)$$

where :

μ_m: maximum specific growth rate.

K_s: half saturation coefficient.

Also, the decay coefficient can be expressed as:

$$\mathbf{r_{xd} = K_d . X} \qquad \textbf{(3. 5)}$$

where :

K_d: decay coefficient.

It should be noticed that the growth and decay coefficients depend on the concentration of the organic matter and the microorganism type. a laboratory experiments can determine these values if needed.

Combining the equations produces:

$$\mathbf{\frac{dXm}{dt} V = Qi.Xi - [Qw.Xw + Qe.Xe] + V(\frac{\mu m.Sm}{Ke+Sm} Xm - Kd.Xm} \qquad \textbf{(3. 6)}$$

In the same way the mass balance for substrate can be written as:

$$\boldsymbol{rs = -\frac{1}{Y}\frac{\mu m.Sm}{Ke+Sm} Xm} \qquad \textbf{(3. 7)}$$

$$\mathbf{\frac{dSm}{dt} V = Qi.Si - [Qw.Sw + Qe.Se] - \frac{V}{Y}(\frac{\mu m.Sm}{Ke+Sm} Xm)} \qquad \textbf{(3. 8)}$$

Where:

Y: Yield, the ratio of substrate consumed to biomass produced.

The previous equation can be simplified to determine the relationships between the influent flows, the concentration, and tank volume.

To simplify the equations, the following assumptions should made (Hammer and Hammer, 2008):

- All flow rates are constants.
- Influent substrate concentration is constant.
- No changes in solids storage in the clarifier.
- Influent biomass concentration is zero.
- No change in mixed liquor and substrate concentration in the reactor.

- Biological activity takes place only in the aeration tank.

These assumption do not account for many conditions as encountered in real activated sludge system, these include (Gall, 1999):

- Time varying influent flows and concentrations.
- Time varying waste flows and recycles flows as dictated by process control needs.
- Changes in mass stored in the clarifier as sludge blankets rise and fall and settleability changes.
- Non-zero influent biomass concentrations.
- Complex flow streams (e.g., step feed, internal recycles).
- Complex substrates that cannot be reasonably modeled as one composite substrate.
- Simultaneous nutrient removal with multiple biomass populations (e.g., nitrifiers).
- Kinetic coefficients that are affected by variables not included in the equations (e.g., toxicity, temperature).

These conditions have three effects on the utility of steady-state design flow equations (Gall, 1999):

- They produce transient behaviors that are not predicted by steady-state equations.
- They complicate the mass balance equations to the extent that explicit solutions are not possible.
- They do not account for biological and chemical processes that can confound the reactions expressed in previous equations.

Because of the previous problems, comprehensive models have been developed.

The dynamic model is the common name for the mathematical system models which exist as a set of coupled differential or transform equations. they are used in the theoretical analysis of a system behavior and in the subsequent reconfiguration of the system and controller design (Wellstead, 2005).

The current breed of dynamic activated sludge models represents a convergence of:

- Fundamental knowledge – basic biology, chemistry, and physics of wastewater treatment processes.
- Model development – synthesis of fundamental knowledge into mathematical form.
- Simulation – solution of models using numerical methods and computer hardware.

The IWAQ family of models represents the convergence of fundamental knowledge with model development (Gall, 1999).

3.3.3 IWAQ model:

To encourage researcher to use AS models more extensively, International Water Association (IWA) established a group to review and develop a model which describing as activated sludge process (Henze et al., 1987).

ASM1, the Activated Sludge Process Model No.1: is the first model that was developed by that group and it can be considered as the framework for the description of biological processes in suspended growth (activated sludge) systems, including carbon oxidation, nitrification, and de nitrification (Makinia, 2010).

The model, furthermore, aims at yielding a good description of the sludge production. COD (Chemical Oxygen Demand) was adopted as the measure of the concentration of organic matter (Mulas, 2006).

The models that come after ASM1 such as: ASM2 and ASM2d was built to add or extend the capabilities of the ASM1 to the description of bio-phosphorus and adding the denitrifying activity of PAOs1 respectively (Makinia, 2010).

ASM3, the Activated Sludge Process Model No.3 was also developed for biological nitrogen removal, with basically the same goal as the ASM1. The major difference between the ASM1 and the ASM3 models is that the latter recognizes the importance of storage polymers in the heterotrophic activated sludge conversion (Mulas, 2006).

3.3.4 Simulation of AS Systems:

Simulation of activated sludge system behavior, incorporating phenomena such as carbon oxidation, nitrification and de nitrification, must necessarily account for large number of components. To be mathematically tractable while providing realistic predictions, the reaction must be representative of the most important fundamental processes occurring within the system (IWA, 2000).

Simulators are really computer programs used to solve IWA models, which predict the response of activated sludge system to any change in various parameters, it also can predict the reaction of the system under different conditions thus providing operators with insight into the internal workings of the physical system and help them avoid many unfavorable situations before actually turning them into operational problems (Sorour and Bahgat, 2004).

Simulators give tools to the operator to understand what the design engineer is proposing, help meet permit under all conditions, improve the economics of operating an AS facility, and understand exactly what is happening within these processes (WEF, 2006).

Table 4 lists the names and websites for five of the current software products that can be used for simulating activated sludge processes. Providing this information does not endorse any of these products.

Table 4:Simulator Software Products.

Product name	***Manufacturer (location)***	***Website***
BioWin	EnviroSim Associates, Ltd. (Flamborough, Ontario, Canada)	www.envirosim.com
EFOR	DHI Software (Hørsholm, Denmark)	www.dhisoftware.com/efor/
GPS-X	Hydromantis, Inc. (Cambridge, Ontario, Canada)	www.hydromantis.com
SimWorks	Hydromantis, Inc. (Cambridge, Ontario, Canada)	www.hydromantis.com
STOAT	WRc plc Blagrove, Swindon, England.	http://www.wrcplc.co.uk/stoat.aspx

3.3.5 STOAT :

STOAT, is the program that will be used for modeling purposes in the treatment plant. Also it is a free available software by WRc plc, England.

STOAT is a PC-based computer modeling tool designed to dynamically simulate the performance of a wastewater treatment works. The software can be used to simulate individual treatment processes or the whole treatment works, including sludge treatment processes, septic tank imports and recycles. The model enables the user to optimize the response of the works to changes in the influent loads, works capacity or process operating conditions (WRC, 2010).

In STOAT (stands for Sewage Treatment Operation Analysis over Time) models for all common wastewater treatment processes are available, both on the wastewater and sludge treatment sides. The biokinetic models include the common IWA models ASM1, ASM2d and ASM3, as well as various extensions of these models. Specific activated sludge systems, such as oxidation ditches and Sequence Batch Reactors (SBRs) can be modeled. The program contains sensitivity analysis, model calibration and optimization routines as well as two types of controllers (PID and ladder logic) (Makinia, 2010).

Petrie and Jack (1994) used STOAT to develop an integrated catchment management plan for the city of Pert, STOAT used on simulating Sleepless Inch WWTP, they calibrated it from the data which collected and analyzed by Water Service Department of Quality and Treatment, but they didn’t calibrate the storm tank.

On 1996 team of experts tried to demonstrate the conditions necessary to up-rate the DUNNSWOOD STW plant to achieve nitrification. They achieved 95% of nitrification and STOAT was used extensively to pre-test the effect of plant changes and the predicted effluent concentrations were very close to that actual one. Another note should be notice that the simulation time was 30 days at least.

Smith and Dudley (1997) published a paper on Dynamic Process Modeling Of Activated Sludge Plants, they applied STOAT on two treatment plants: Bellozanne STW, Jersey with scope of reviewing the process strategies to up rate Bellozanne STW to treat additional flow, and Daldowie STW, Glasgow with aim of assessing the future ability of the plant to achieve its nitrification consent. Their main recommendations are:

1. The most important part of modeling is the data collection which will allow the model to be accurately calibrated and validated for all conditions.
2. Computational fluid dynamics will be used to more accurately model the flow behavior of the final settlement tanks, which are often the cause of failure of an activated sludge plant.

Christabel White and Mark Smith tried to review the developments in process modeling for wastewater treatment, and outline the advantages that can be gained from dynamic modeling to enhance treatment plant performance.

They recommended that the simulation can be used to investigate various operation strategies and to optimize plant performance.

This research depends on STOAT because it capable to achieve the objectives of this research and because it is free to use.

3.3.6 Advantages and disadvantages of mathematical modeling and computer simulation.

The mathematical models and the computer simulator have many advantages compared to the experimenting with real systems (McHaney, 1991). Which can be summarized as follows:

- Experimentation conducted without disruptions to existing systems (testing of new ideas may be difficult, costly or otherwise impossible in systems that already exist).
- Testing a concept prior to installation, which may reveal unforeseen design flows and improve the design concept.
- Detection of unforeseen problems or bugs, which may exist in the system's design (debugging time and rework costs can be avoided) or operation (improvements to system operation may be discovered).
- Gaining in system knowledge, which might be dispersed at the beginning.
- Much greater speed in analysis (simulation permits "time compression" to fractions of seconds or minutes representing minutes, hours, days, or even years of system time. (This feature is especially important in wastewater treatment systems where the rates of biological processes are relatively slow and physical experimentation may require weeks or even months (Andrews, 1992)).

- Forcing system definition in order to produce a valid working model of a system.
- Enhancing creativity which can be exercised without the risk of failure.

Although computer simulation can be a powerful method of analysis, certain limitations and disadvantages must be acknowledged:

- It is neither cheap nor easy to apply this tool correctly and effectively (Bratley et al, 1987). Moreover, is not generally set up to produce quick answers to questions. In many cases, data collection, model development and implementation, analysis, and report generation will be costly and require considerable amounts of time.
- Simulation results can be no better than the model (and data) on which they are based on (USEPA, 1993). Since a simulation model encodes concepts that are difficult to completely define, it is easy to create a model that is not a reasonable representation of the real system. Another limitation is the availability of accurate and appropriate data for describing the behavior of the system (Smith, 1999). Incorrect or incomplete models and/or poor data can result in simulations generating large quantities of worthless, inaccurate or even completely misleading results.
- Due to approximations made while creating the model, it is known in advance that the real system and its model do not have identical output distributions (Bratley et al, 1987). Therefore, it should be realized that a simulation model yields only approximate results, i.e.

measurements of general trends, rather than exact data for specific problems (Smith, 1999).

- The attempt to use computer simulation to find an optimum solution to a problem might rapidly degenerate into a trial-and-error process.
- In the case of wastewater treatment, computer simulation is a much cleaner job than physical experimenting. This factor is dangerous and can result in neglecting the validation of the simulation model (Andrews, 1992).

Chapter Four

Result and discussion

4.1 General:

The main objectives of this study are to model the NW-WWTP and to study its performance under different load conditions.

The main inputs data for the research were collected from different agencies and are listed in appendix (A):

1. Nablus-West Wastewater Treatment Plant dimensions (Annex A1)..
2. Wastewater constituents concentrations in wadi Zeimar that obtained from Nablus municipality report 2007 (Annex A2).
3. The Design influent wastewater characteristics for Nablus WWTP (Annex A3).
4. Nablus WWTP designed effluent concentrations (Annex A4).
5. Wastewater characteristics for the influent and the effluents from NW-WWTP (Annex A5).
    - Chemical Oxygen Demand COD test results (A5.1).
    - Examination of Ammonium (A5.2).
    - Examination of Phosphate –Total P (A5.3).
6. Industrial wastewater characteristics in Nablus (Annex A6).
7. Palestinian guideline for wastewater treatment (Annex A7).

The detailed graph results for the simulated scenarios can be noted in appendix (B):

1. Long term simulation” dynamic equilibrium’’ results variations.(Annex B1).

2. Comparison between the measured and the model prediction results graphs .(Annex B2).
3. Results for case of Studying the effects of malfunction RAS pumps for one tank .(Annex B3).
   - Failure at all simulation period(Annex B3.1).
   - Failure for 24 hrs (Annex B3.2).
4. Results for case of Studying the effects of malfunction of WAS pumps(Annex B4).
   - Failure of two tanks pumps at all simulation period(Annex B4.1).
   - One Tank failure after 500hr(Annex B4.2).
5. Malfunction of completely one line results variations (Annex B5).
6. Variation of the effluent components concentrations over time For All Industrial Sector Flow (Annex B6).
7. Variation of the effluent components concentrations over time for some Industrial Sector Flow (Annex B7).

4.2 Long term simulation (dynamic equilibrium).

Simulation of NW-WWTP using STOAT program required input parameters as initial conditions.

Initial conditions parameters are the concentration of the constituents in the treatment plant before the period of simulation.

Period of simulation can be either short such as a few days as it can be longer to achieve dynamic simulation. STOAT as one of the simulation programs can deal with these two types of periods, Short term simulation when it is used in activated sludge model the results from the model will be heavily dependent on the initial conditions that be used.

This research will focus on the long term simulation because the effects of the initial conditions are ignored.

After modeling that values as an influent flow for the proposed treatment plant (Table 2),the dynamic equilibrium point for this case came after about 1512hr (63days) of simulation. Which means no effects for initial conditions (Table 5, Figure6) .

Table 5: Summary table for long term simulation results of plant effluent for average daily flow as 617.7m^3/h and peak flow as 925.7m^3/h..

	Total SS	**Total COD**	**Ammonia**	**Nitrate**	**Total P**	**Total N**
Mean (mg/l)	72.80	18.81	14.51	64.77	20.15	79.28
Maximum (mg/l)	486.2	116.1	97.33	75.88	21.07	102.6
Total mass (kg)	81309	20911	12049	61736	18738	73785
Peak load (g/s)	108.6	25.93	25.03	19.46	5.133	26.01

The activated sludge process results can be summarized as:

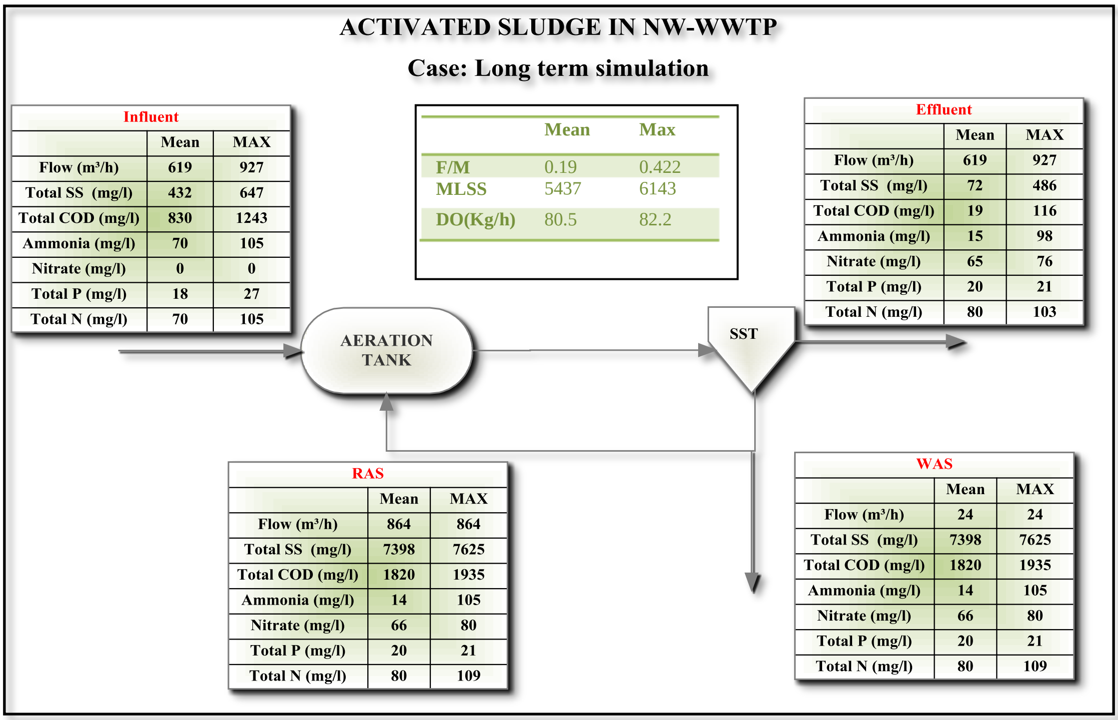

Figure 6: Activated Sludge Process Results in case of reviewing TP based on designer data..

Figure 6 shows summary of the effluents, RAS, and WAS concentrations in the case of using the designer values as influents.

Food to Mass ratio (F/M) has a mean value of 0.19 (gCOD/gMLSS.d) and max. of 0.422 (gCOD/gMLSS.d) that means the sludge settleability expected to be good at mean value, and fair at peaks.

Mixed Liquor Suspended Solids (MLSS) has also mean value of 5437 mg/l and max of 6143 mg/l. these values of F/M and MLSS approved that the treatment plant as designed to be Extended Aeration.

Hydraulic retention time in the aeration tank is 21 hrs. The mean cell residence time (MCRT) can be calculated through equation 4.1 as follows:

$$\theta c = \frac{MLSS \times V}{Excess\ Sludge} \qquad \textbf{(4. 1)}$$

θc equals 7.49 days.

Fraction of BOD converted to excess solids is about 0.45 (Ib of SS/Ib of BOD).

The needed amount of supplied oxygen per hour is about 80 kg.

COD has a mean value of 18.8 mg/l and max of 70 mg/l in steady state period, the overall efficiency for the treatment plant is about 98% based on COD (Figures 7 and 8).The designed effluent concentrations and Palestinian Standards (Appendix A6) have been met for COD.

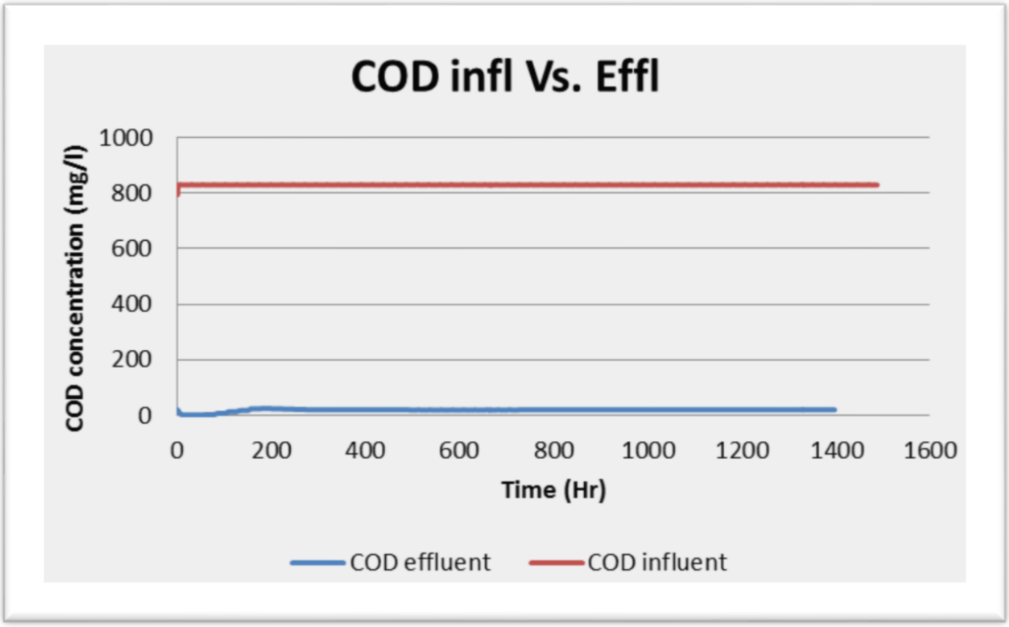

Figure 7: Effluent COD of NW-WWTP under dynamic equilibrium simulation and based on initial conditions of input parameters OR designed values of input parameters.

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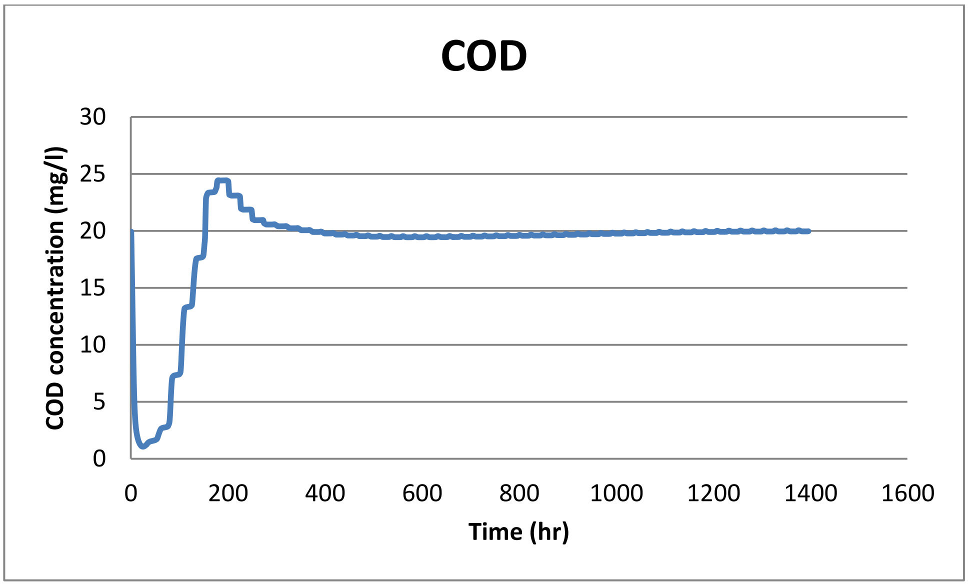


Figure 8: COD effluents from TP.

TSS expected to vary according to this curve because the influents varies in the same manner. TSS has a mean of 72 mg/l and a max of 486 mg/l because of initial condition effects

During simulation 81% of influent ammonia has been nitrified, Nitrification process occurred here but not completely.

No changes on P concentration.

presented Detailed variation for COD, TSS, N, and TP are in appendix B1.

4.3 Comparison between the laboratory measured parameters and results of the STOAT-model.

Laboratory measurements that were conducted on August and September/2013 on the influent of NW-WWTP (Appendix A4) were used as input to build STOAT model to verify if the model is working well or not. If the effluents from NW-WWTP model match the result data then the model is working properly. If not further calibration should be applied.

The model output ranges are similar as follow:

Table 6: Effluent results in case of reviewing TP based on experiment data.

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	115.6	30.93	19.15	60.13	20.15	79.28
Maximum (mg/l)	993.8	234.9	97.33	75.23	21.07	102.6
Total mass (kg)	132160	35136	16335	57449	18738	73785
Peak load (g/s)	223.2	52.75	25.03	19.32	5.133	26.01

Figure 9 summarizes the components concentrations under this case loads:

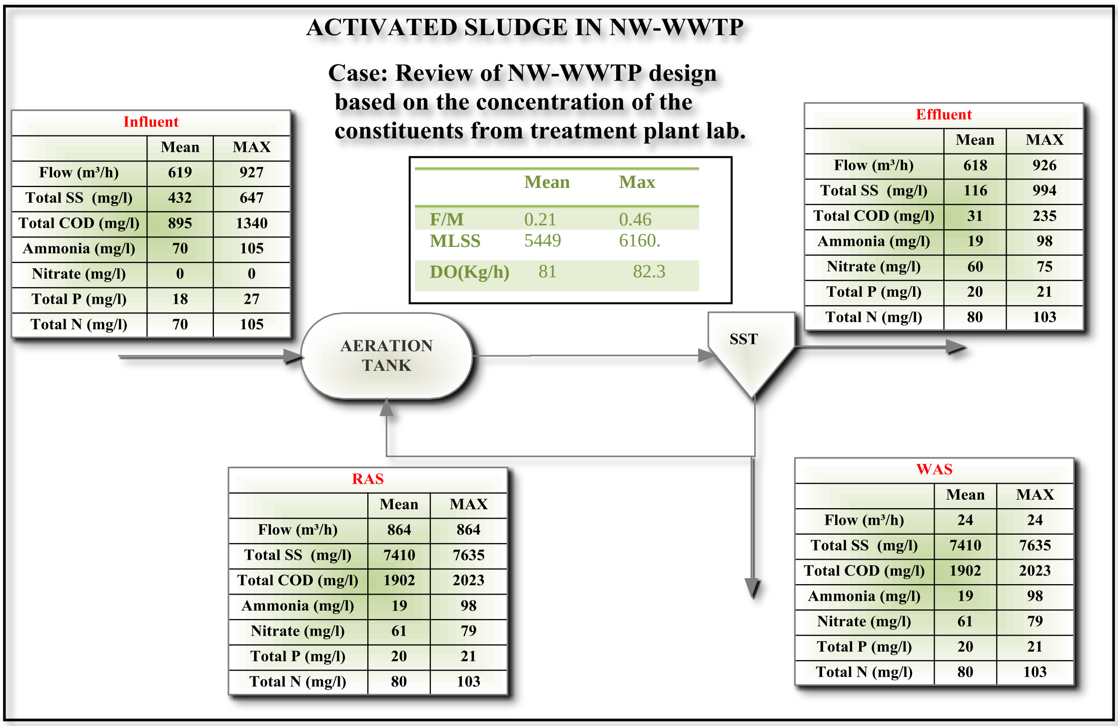


Figure 9: Activated sludge process results in case of reviewing TP based on experiment data..

F/M is about 0.21 (gCOD/gMLSS.d) at mean and 0.46 (gCOD/gMLSS.d) at peaks. The settleability of the sludge is good to fair. And this result same to the previous case.

MLSS has a mean of 5449 mg/l and peaks of 6160 mg/l and satisfying Extended Aeration ranges. (MCRT) is about 7 days.

Fraction of BOD converted to excess solids is about 0.45 (IB of SS/Ib of BOD).

The needed amount of supplied oxygen per hour is about 81 kg By comparison the results from this case and the previous one, note that COD concentration increase to reach 31 mg/l at mean and the overall efficiency expected to be 96.5% instead of 98.3%. as shown in the figure below:

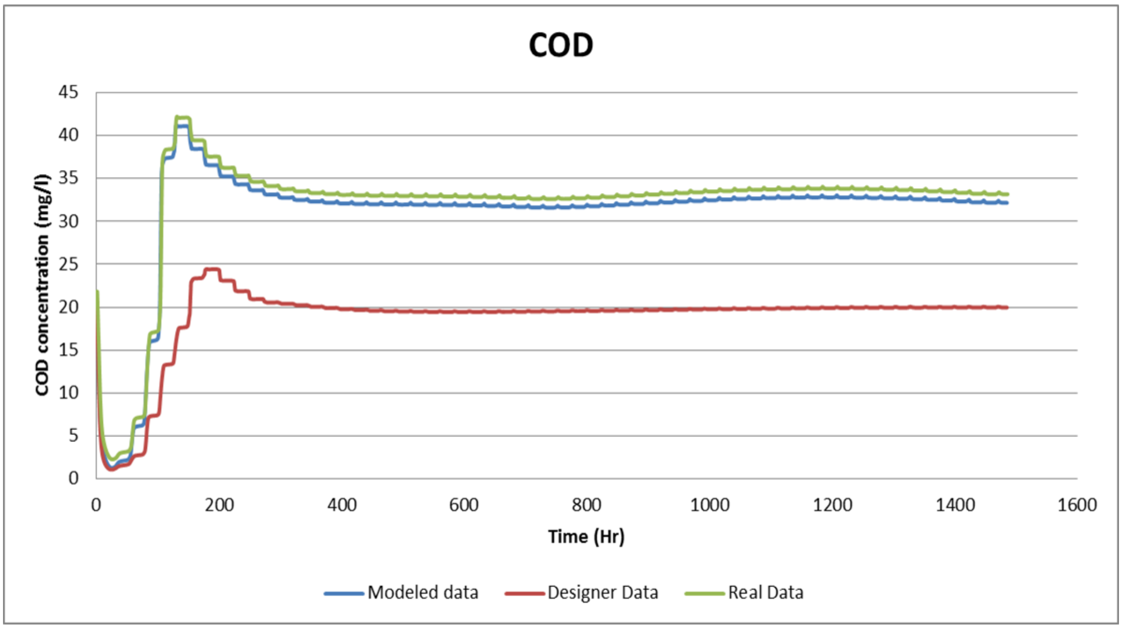


Figure 10: COD results for real vs. designer data.

Nitrification will not be completely, Effluent expected to have a 60.13 mg/l Nitrate and 19.15 mg/l ammonia. and 75.85% of the ammonia converted to nitrate instead of 81% in the previous.

Phosphorus removal will not occurs and no change in the effluent concentration.

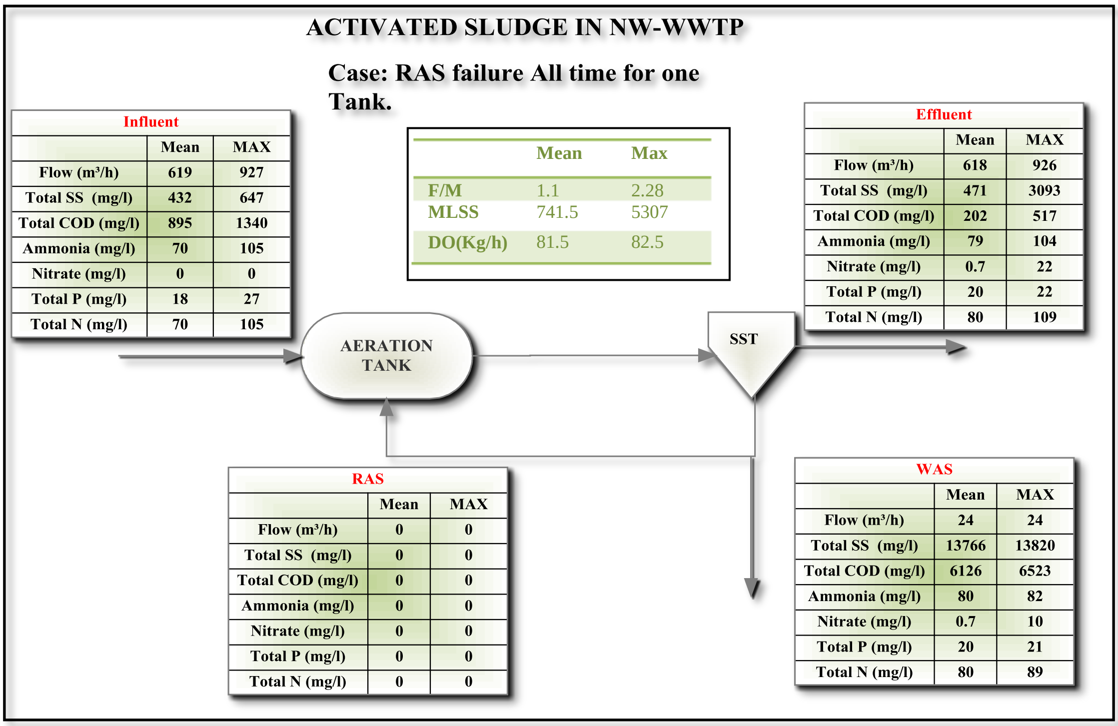
These results match the results obtained from Nablus municipality lab so that the judgment on the model is working well.

Also, the detailed variation for COD, TSS, N, and TP can be notice in the appendix B2.

4.4 Study the effects of RAS pumps malfunction

One of the cases that had been dealt is the malfunction of the hydraulic equipment. As an example return activated sludge pumps (RAS) when one of the tanks pumps had been shut and the RAS became zero the result expected to be as the following:

Case1: failure at all simulation period:



	Mean	Max
F/M	1.1	2.28
MLSS	741.5	5307
DO(Kg/h)	81.5	82.5

Influent

	Mean	MAX
Flow (m^3/h)	619	927
Total SS (mg/l)	432	647
Total COD (mg/l)	895	1340
Ammonia (mg/l)	70	105
Nitrate (mg/l)	0	0
Total P (mg/l)	18	27
Total N (mg/l)	70	105

Effluent

	Mean	MAX
Flow (m^3/h)	618	926
Total SS (mg/l)	471	3093
Total COD (mg/l)	202	517
Ammonia (mg/l)	79	104
Nitrate (mg/l)	0.7	22
Total P (mg/l)	20	22
Total N (mg/l)	80	109

RAS

	Mean	MAX
Flow (m^3/h)	0	0
Total SS (mg/l)	0	0
Total COD (mg/l)	0	0
Ammonia (mg/l)	0	0
Nitrate (mg/l)	0	0
Total P (mg/l)	0	0
Total N (mg/l)	0	0

WAS

	Mean	MAX
Flow (m^3/h)	24	24
Total SS (mg/l)	13766	13820
Total COD (mg/l)	6126	6523
Ammonia (mg/l)	80	82
Nitrate (mg/l)	0.7	10
Total P (mg/l)	20	21
Total N (mg/l)	80	89

Figure 11: Activated sludge process results in case of RAS pump failure for all simulation period.

Failure of RAS pumps during simulation period cause increasing the food to mass ratio and reducing MLSS.

F/M has a mean of 1.1 (gCOD/gMLSS.d) and max value of 2.28 (gCOD/gMLSS.d), the settleability of the sludge is poor.

MLSS has a mean value of 742 mg/l and a max of 5307 mg/l and (MCRT) expected to be 10.29 hrs.

The needed amount of supplied oxygen per hour is about 81.5 kg.

Table 7:Summary table for RAS pump failure all time.

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N (
Mean (mg/l)	471.3	202.2	78.88	0.700	20.23	79.57
Maximum (mg/l)	3093	516.5	103.7	22.09	21.73	108.6
Total mass (kg)	528763	228301	73142	663.11	18743	73805
Peak load (g/s)	734.2	113.9	26.51	5.309	5.120	27.92

COD variation expected to be affected heavily, COD has a mean of 202.2 mg/l and max of 517 mg/l in steady state period. No jumps occurs here because the malfunction period same to simulation period. The overall efficiency expected to be 77.4% instead of 98.3%

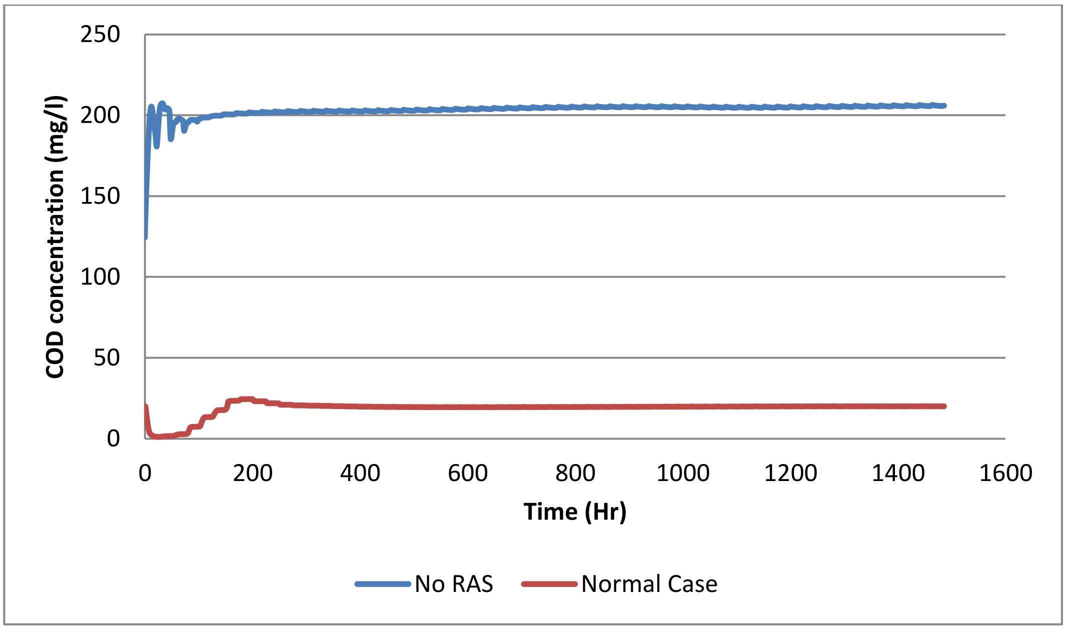
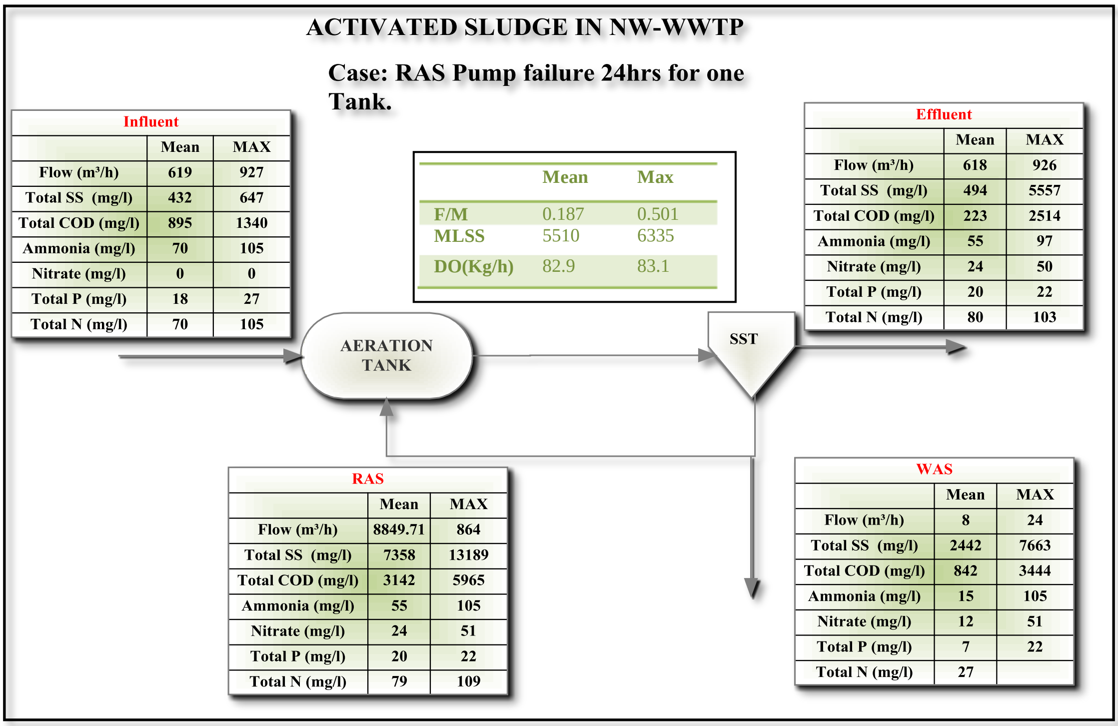


Figure 12: No RAS(malfunctioning all simulation period) Vs. normal case COD results.

In this case the TSS expected to vary in wide range with 471 mg/l mean and max of 1200 mg/l in steady state conditions, few amount of ammonia converts to nitrate, and nitrification process will be effected heavily, and no changes in this case from the other cases.

<u>Annex B3 shows the detailed graphs for TSS,COD,N, and TP variations.</u>

<u>Case2: failure for 24 hrs:</u>



Influent	Mean	MAX
Flow (m³/h)	619	927
Total SS (mg/l)	432	647
Total COD (mg/l)	895	1340
Ammonia (mg/l)	70	105
Nitrate (mg/l)	0	0
Total P (mg/l)	18	27
Total N (mg/l)	70	105

	Mean	Max
F/M	0.187	0.501
MLSS	5510	6335
DO(Kg/h)	82.9	83.1

Effluent	Mean	MAX
Flow (m³/h)	618	926
Total SS (mg/l)	494	5557
Total COD (mg/l)	223	2514
Ammonia (mg/l)	55	97
Nitrate (mg/l)	24	50
Total P (mg/l)	20	22
Total N (mg/l)	80	103

RAS	Mean	MAX
Flow (m³/h)	8849.71	864
Total SS (mg/l)	7358	13189
Total COD (mg/l)	3142	5965
Ammonia (mg/l)	55	105
Nitrate (mg/l)	24	51
Total P (mg/l)	20	22
Total N (mg/l)	79	109

WAS	Mean	MAX
Flow (m³/h)	8	24
Total SS (mg/l)	2442	7663
Total COD (mg/l)	842	3444
Ammonia (mg/l)	15	105
Nitrate (mg/l)	12	51
Total P (mg/l)	7	22
Total N (mg/l)	27	

Figure 13: Activated sludge process results in case of 24 hrs. period RAS pump failure

This case simulates the failure of RAS pumps for 24 hrs.

For this case F/M has a mean of 0.187 (gCOD/gMLSS.d) and max value of 0.501 (gCOD/gMLSS.d), the settleability of the sludge is good on mean and fair on peaks.

MLSS has a mean value of 5510 mg/l and a max of 6335 mg/l and (MCRT) expected to be 8.76 days.

The amount of dissolved oxygen per hour is about 82.9 kg.

Table 8: Summary table for 24 hrs. failure of RAS pump.

	Total SS	Total COD)	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	494.3	222.9	54.92	24.38	20.15	79.3
Maximum (mg/l)	5557	2514	97.33	49.53	21.33	102.6
Total mass (kg)	602468	271897	50421.0	23423.8	18753.6	73844.7
Peak load (g/s)	1389.89	628.863	25.029	12.721	5.1490	26.0100

A jump can be noted in the figure below. This jump formed in the duration where the malfunction of RAS pumps occurs. The peak reaches a 2514 mg/l and it decrease gradually.

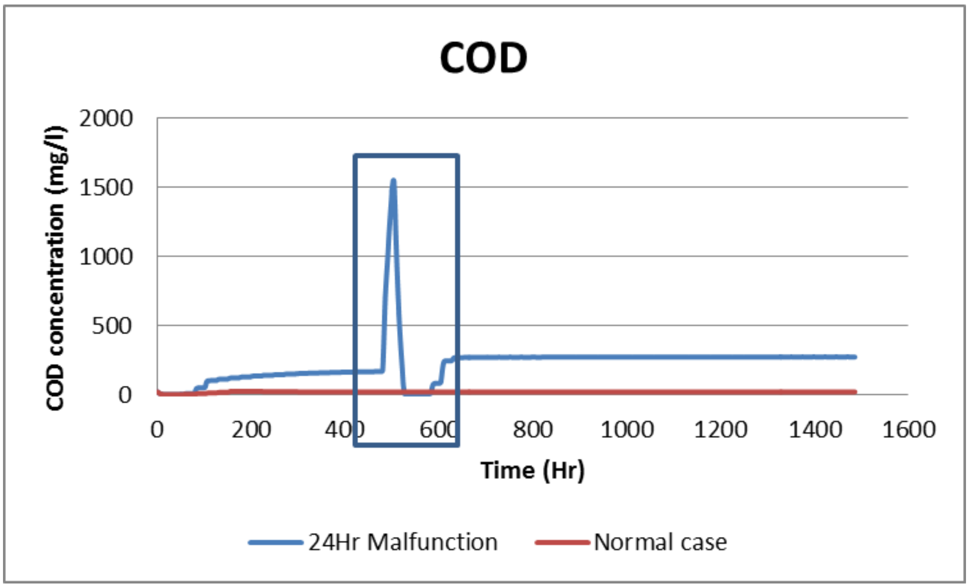


Figure 14: COD variation in 24 hrs malfunctioning of RAS pump.

This results show the effect of RAS malfunction. RAS flow set to zero two times, all simulation period in the first and just for 24 hrs in the second. As an example COD has a mean value of 202.21mg/l in the first and 221.94 mg/l in the second. And that is make sense because the dynamic simulation. But the max values are 516.48 mg/l in the first and 2513.76 in the second. This large value is because of the shock that represent with zero RAS flow on the activated sludge system. the nitrification will heavily affected, and only 30% of ammonia converts to nitrate instead of 81% in the normal case.

Annex B3 presents the detailed graphs for TSS,COD,N, and TP variations.

4.5 Study the effects of malfunction of WAS pumps.

Also when the pumps that response on wastage flow failed for one or two tanks the effluent results expected to be as the following:

Case1: failure of two tanks pumps at all simulation period:

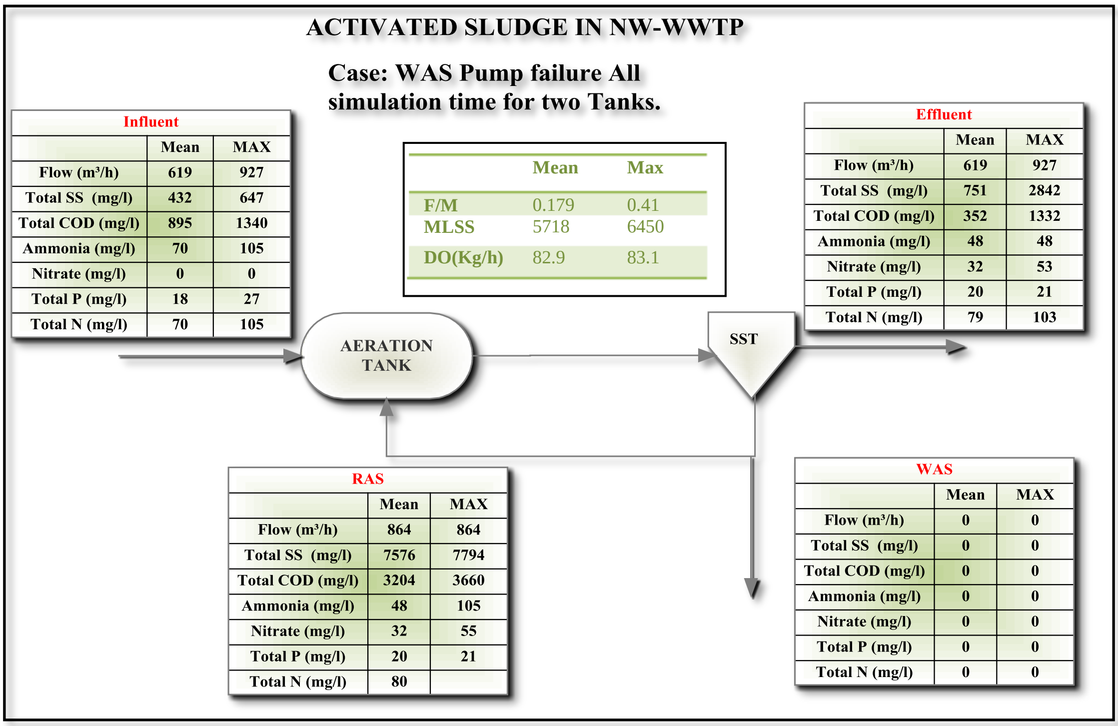


Figure 15: Activated sludge process results under WAS failure all simulation period.

This case simulates the effects of WAS pumps failure during simulation period. Through this case MLSS increased but the F/M decreased.

F/M has a mean of 0.179 (gCOD/gMLSS.d) and max value of 0.41 (gCOD/gMLSS.d).

MLSS has a mean value of 5718 mg/l and a max of 6450 mg/l and (MCRT) expected to be 6.77 days.

The amount of dissolved oxygen per hour is about 82.9 kg.

Table 9: Summary table for WAS pump failure all time (2Tanks)

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	750.6	325.2	47.82	31.57	20.18	79.39
Maximum (mg/l)	2842	1332	97.42	53.07	21.06	102.8
Total mass (kg)	944469	409337	43664.7	30334.7	18793.7	73999.4
Peak load (g/s)	727.958	340.915	25.0530	13.6340	5.14100	26.0340

TSS varies in a wide range, and the concentration of TSS increases. The peak of this case is about 2842 mg/l and 751 mg/l as mean value. Another note is the steady state conditions reached quickly. And only 39.4% of the ammonia converts to nitrate.

COD also affected extremely. The peak value during steady state period is about 1332 mg/l and the mean value is 352 mg/l. the overall efficiency reduced to 61% based on COD removal as shown in figure(21) below.

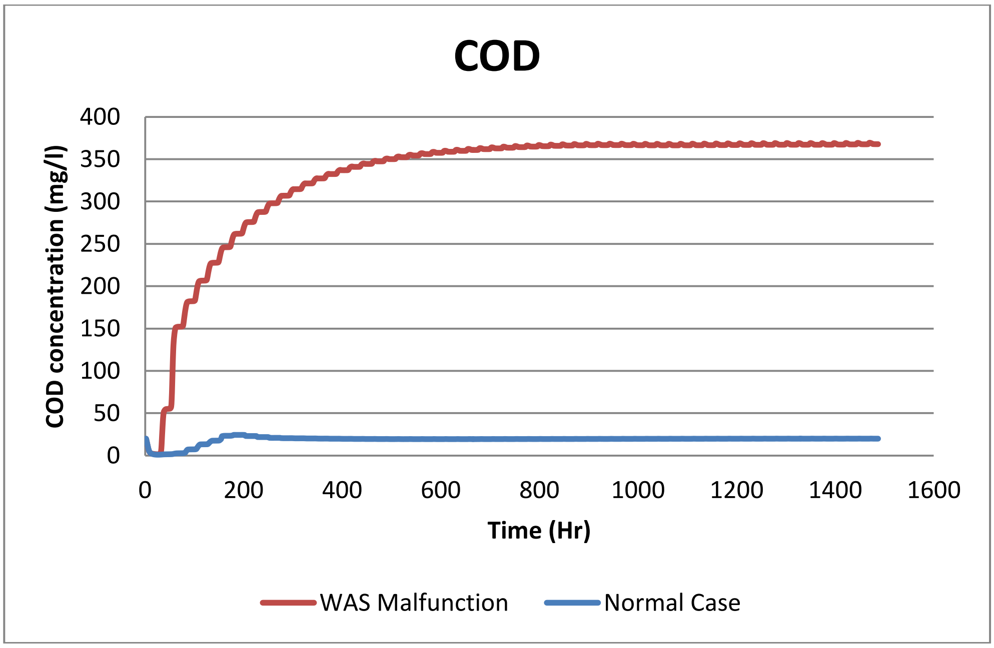


Figure 16: COD graph in case of WAS pump malfunction.

Annex B4 shows the detailed graphs for TSS,COD,N, and TP variations for this case.

Case2: one Tank failure after 500hr:

Table 10: Summary table for WAS pump failure after 500hr (1Tank)

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	480.9	216.9	53.33	25.97	20.15	79.29
Maximum (mg/l)	2249	1056	97.33	49.53	21.07	102.6
Total mass (kg)	597344	269656	48905.7	24937.3	18753.2	73843.0
Peak load (g/s)	563.23	264.61	25.029	12.721	5.1380	26.010

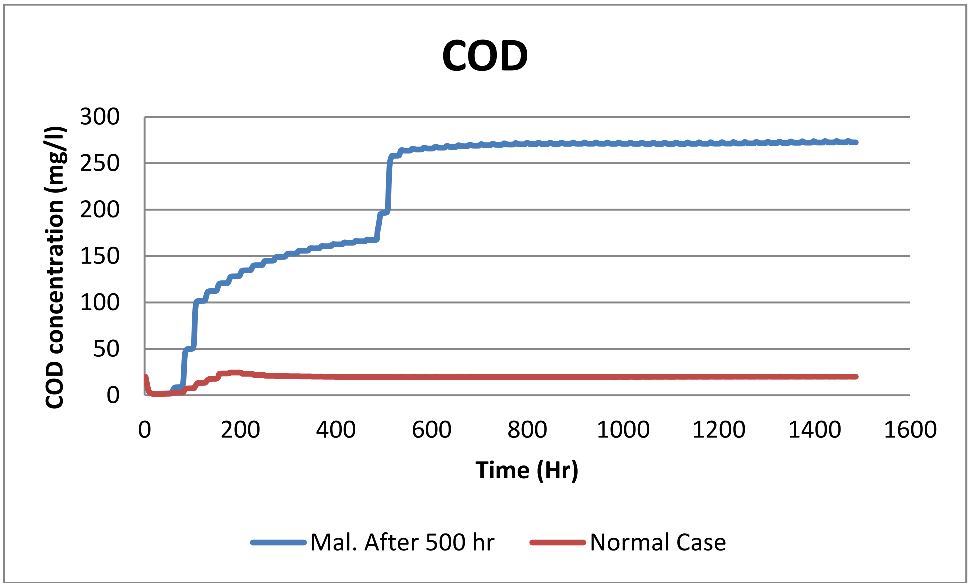


Figure 17: COD variation for malfunction of WAS pump after 500 hrs.

This case simulate the effect of WAS malfunction in one tank after 500hrs. this results show that the peak reached at the malfunction duration , as an example COD has a mean value of 216.88mg/l while the max value reached 1055.7 mg/l. the general note about these curve is peak reached value (ex:1055.7mg/l) and no drop from the peak value because the mal function of one tank and the other still under operation.

In addition to that the 33% of the ammonia will convert to nitrate.

Annex B4 shows the detailed graphs for TSS,COD,N, and TP variations for this case.

4.6 Study the effects of malfunction of completely one line:

This case simulates the treatment plant if one line heave to for any reason while the influent data (flow and concentrations) still similar to the design data, the wastewater effluent expected to be:

In case of 24 malfunction:

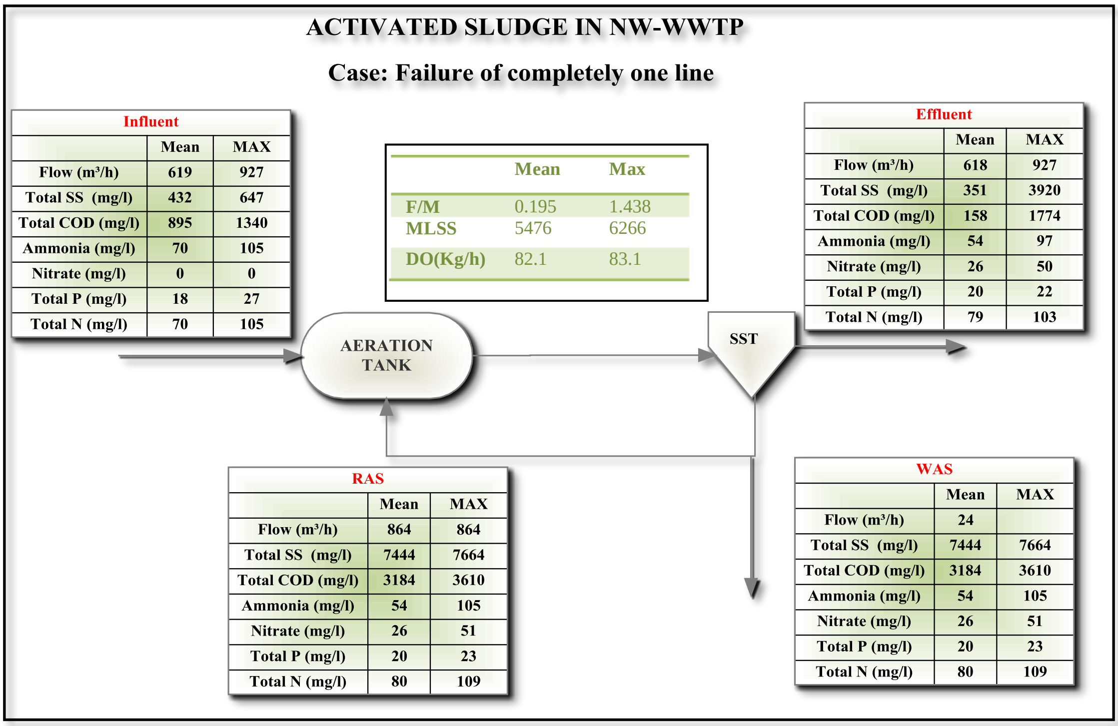


Figure 18: Activated sludge process results in case of one wastewater line for a period of 24 hrs.

In case of malfunction of completely one line for 24 hrs, the MLSS expected to be 5476 mg/l on mean and 6266 mg/l on peaks. And expected Food to Mass ratio expected to have a wide range with mean 0.195(gCOD/gMLSS.d) and peak of 1.438 (gCOD/gMLSS.d). MCRT expected to be 5.24 days.

The needed amount of supplied oxygen per hour is about 82.1 kg.

Table 11: Summary table for 24 hrs malfunction of completely one line .

	Flow (m^3/h)	**Total SS (mg/l)**	**Total COD (mg/l)**	**Ammonia (mg/l)**	**Nitrate (mg/l)**	**Total P (mg/l)**	**Total N (mg/l)**
Mean	617.8	351.4	157.7	53.74	25.56	20.15	79.30
Maximum	925.9	3920	1774	97.33	49.53	22.45	102.6
Total mass (kg)		430177	192547	49253.0	24541.	18740.	73794.
Peak load (g/s)		907.01	410.34	25.0290	12.721	5.1340	26.010

COD curve affected by this case, the peak value is 1774mg/l and the mean value in this case is 158 mg/l. the overall efficiency is 82.3% with 15% reduction from the normal case as shown in figure() below.

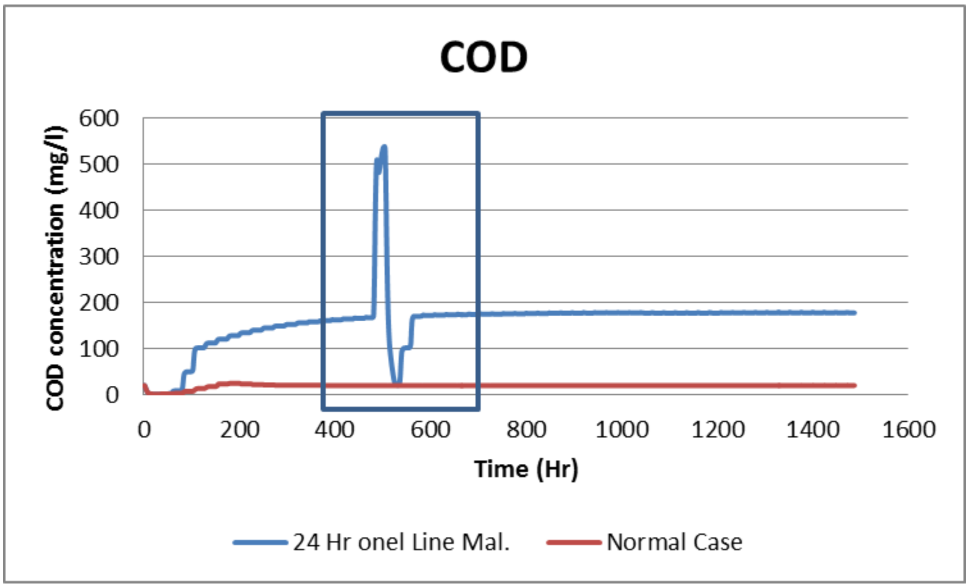


Figure 19: COD graph in case of one wastewater line for a period of 24 hrs.

In this case TSS curve has the sharpest peak from the other cases. The max value reaches 3920mg/l and the mean value reaches 359.49 mg/l, Nitrification expected to occur and 32.23% of ammonia converts to nitrate, and No phosphorus removal activities in the treatment plant.

Annex B5 presents the detailed graphs for TSS,COD,N, and TP variations for this case.

4.7 effect of most common industrial activities in Nablus:

Nablus is a commercial trade center dealing in traditional industries such as the production of soap, olive oil, and handicrafts. Other industries include furniture production, tile production, stone quarrying, textile manufacturing and leather tanning.

Industrial wastewater Flow and characteristics depend on the activity type in each one. Industries in Nablus west aren’t clear, so the industrial activity in Nablus west assumed to be same as in Nablus east.

In general, table 18 summarizes its characteristics.

Table 12: Industrial sector, flow and COD in Nablus (Nablus Municipality ,2012).

Sector	**Flow(m^3/d)**	**COD(Kg/d)**
Textile	197	**100**
Olive Oil Mills	120	**12,000**
Tahina Factories	61	**440**
Diary	77	**7,650**
Slaughterhouse	48	**1,620**
Others	60	**50**

Case1: all the industrial wastewater arrives to TP during the period of the simulation

This case simulates the case of arrival the industrial wastes to the treatment plant during olive mill season (including all industries that listed in table18) for simulation period (63days).

Mass balance concept used to determine the influents concentration and flow quantity.

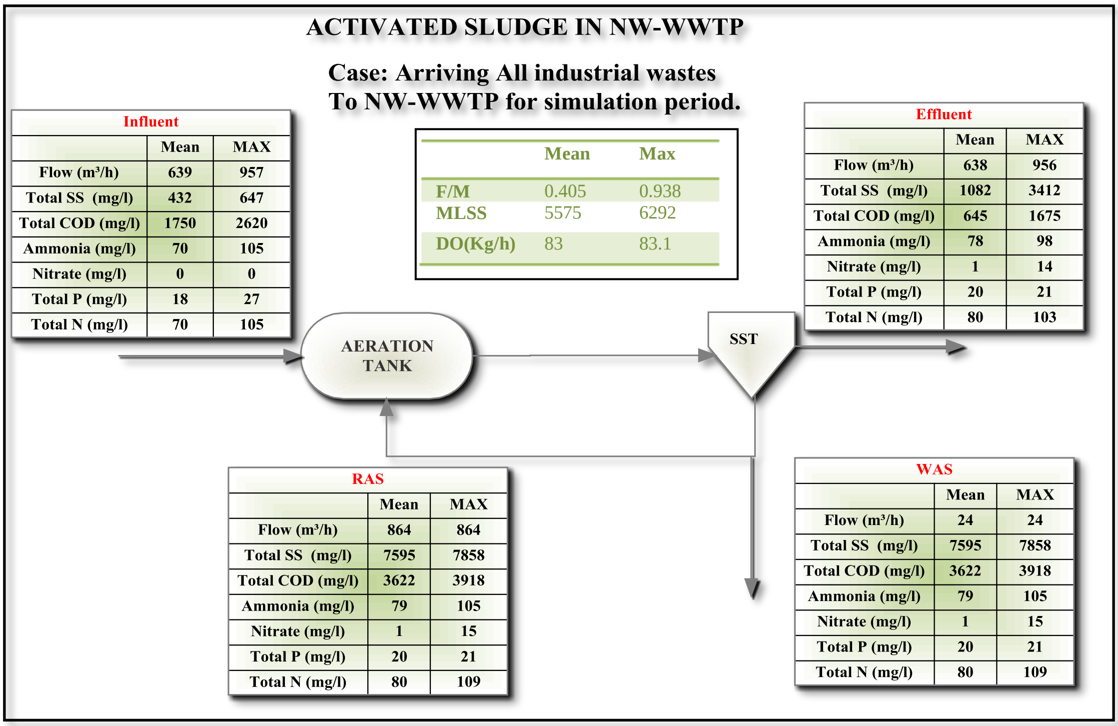


Figure 20 : Activated sludge system in case of discharging industrial wastewater (including Olive mill wastes) at the head of TP.

Food to Mass ratio increase to reach 0.405(gCOD/gMLSS.d) at mean value and 0.938(gCOD/gMLSS.d) at peak. This value because of highly influent concentrations that discharge at the head of the treatment plant. MLSS has mean value of 5575 mg/l and max of 6292 mg/l at peak instead of 5437 mg/lat mean ,and 6143 mg/l at peaks during simulation normal conditions. MCRT has a value of 2.96 days instead of 7.49 in normal conditions.

The needed amount of supplied oxygen per hour is about 83 kg.

Sludge settleability according F/M is poor.

Table 13: Results Summary table in case of discharging industrial wastewater (including Olive mill wastes) at the head of TP.

	Flow (m^3/h)	Total SS (mg/l)	Total COD (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Total P (mg/l)	Total N (mg/l)
Mean	637.8	1082	644.6	78.33	1.020	20.17	79.35
Maximum	955.7	3411	1675	97.72	13.94	21.13	102.9
Total mass (kg)		141106	766156	75159.0	1012.4	19351	76171
Peak load (g/s)		904.5	443.8	25.94	3.700	5.280	26.99

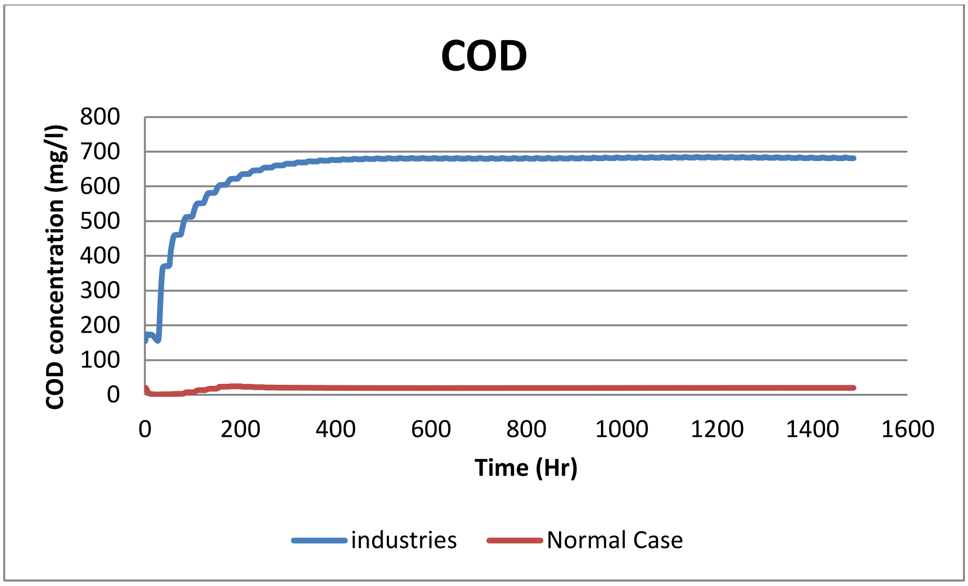


Figure 21: COD effluent concentrations over time in case of discharging industrial wastewater (that includes Olive mill wastes) at the head of TP.

This case assumed all the industrial effluents that shown previously to be received by the treatment plant. Using the mass balance concept the mixed flow (from domestic and industries) simulated as influents.

It is clear that the industries have large effects on the effluents quality , it will rise the effluents concentration dozens, for example COD varies from about 18mg/l in the normal case to about 645mg/l in this case.

The efficiency of the treatment plant is about 63%. And no nitrification will occur.

Annex B6 presents the detailed graphs for TSS,COD,N, and TP variations for this case.

Case2: some of the industrial wastewater arrives to TP during the period of the simulation

This case shows the effect of industrial wastes in absence of olive mill wastes. Period of simulation is 63days and the industrial waste arrives all time.

Table 14:Case2: Industrial sector, flow and COD in Nablus.

Sector	**Flow(m^3/d)**	**COD(Kg/d)**
Textile	197	**100**
Diary	77	**7,650**
Slaughterhouse	48	**1,620**
Others	60	**50**

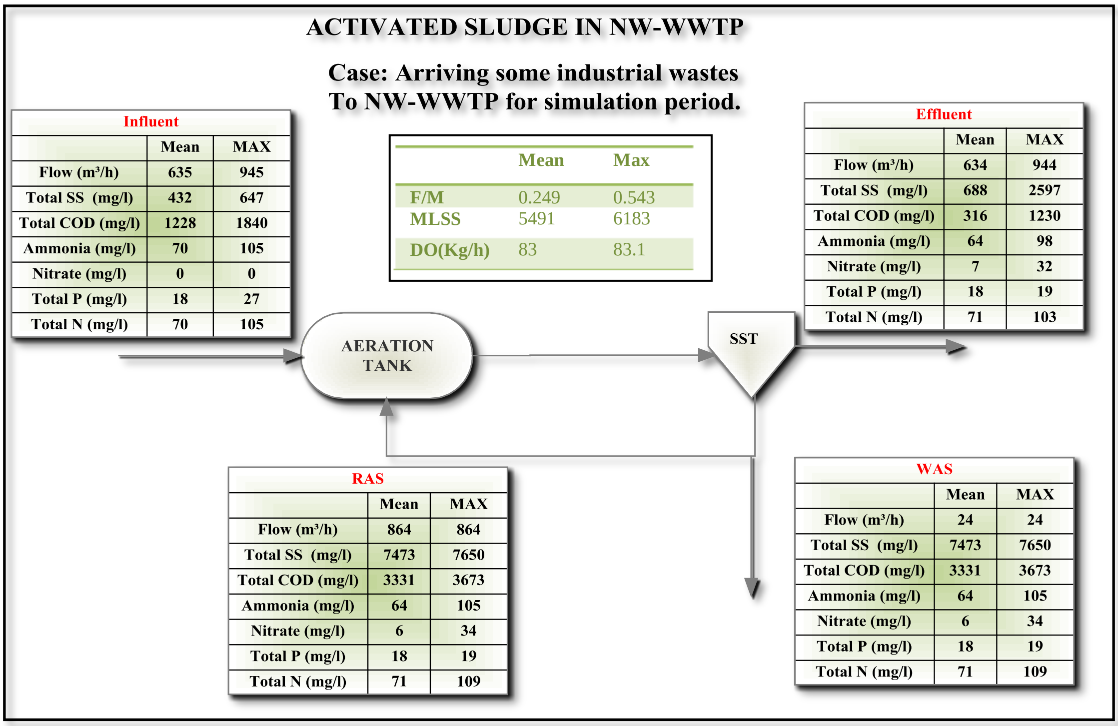


Figure 22: Activated sludge system in case of discharging industrial wastewater (that excludes Olive mill wastes) at the head of TP.

This case simulates the effect of industrial discharge excluding the wases of olive mill . Food to Mass ratio increase to reach 0.249 (gCOD/gMLSS.d) at mean value and 0.0.543(gCOD/gMLSS.d) at peak. This value is lower than the previous case but also larger than normal case. Sludge settleability according F/M ratio is good at mean and fair at peaks.

MLSS has mean value of 5491 mg/l and max of 6183 mg/l at peak. MCRT has a value of 3.85 days instead of 2.96 in the previous case.

The needed amount of supplied oxygen per hour is about 83 kg.

Table 15: Results Summary table in case of discharging industrial wastewater (that excludes Olive mill wastes) at the head of TP.

	Flow (m^3/h)	Total SS (mg/l)	Total COD (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Total P (mg/l)	Total N (mg/l)
Mean	633.9	687.6	315.6	63.95	6.590	17.90	70.54
Maximum	944.4	2597	1230	98.25	32.44	19.06	103.2
Total mass (kg)		755974	346994	61351.0	6295.55	17159.9	67646.6
Peak load (g/s)		604.1	287.4	22.92	7.772	4.941	26.54

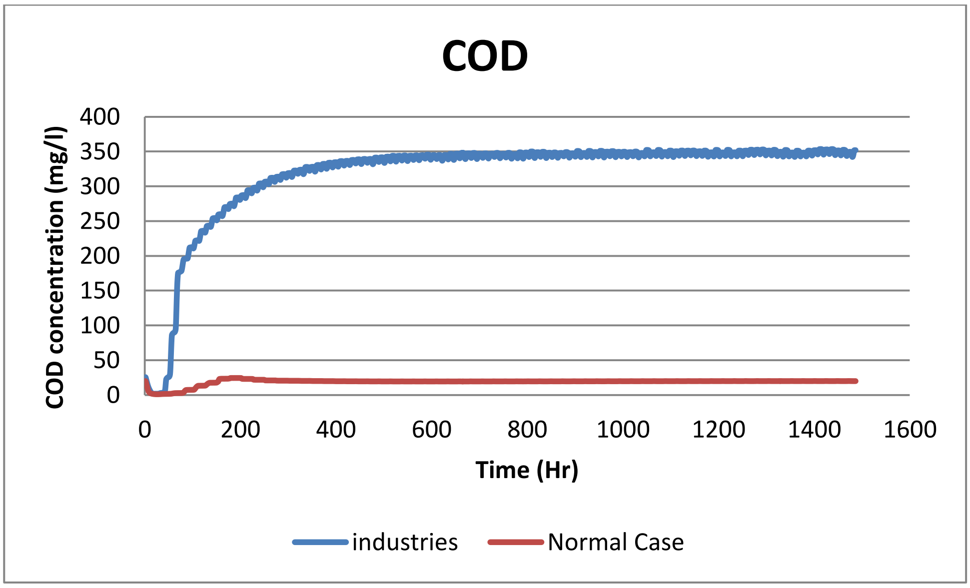


Figure 23: COD effluent concentrations over time in case of discharging industrial wastewater (that excludes Olive mill wastes) at the head of TP.

This case assumed all the industrial effluents-excluding olive oil that were shown previously to be received by the treatment plant. Using the mass balance concept the mixed flow (from domestic and industries) simulated as influents.

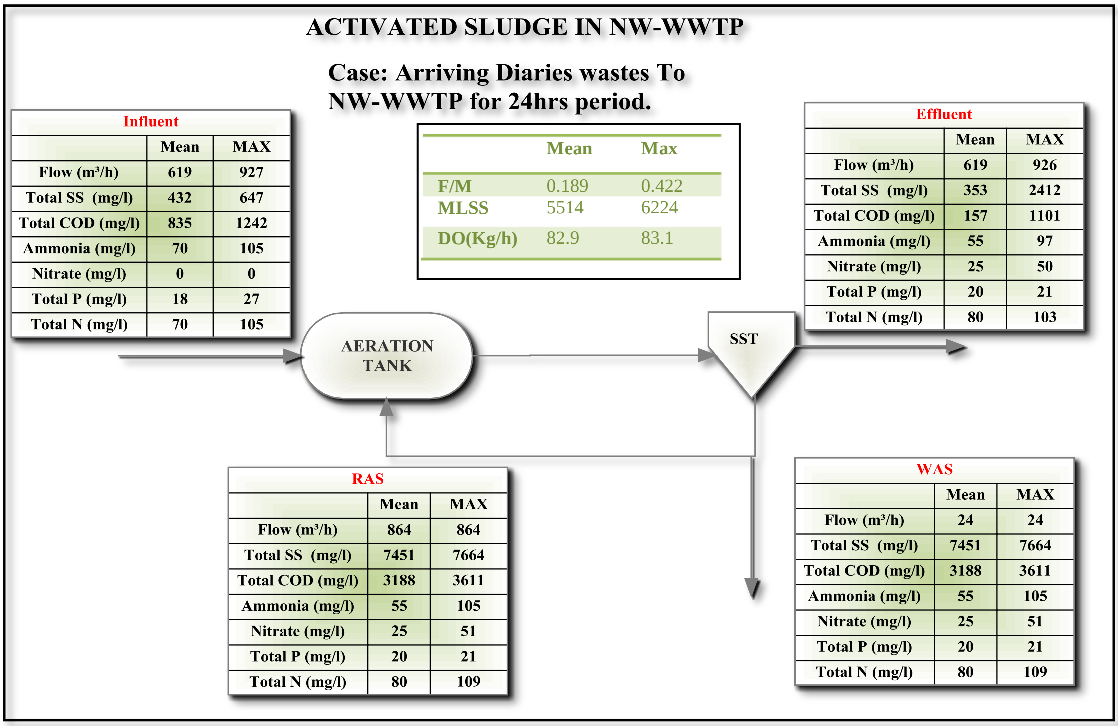
This case has an effect on the effluents but less than the previous case; the efficiency of the treatment plant is 74.3% based on COD. COD has a mean value of 316 mg/l and max of 1230 mg/l.TSS affected extremely with mean value of 688 mg/l and max of 2597 mg/l. As before the nitrification expected to occur for the first 600hrs. no phosphorus removal.

Annex B7 shows the detailed graphs for TSS,COD,N, and TP variations for this case.

Case 3: Diary industries wastewater only for 24 hrs.

This case study the effects of diary industries on the treatment plant if its waste arrived for 24 hrs. This case ignoring all other industrial wastes.

Diaries flow is about 77m^3/d with 7650 kg/d COD. And the domestic flow characteristics as shown in table 9.



Influent	Mean	MAX
Flow (m³/h)	619	927
Total SS (mg/l)	432	647
Total COD (mg/l)	835	1242
Ammonia (mg/l)	70	105
Nitrate (mg/l)	0	0
Total P (mg/l)	18	27
Total N (mg/l)	70	105

	Mean	Max
F/M	0.189	0.422
MLSS	5514	6224
DO(Kg/h)	82.9	83.1

Effluent	Mean	MAX
Flow (m³/h)	619	926
Total SS (mg/l)	353	2412
Total COD (mg/l)	157	1101
Ammonia (mg/l)	55	97
Nitrate (mg/l)	25	50
Total P (mg/l)	20	21
Total N (mg/l)	80	103

RAS	Mean	MAX
Flow (m³/h)	864	864
Total SS (mg/l)	7451	7664
Total COD (mg/l)	3188	3611
Ammonia (mg/l)	55	105
Nitrate (mg/l)	25	51
Total P (mg/l)	20	21
Total N (mg/l)	80	109

WAS	Mean	MAX
Flow (m³/h)	24	24
Total SS (mg/l)	7451	7664
Total COD (mg/l)	3188	3611
Ammonia (mg/l)	55	105
Nitrate (mg/l)	25	51
Total P (mg/l)	20	21
Total N (mg/l)	80	109

Figure 24: Activated sludge system results in case of discharging of diaries mill wastes for 24hrs

This case explores the effect of diaries industries wastes, the effect of diary wastes as follows:

Food to Mass ratio increase to reach 0.189 (gCOD/gMLSS.d) at mean value and 0.422 (gCOD/gMLSS.d) at peak. This value is lower than the previous cases and close to normal.

MLSS has mean value of 5514 mg/l and max of 6224 mg/l at peak. MCRT has a value of 5.27 days instead of 7.49 in the normal conditions. Sludge settleability according F/M ratio is good .

The needed amount of supplied oxygen per hour is about 82.9 kg.

Table 16: Results Summary table in case of discharging of diaries mill wastes for 24hrs.

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	352.6	157.2	54.62	24.51	20.11	79.13
Maximum (mg/l)	2412	1101	97.33	49.53	21.07	102.6
Total mass (kg)	430910	192235	50154.3	23528.3	18711.5	73682.7
Peak load (g/s)	620.0	283.0	25.03	12.72	5.134	26.01

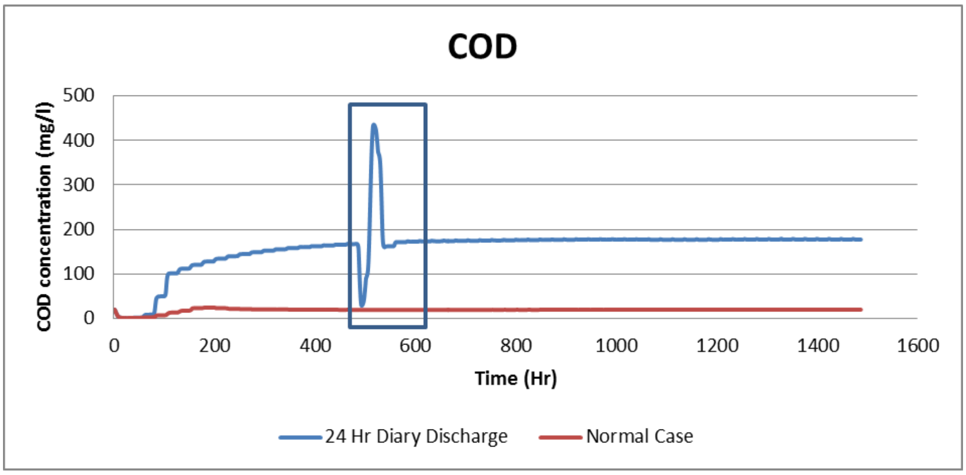


Figure 25: COD concentration for diary discharge for 24 hrs period

This figure shows the variations of the COD concentration for diary discharge for 24 hrs period. In these figures a jump occurs at the discharging time. The max is 2412 mg/l for TSS, and 1101mg/l COD, but the mean is 353 and 157 mg/l for TSS and COD respectively.

The overall efficiency is 81.2% at mean values, and 32% at peaks based on COD removal.

31% of ammonia will convert to nitrate instead of 81 at normal conditions. and no phosphorus removal will occur.

Case 4: Slaughterhouses wastewater only for 24 hrs.

This case simulates the illegal connection for slaughterhouses and arrival of its wastes to the treatment plant for 24 hrs. The slaughterhouses wastes flow 48m^3/d with 1620kg/d COD.

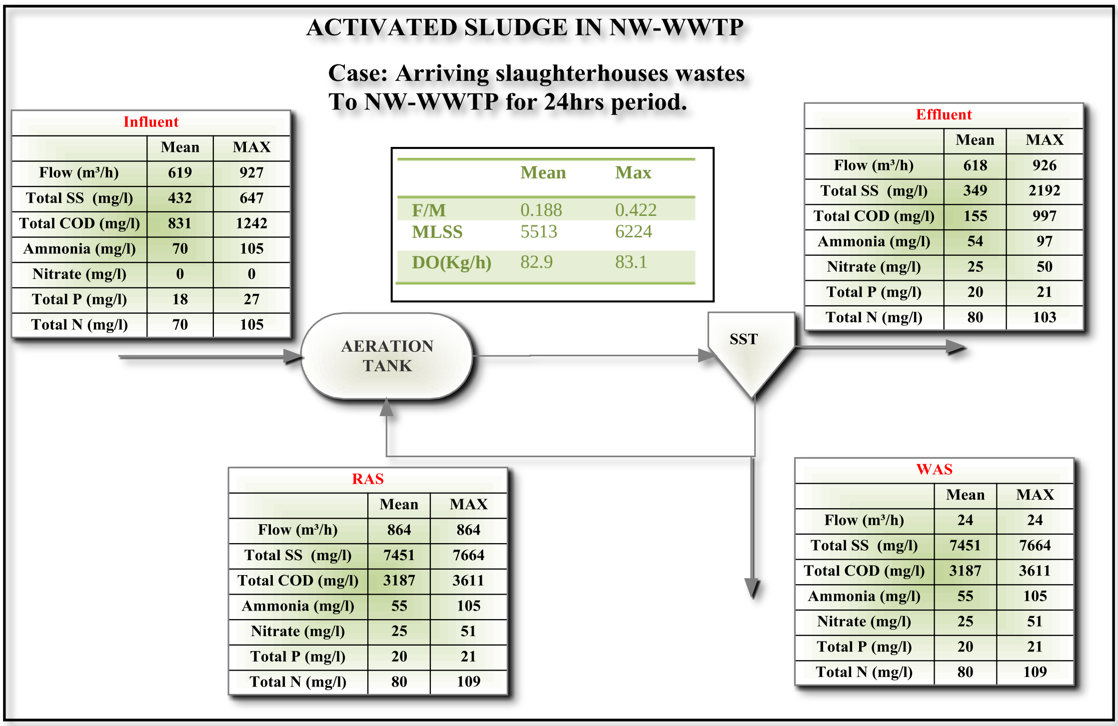


Figure 26: Activated sludge system results in case of discharging of slaughterhouses wastes for 24hrs.

F/M has a mean of 0.189 (gCOD/gMLSS.d) and max value of 0.422 (gCOD/gMLSS.d), the settleability of the sludge is good.

MLSS has a mean value of 5513 mg/l and a max of 6224 mg/l and (MCRT) expected to be 5.29 days.

The needed amount of supplied oxygen per hour is about 82.9 kg.

Table 17: Results Summary Table in case of discharging of slaughter houses wastes for 24hrs.

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	348.5	155.3	53.92	25.21	20.11	79.13
Maximum (mg/l)	2192	997.2	97.33	49.53	21.07	102.6
Total mass (kg)	426396	190082	49477.2	24202.0	18710.6	73679.2
Peak load (g/s)	563.5	256.4	25.03	12.72	5.134	26.01

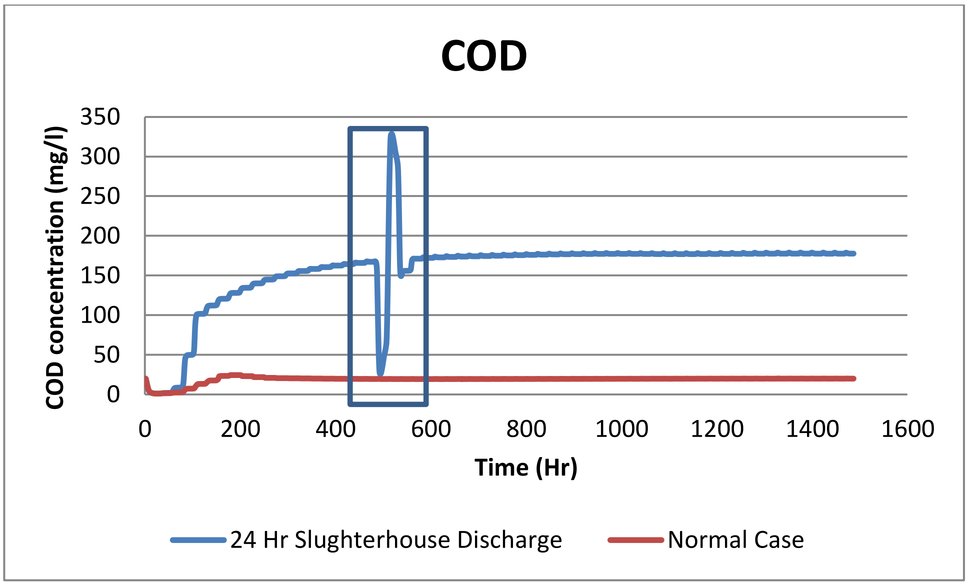


Figure 27: COD concentration for discharging slaughterhouse wastes for 24 hrs period

The jump due to slaughterhouse discharges into the treatment plant for 24 hrs. the peak in TSS due to this jump is about 2192 mg/l and in COD is about 997 mg/l. COD has mean value of 155 mg/l with overall efficiency 80% based on COD removal at mean values. Nitrification also affected with this jump and only 32% of the ammonia will convert to nitrate. As before no phosphorus removal excepted to occur.

<u>Case 5: olive mill wastewater only for 24 hrs.</u>

This case simulates the illegal discharge of olive mill wastes into the treatment plant for 24 hrs. Olive mill wastes has a flow of 120 m^3/d and 12000 kg/d COD.

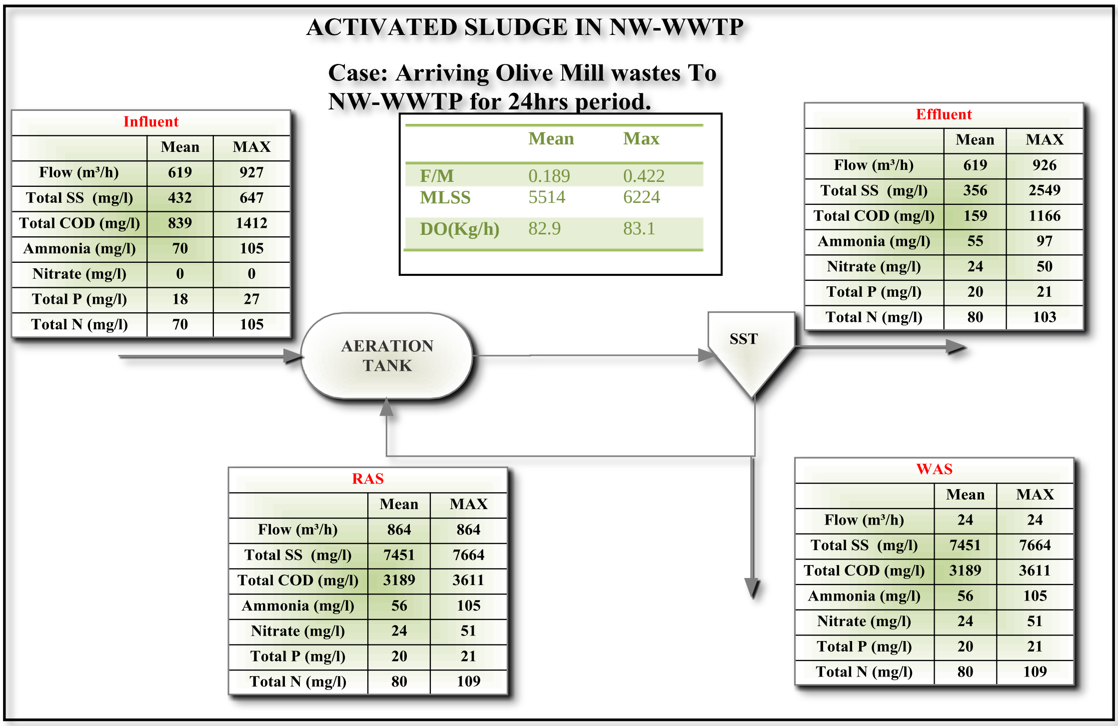


Figure 28: Activated sludge system results in case of discharging of olive mill wastes for 24hrs.

F/M has a mean of 0.189 (gCOD/gMLSS.d) and max value of 0.422 (gCOD/gMLSS.d), the settleability of the sludge is good.

MLSS has a mean value of 5513 mg/l and a max of 6224 mg/l and (MCRT) expected to be 5.25 days.

The needed amount of supplied oxygen per hour is about 82.9 kg.

No changes for the previous three cases on F/M and MLSS.

Table 18: Summary table in case of discharging olive mill wastes for 24 hrs

	Total SS	Total COD	Ammonia	Nitrate	Total P	Total N
Mean (mg/l)	355.7	158.7	55.14	24.00	20.11	79.13
Maximum (mg/l)	2549	1166	97.33	49.53	21.07	102.6
Total mass (kg)	434195	193804	50650.3	23034.2	18712.0	73684.4
Peak load (g/s)	655.3	299.8	25.03	12.72	5.134	26.01

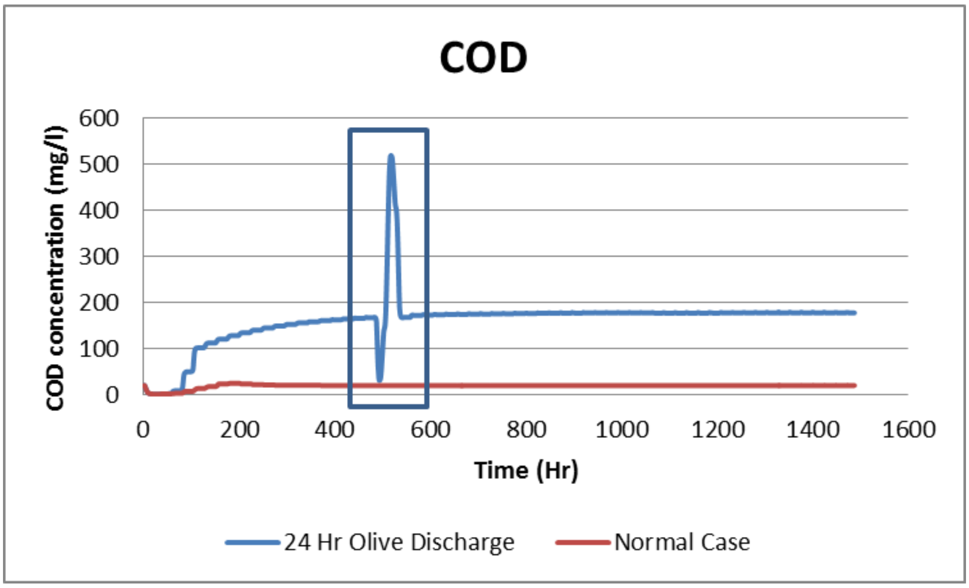


Figure 29: COD concentration in case of olive oil discharging for 24 hrs period

These results have a peak values affect the performance of the treatment plant, the performance at peak values for olive oil 40%. While the efficiency at the mean value for olive oil is: 81%. 30 % of ammonia will convert to nitrate in the cases of olive oil

The results in the last three cases show that the effluents are relatively same and that because the influents flow and concentration have approximate same values.

4.8 Operational activities to face simulated scenarios:

many cases modeled in this research, which have an extreme effects on treatment plant. And because the effluents will be used for agricultural activities, the variation of effluent quality will reduce the confidence in using the treated water.

In order to solve that problems, the expected solutions were modeled by STOAT as follow:

1. Increasing RAS flow rate:

increasing of Return activated sludge flow rate is One of the possible solution for the simulated cases, but the challenge here is to get the optimum value for RAS.

This solution is partially suitable for the cases where industrial flows reach the treatment plant all time.

The treatment plant expected to achieve efficiency of 87% based on COD removal instead of 63% when the return activated sludge (RAS) increase from 864 m3/h to 920m3/h.

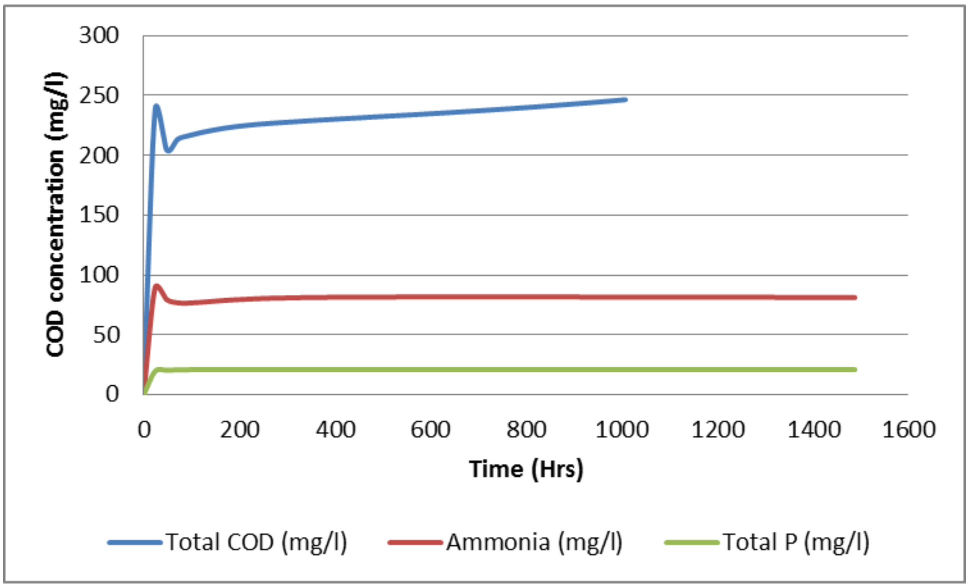


Figure 30: shows the variation of the effluent components concentrations over time for all industrial sector flow when RAS=920m^3/h.

Also, this value will decrease the concentration of COD to 50 mg/l in case of in

.dustrial shock for 24hr.

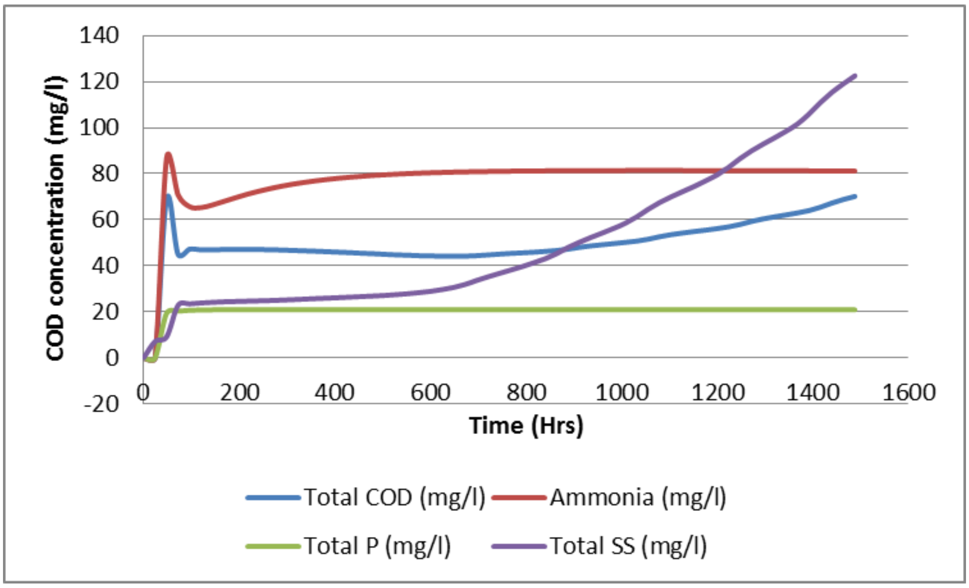


Figure 31: Variation of the effluent components concentrations over time for 24 hrs olive oil flow when RAS =920 m3/hr instead of 864 m3/hr

This solution will not beneficiary in cases of hydraulic malfunctions.

2. Reducing WAS flow rate:

Reducing WAS flow rate is Another solution for the industrial shocks to 12 m3/h that leads to reduce the concentration of COD to 83 mg/l.

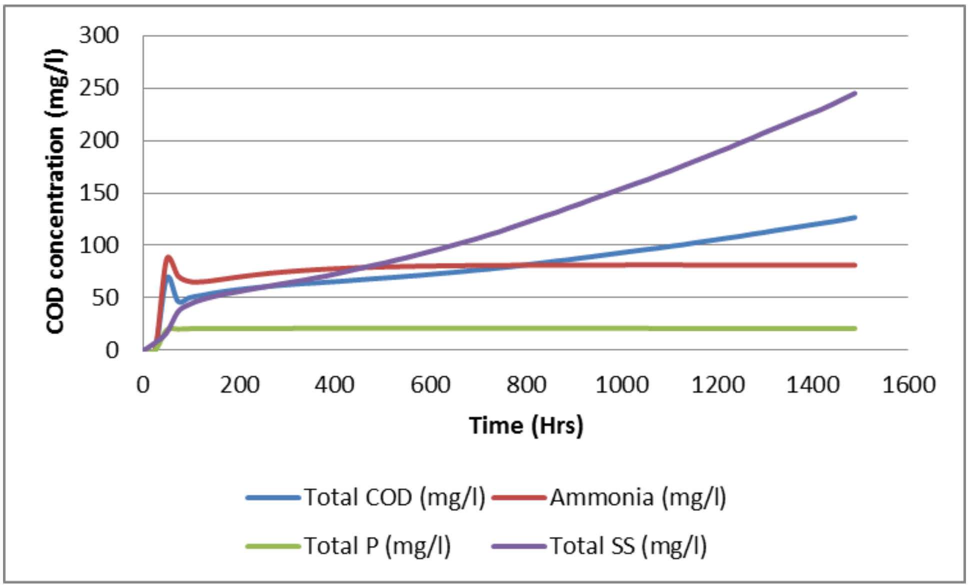


Figure 32: Variation of the effluent components concentrations over time For 24 hrs olive oil flow when WAS =12 m3/hr instead of 24m3/hr.

This solution depends on WAS pump rang variation, it will increase the hydraulic retention time in the secondary clarifier.

3. Return flow to the head of PST:

This solution is based on to return part of RAS to the head of the primary sedimentation tank (PST).

If this solution applied during the normal case the effluent of NW-WWTP will reach 99.3% based on COD removal as shown in the figure below.

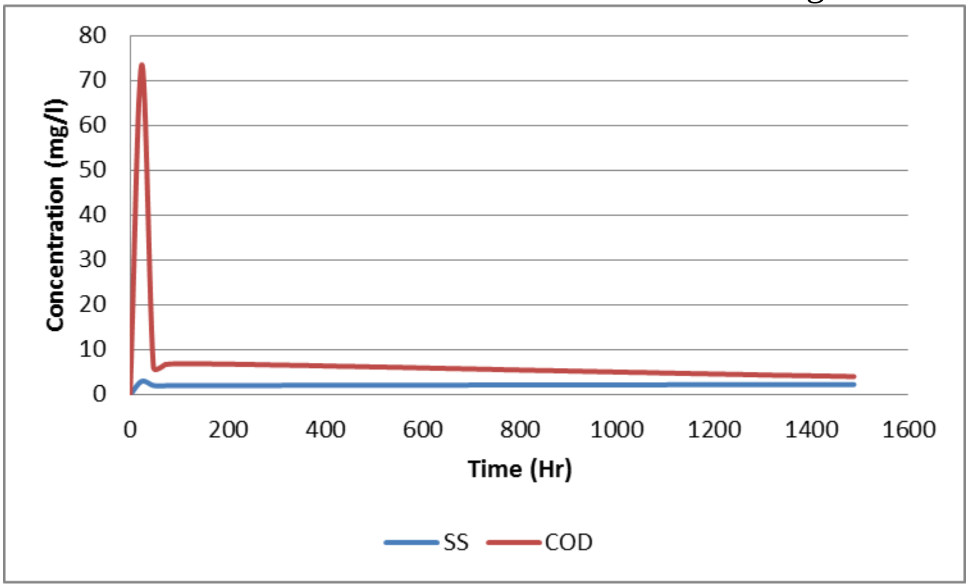


Figure 33: Effect of returning flow to the head of PST on COD and TSS.

This solution has a notable effect on TS effluents. But not on COD when industries flow reach TP.

This solution will be an excellent practice during hydraulic malfunctions especially when WAS pump malfunction.

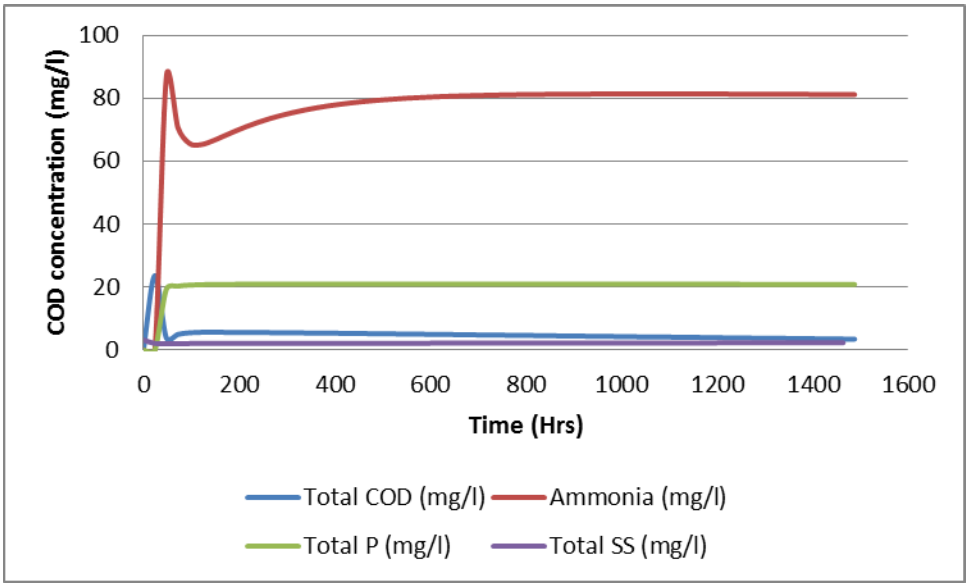


Figure 34: Effect of returning flow to the head of PST when malfunctioning of WAS pumps graph.

4. Constructing Offline Tank:

This is an expensive choice to deal with up normal cases in the treatment plant. It bases on constructing a tank (after preliminary treatment) to hold wastewater during high flow and then pump down during period of low flow.

Chapter Five

Conclusion and Recommendation

5.1Conclusion:

The objective of this research was to investigate the performance of Nablus-West wastewater treatment plant (NW-WWTP) under different conditions based on computer model by using STOAT program. The following conclusions were obtained from the results of the study

- The characteristics of the influent to the treatment plant have a wide range of variability, and this affects the performance of the treatment plant, and consequently the effluents concentrations results vary up to level beyond the Palestinian guideline.
- The performance efficiency of the treatment plant in COD removal is 98% out of design value, and the average and maximum value of COD in the effluent are 18mg/l and 80 mg/l respectively. The percentage of ammonia that will convert to nitrate is about 81%.
- The hydraulic equipment malfunction affect clearly the effluent quality and the overall performance.
- The effect of hydraulic faults which had been modeled on the overall performance up to 37% based on COD removal.
- Industrial wastewater affects extremely on the TP effluents as follows:

  A. During olive mill season: the average and maximum value of COD in the effluent are 644.6mg/l and, 1675.2 mg/l respectively, and the overall performance efficiency is61.52%.

B. Other periods: The average and max value of COD in the effluent are 316mg/l and 1230 mg/l respectively and the overall performance efficiency is 74.31%.

- The effluent from NW-WWTP is planned to be used for agricultural purposes, therefore its characteristics have to meet the Palestinian guidelines, therefore, a comparison had been conducted between the effluent results from simulation cases and the Palestinian guideline and the conclusion was that the effluent can be used for agriculture purposes except the case of high concentration may take place as a result of malfunction of hydraulic equipment or illegal flowing of untreated industrial wastewater to the treatment plant .
- Food to microorganisms (F/M) values range from (0.19-0.46) while the MLSS range from (5430-6200) mg/l in the normal case-without any troubleshooting.
- F/M varies from case to another, in case of malfunctioning of RAS pumps for 24 hrs it ranges from (0.5-1), the range becomes (1.1-2.28) in case that there is no RAS from one tank along the time of simulation. In case of malfunction of one line completely then the range will be (0.195-1.438). While the range as a result of flowing of industrial wastewater is (0.25-0.94). This means that the hydraulic malfunction will affect the F/M ratio larger than the effect of industrial wastewater flow since the industrial wastewater flow is relatively smaller than domestic wastewater flow.

- The settleability of sludge can be considered fair to good according to F/M values.
- Increasing RAS flow from 864 m^3/hr. to 920m^3/hr affects NW-WWTP performance in case of considering the industrial wastewater flow. And despite that it could be proper solution for unexpected loads.
- Reducing WAS pump rate to 12m^3/hr will affect positively the untreated industrial wastewater flow case.
- The best solution for the all modeled cases is returning the flow from secondary sedimentation tank (SST) to the head of the primary sedimentation tank (PST), this will decrease the TSS in addition it is suitable for hydraulic malfunction case since it will increase the hydraulic retention time.
- Construction of offline tank to intake wastewater during high flow then to drainage it down during period of low flow is the most expensive solution in the modeled cases.

5.2 General Recommendations:

The following recommendations will be requested for any future developing of this study, in order to build on the achieved results :.

- The kinetic parameters(Y, K_d, K_s, K) for wastewater still need to be explored, also the particulate BOD hydrolysis rate and particulate BOD half-rate constant to be specified.

- Industrial activities in Nablus-West still need tremendous efforts in order to count and classify them into main categories. Also wastewater production and it's characteristics should be specified.
- Municipality should monitor Wadi –Zeimar and strict regulations should be enacted to prevent illegal connections.
- The research recommends to install a modern weather station (e.g rain gages, Lysimetre….etc) to make a precise study on the effect of storm water on the treatment plant.
- Flow which enters the treatment plant should be measured and logged continuously; classification of that flow will be helpful in the simulation process.
- Further researches should be carried out to study the solid line and the gas production from digester.
- In order to benefit from operating of the treatment plant, a feasible strategy for effluent water reuse should be elaborated.

5.3 Special Troubleshooting and Operation Guide:

As shown above, NW-WWTP will receive variable influents and the treatment plant operators should be aware of that as it relates to the following issues:

- The characteristics of the influent that is flowing to the aeration basin.
- The environment in the aeration basin that have to be maintained to ensure sufficient treatment.

- The operating conditions within the secondary clarifier, which affects on the efficiency of solid separation.

To control the process of activated sludge the operators of NW-WWTP need some procedure to help them in maintaining control over the four key areas of the process:

- Providing of controllable influent feeding in front of the aeration tanks.
- Maintaining of proper dissolved oxygen and mixing levels in the aeration tanks. This requires continuous monitoring by the system operators using D.O meters.
- Controlling of the RAS Pumping Rate in the secondary sedimentation tanks through sludge settleability test known as settlemeter.
- Maintaining of the Proper Mixed Liquor Concentration (controlling the F/M ratio of the system).

The following procedures were suggested to deal with the different modeled cases and to control NW-WWTP operation; table (24) listed the solution name, solution procedure, suitability for the different cases, and the restriction on applying it.

Table 19: NW-WWTP operational plan for the different modeled cases .

No.	Solution	Procedure	Cases	Suitability	Restrictions
1	Increasing RAS flow rate	Increase RAS to reach 920 m^3/hr.	Industrial wastewater discharged into treatment plant.	relatively suitable	Getting optimum RAS flow rate. More power needed
			Illegal discharge and shock load.	suitable	
			Hydraulic malfunction	not suitable	
2	Reducing WAS flow rate	Decrease WAS to 12m^3/hr	Industrial discharge into treatment plant.	relatively suitable	Increasing of HRT in SST
			Illegal discharge and shock load.	suitable	
			Hydraulic malfunction	not suitable	
3	Return flow to the head of PST	Return the flow from SST to the head of the PST.	Industrial discharge into treatment plant.	Suitable for TSS.	More Power needed.
			Illegal discharge and shock load.	Suitable for TSS.	
			Hydraulic malfunction	Suitable	
4	Constructing Offline Tank	constructing a tank (after preliminary treatment) to hold wastewater during high flow and then pump down during period of low flow	Industrial discharge into treatment plant.	Suitable	More Power needed. Large area and volume needed. Expensive choice
			Illegal discharge and shock load.	Suitable	
			Hydraulic malfunction	Suitable	

To avoid TP failure under the previous cases or under different conditions, it is recommended to review the following problems and their remedial actions which were listed in worldwide TP (Giordano. and Petta, 2004).

Table 20 : treatment plants problems and their possible remedy actions

Unit	problems	Observed Effect(s)	Main Causes	Remedial Actions
Screen	Sand accumulation in the screen channel	1. Water level increase in the screening channel 2. Sand reduction collected from the grit chamber	1.Reduced approach velocity. 2.Obstruction occurrence in the screening channel.	1.If the approaching velocity is less than 0.5 m s^{-1} then an increase is needed: a temporary solution could be the flow rate increase through a recycle flow, a reduction of the screening channels (if there are more than two working in parallel) a water level reduction modifying the out flow weir. 2.Empty the screen channel and remove all the bottom irregularities
	Solid transport though the screen.	1.Regular clogging of the pipes downstream the screen. 2.Finding inappropriate materials in the pump impeller shown by high electrical input and unusual noises.	1.Solids removal not effective. 2.Unsuitable pumps. 3.Incorrect piping design or installation.	1.As temporary solution reverse the pump rotational movement. 2.Modify the suction pipe setting up a protection barrier. 3.Replace the pump. 4.Modify the solid removal system upstream.
Grit Chamber	Grit transport though the grit chamber.	1.High inert content in the biological aeration tank. 2.Quantity of collected grit smaller than normal conditions.	High velocity and / or too short hydraulic retention time	1.In the rectangular horizontal-flow grit chamber, increase the frequency of grit removal in order to increase the available water section. 2.Reduce the velocity of roll or agitation. 3.Increase the number of the grit chamber. 4.Reduce air flow rate in case of aerated grit chamber. 5.Replace the pump. 6.Modify the solids removal system upstream.
	High content of organic material in the collected grit.	1.Quantity of grit removed higher than the normal. 2.Dark color of the grit removed. 3.Mixture more doughy than the normal. 4.Foul smell from the collected grit.	Low velocity and / or too high hydraulic retention time	1.If possible, reduce the number of the grit chambers working in parallel. 2.In case of rectangular horizontal-flow grit chambers, reduce the water section or modify (reduce) the water level in the chamber by regulating the weir. 3.In case of aerated grit chamber increase the air flow rate. 4.Increase the velocity of roll or agitation.
Sedimentation	Presence of septic sludge, containing bubble gas, on the water surface.	1.Presence of floating material on water surface. 2.Emanation of sulphides smell from clarifier.	1. Sludge degradation due to high hydraulic retention time 2. The trouble could take place in a limited zone of the clarifier due to the problems of the sludge collector mechanism.	1. Increase the scraper velocity 2. Increase the extraction time or the frequency of the sludge removal
		1.Low settleable solids removal efficiency. 2.% removal lower than the normal. 3.Presence of suspended solids in the effluent.	1.High overflow rate 2.Presence of short-circuit in the clarifier	1.If the trouble is caused by the high overflow rate, evaluate the possibility of realize another clarifier or equalization tank 2.If the trouble is caused by short-circuit, modify the flow characteristics installing screens and enhancing the inlet and outlet distribution systems

	Low floatable material removal efficiency.	Presence of oils and greases in the clarifier effluent	Incorrect skimmer operation	1.Install a screen in the clarifier: floating materials exceed the outlet weir, and therefore periodical screen cleaning operation are needed. 2.Install sprinkler in order to convey floating material to the extraction zone. 3.In case of wastewater containing high quantity of oil and grease evaluate the chance of installing a flotation unit upstream the clarifier.
	Excessive sedimentation in the clarifier approaching channel.	Solid presence in the clarifier approaching channel and/or distribution system.	Low velocity in the approaching channel	1.Reduce the channel section or increase the turbulence in the approaching channel through recycled wastewater or air. 2.Enhance the grit chamber efficiency.
	Problems during sludge extraction.	1.Clogging of the extraction line. 1.Incorrect operation of the extraction sludge pumps. 3.Sand presence in the clarifier.	1.High content of sand or clay. 2.Low velocity in extraction sludge line.	1.Back-wash the clogged line. 2.Enhance the grit chamber efficiency. 3. Remove the sludge more frequently, trying to remove curves and valves. 4.If needed reduce the sludge pipe diameter.
	Sludge presence in the final effluent (secondary clarifier)	High TSS content in the secondary clarifier effluent	1.Bad sludge settling characteristics. 2.High overflow rate. 3.Not properly functioning of the scraper.	1.Enhance the weir layout and eventually place some screen wind. 2.Increase the sludge extraction and recycle flow rate.
	Floating sludge presence in the secondary clarifier	1.High TSS content in the secondary clarifier effluent. 2.Floating sludge presence in the secondary clarifier.	Denitrification process in the secondary clarifier	1.Reduce SRT 2.Reduce sludge retention time in the clarifier
Activated Sludge	Sludge Bulking (filamentous microorganisms)	1.High TSS content in the secondary clarifier effluent. 2.Filamentous microorganisms in mixed liquor.	1.Low nutrient concentration in the incoming wastewater. 2.Toxic compounds in the incoming wastewater. 3.Wide pH and temperature oscillations. 4.High organic loading rate. 5.Insufficient aeration.	1.Chlorine or oxygen peroxide dosage in the return sludge line (5 – 15 g Cl kg-1SS d-1). 2.Inorganic coagulants (cake, ferric chloride, etc.) dosage. 3.Increase SRT. 4.IncreasePH and DO. 5.IncreaseBOD5:N:P ratio correction in the incoming wastewater.
	Foaming	Scum presence in the aeration basin.	High content of foaming agents and/or oils and greases in the incoming wastewater.	1.Foam removal through water sprinkling. 2.Chlorine dosage.
	Low DO value in the aeration basin	1.Efficiency reduction. 2.DO reduction in the aeration basin; and temporary bulking. 3.Mixed liquor dark color.	1.Insufficient aeration. 2.Wide oscillation of the organic loading rate.	1.Increase the volume of the aeration basin (raising the water level). 2.Increase the aeration.

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Appendix (A)

Annex A1. Nablus-West Wastewater Treatment Plant dimensions

NW-WWTP PROCESS DESCRIPTION			
Coarse screens	Number of units	2	unit
	Type	automatic cleaning	
	Bar spacing	30	mm
	Width of channel	1	m
Fine screens	Number of units	2	unit
	Type	automatic cleaning	
	Bar spacing	6	mm
	Width of channel	1	m
GRIT AND GREASE REMOVAL CHAMBER	Number of grit and grease chambers	2	unit
	Width of each grit chamber	2	m
	Width of each grease chamber	1	m
	Depth of each grit chamber	2.23	m
	Length of each chamber	25	m
PRIMARY SEDIMENTATION TANK	Number of tanks	2	unit
	Length of tank	27	m
	Width of tank	8	m
	Water depth	4	m

	Effective volume per tank	864	m3
Aeration tanks	Number of activated sludge tanks	2	unit
	Length of each AST (incl. round tracks)	107.5	m
	Width of each aeration tank	16.7	m
	Water depth of each aeration tank	3.88	m
Aeration system	Type of aerators	Surface aerator, Mammoth Rotors	
	Number of aerators per tank	8	units
	Diameter of rotors	1000	mm
	Length of rotors	7.05	m
	Capacity per aerator	62	kg O2/hr in clean water
	Rated power per unit	37	kw
FINAL SEDIMENTATION	Number of FST	2	units
	Diameter of FST	34	m
	Water depth at 2/3 - radius	4.25	m

Annex A2. Wastewater constituent's concentrations in Zeimar wadi that obtained from Nablus Municipality 2007.

		pH	NH3-N	BOD5	COD	SS	TSS	NO3-N	P-PO4	Nitrogen Ntot	Ptot	TKN	TKN calculated	Norg calculated
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Samples												**crosscheck**		
No of samples		10	10	10	10	10	10	10	10	10	10	3		
Max		8,06	95,90	656	1280	652	784	8,60	10,10	133,60	22,80	110,00		
Min		7,45	70,41	351	880	400	560	5,60	6,51	93,50	11,28	70,00		
Date	**Day**													
27.03.2007	Tues	8,06	70,41	351	1.280	400	656	8,60	6,51	93,50	11,28		84,90	14,49
09.04.2007	Mon	7,46	89,78	490	960	584	696	7,95	7,73	117,00	12,45		109,05	19,27
18.04.2007	Wed	7,62	90,52	470	880	412	572	6,60	6,88	133,60	15,75		127,00	36,48
30.04.2007	Mon	7,59	92,66	510	960	500	680	7,40	8,84	126,40	18,60		119,00	26,34
07.05.2007	Mon	7,58	95,50	656	1.120	496	560	6,40	9,79	109,70	17,74	70,00	103,30	7,80
15.05.2007	Tues	7,52	95,00	600	1.040	464	644	5,80	9,69	107,50	17,00	110,00	101,70	6,70
16.05.2007	Wed	7,45	95,50	530	960	532	652	6,20	10,10	102,20	17,70	98,00	96,00	0,50
24.05.2007	Thur	7,64	94,60	580	1.120	652	784	5,60	9,50	103,10	17,80		97,50	2,90
26.05.2007	Sat	7,55	93,90	550	1.024	500	604	6,20	9,90	106,00	22,80		99,80	5,90
27.05.2007	Sun	7,64	95,90	612	1.200	544	648	6,80	9,40	114,00	19,40		107,20	11,30

Annex A3: The design influent wastewater characteristics for Nablus WWTP(Nablus Municipality ,2008).

Loads and concentration	2020	2025	2035
BOD_5 (kg BOD_5 /d) / (mg/L)	8,350 / 562	12,375 / 628	**16,700 /610**
COD (kg COD/d) / (mg/L)	16,500/1,110	24,750/1,256	**33,000/ 1,205**
SS (kg SS/d) / (mg/L)	9,625 / 648	14,438 / 733	**19,250 / 703**
Total Nitrogen (kg TKN/d) /(mg/L)	1,654 / 111	2,081 / 106	**3,310 / 121**
P Total (kg P/d) / (mg/L)	269 / 18	341 / 17	538 **20**

Annex A4: Nablus WWTP effluent standards (Nablus Municipality ,2008)..

Standard	2020	2025	2035
BOD5 (mg/L)	≤ 20 mg/l	≤ 10 mg/l	**≤ 10 mg/l**
COD (mg/L)	--	≤ 70 mg/l	**≤ 70 mg/l**
SS (mg/L)	≤ 30 mg/l	≤ 10 mg/l	**≤ 10 mg/l**
Total Nitrogen (mg/L)	--	≤ 25 mg/l	**≤ 25 mg/l**
Fecal Coli.	--	≤ 10 /100ml	**≤ 10 /100ml**

Annex A5: Wastewater characteristics for the influent and the effluents from NW-WWTP.

A5.1: Chemical Oxygen Demand COD test results

Date	Type of Samples	Value(mg/l)	Average	BOD approx
1-Aug	inlet	1072		
	outlet	450		
5-Aug	inlet	527		
	outlet	190		
12-Aug	inlet	793		
	outlet	108		
13-Aug	inlet	1269		
	outlet	<100		
14-Aug	inlet	1267		
	outlet	76		
15-Aug	inlet	465		
	outlet	80		
17-Aug	inlet	381		
	outlet	70		

Date	Type of Samples	Value(mg/l)	Average	BOD approx
18-Aug	inlet	1320		
	outlet	60		
19-Aug	inlet	1323		
	outlet	63		
20-Aug	inlet	1196.5		
	outlet	77		
24-Aug	inlet	320		
	outlet	67		
	Composite samples	960		
25-Aug	inlet	1176		
	outlet	62		
27-Aug	inlet	1225		
	outlet	15		
28-Aug	inlet	1202		
	PST	919		
	outlet	62		
1-Sep	inlet	980		
	outlet composite	153		
3-Sep	Inlet	1135		
	outlet	39		
4-Sep	inlet	1290		
	oulet	48		
5-Sep	inlet	1216		
	outlet	47		
7-Sep	inlet	1293		
	outlet	57		
8-Sep	inlet	1222		
	outlet	58		
9-Sep	inlet composite	1086		
	outlet composite	69		
10-Sep	inlet composite	924		
	outlet composite	79		
11-Sep	inlet composite	945		
	outlet composite	86		
12-Sep	inlet composite	974		
	outlet composite	57		
14-Sep	inlet grab	411		205.5
	outlet grab	37		7.4
15-Sep	inlet composite	865		

Date	Type of Samples	Value(mg/l)	Average	BOD approx
	outlet composite	28		
16-Sep	inlet composite	1025		
	outlet composite	40		
17-Sep	inlet composite	865		
	outlet composite	47		
18-Sep	inlet composite	964		
	outlet composite	57		
19-Sep	inlet composite	969		
	outlet composite	44		
21-Sep	inlet composite	915		
	outlet composite	54		
22-Sep	inlet composite	921		
	outlet composite	52		
23-Sep	inlet composite	933		
	outlet composite	45		
24-Sep	inlet composite	950		
24-Sep	oulet composite	55		
24-Sep	outlet grab	45		
25-Sep	inlet composite	967		
25-Sep	oulet composite	52		
25-Sep	outlet grab	41		

A5.2: Examination of ammonium.

Date	Type of sample	Value (mg/l)	Average
13-Aug	inlet	71.6	
	outlet	70.2	
20-Aug	inlet	70.4	
	oulet	53.8	
24-Aug	inlet	84.9	
	oulet	27	
25-Aug	inlet	>80	
	outlet	34.21	
27-Aug	inlet	78.2	
	outlet	41.6	

A5.3: Examination of Phosphate –Total P.

Date	Type of Sample	Type of measurment	Value (mg/l)
24-Aug	inlet	PO4-P(o-Phosphate)	31
	oulet	PO4-P(o-Phosphate)	<10
	inlet	P	2.38
	outlet	P	0.77
25-Aug	inlet	Ptotal	7.73
	outlet	Ptotal	<0.3
27-Aug	inlet	Ptotal	6.32
	outlet	Ptotal	1.44

Annex A6: Industrial wastewater characteristics in Nablus (Nablus Municipality, 2012).

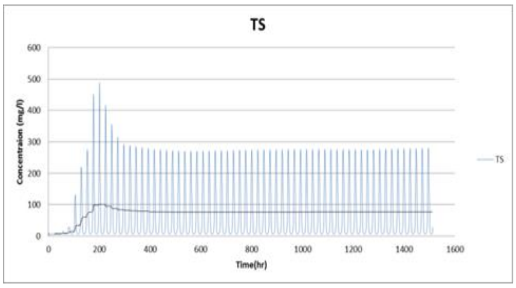
Sector	**Flow(m^3/d)**	**COD(Kg/d)**
Textile	197	**100**
Olive Oil Mills	120	**12,000**
Tahina Factories	61	**440**
Diary	77	**7,650**
Slaughterhouse	48	**1,620**
Others	60	**50**

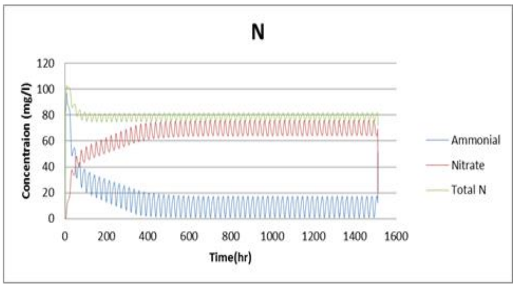
Annex A7: Summary of WHO and Palestinian standards for treated wastewater reuse in agriculture (Mizyed, 2013).

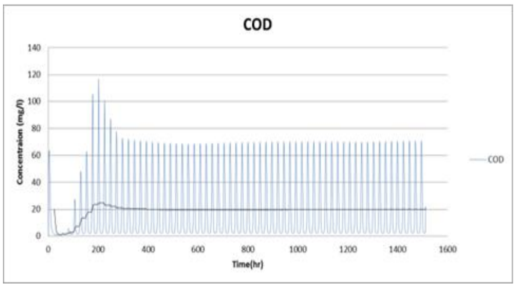
Standard	**Category**	**Reuse Condition, category**	**Intestinal nematodes (mean no. of eggs per liter)**	**Fecal coliforms (mean no. per 100)**	**TSS (mg/l)**	**BOD_5 (mg/l)**	**TN (mg/l)**
Palestinian Guidelines (PSI, 2012)	A	High	≤ 1	200	30	20	30
	B	Good	≤ 1	1000	30	20	30
	C	Average	≤ 1	1000	50	40	50
	D	Low	≤ 1	1000	90	60	90

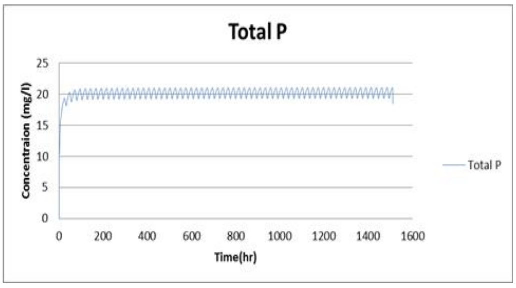
Appendix (B)

Annex B1: Long term simulation" dynamic equilibrium'' results variations.

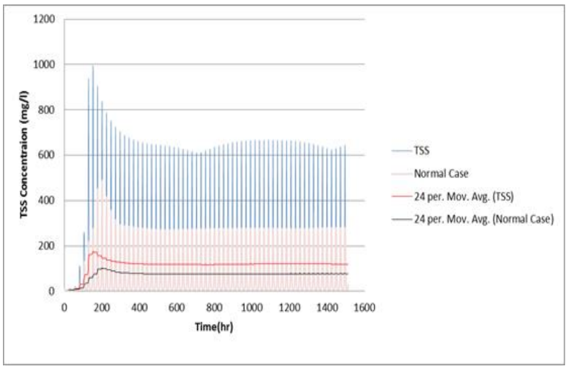


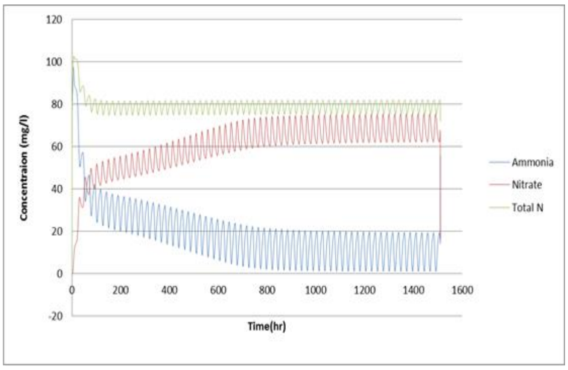


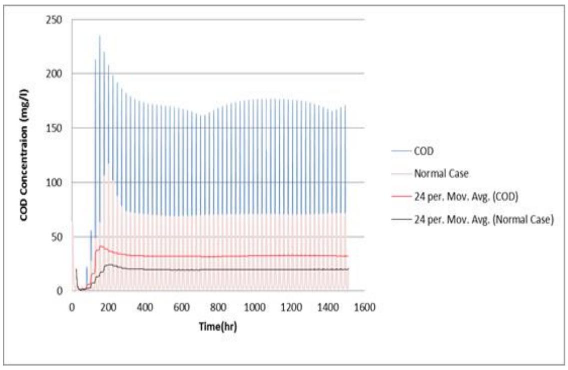


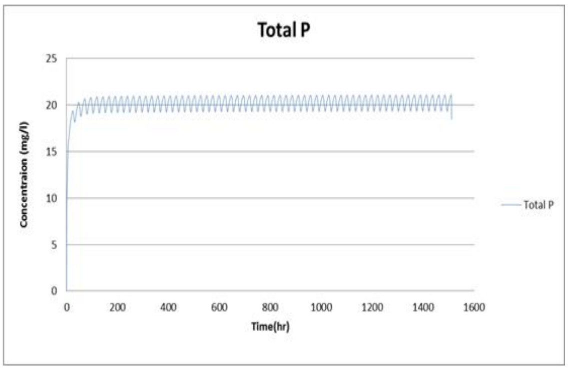


Annex B2: Comparison between the measured and the model prediction results graphs.



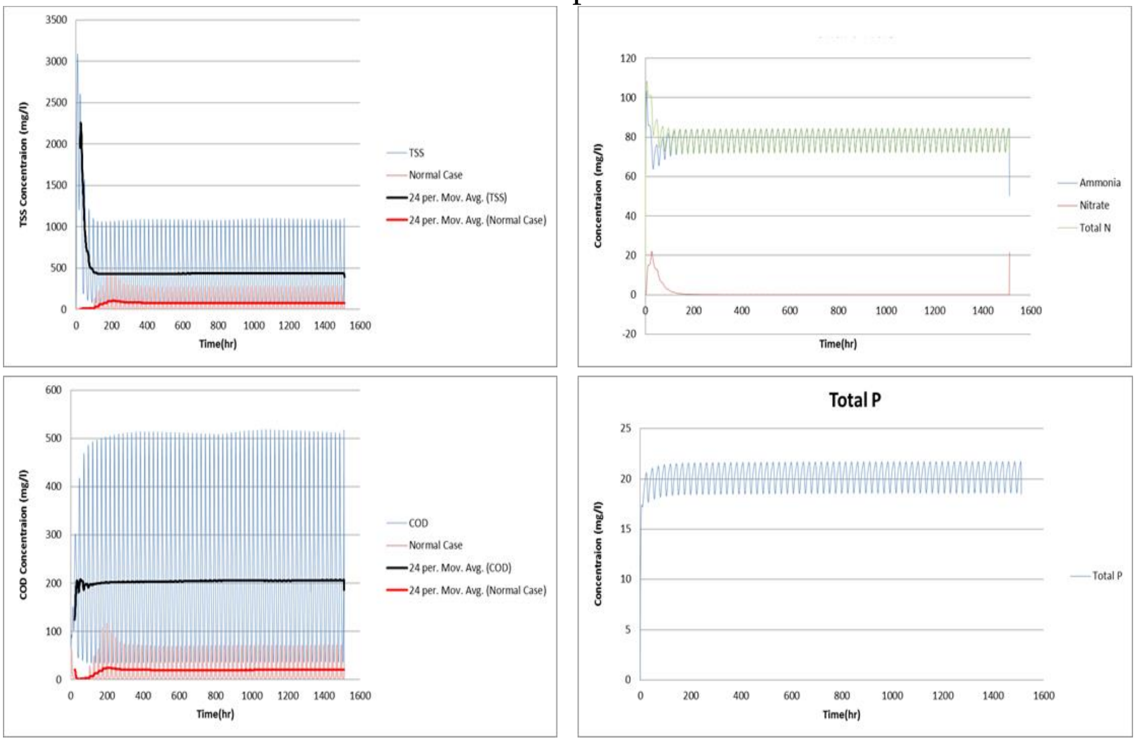




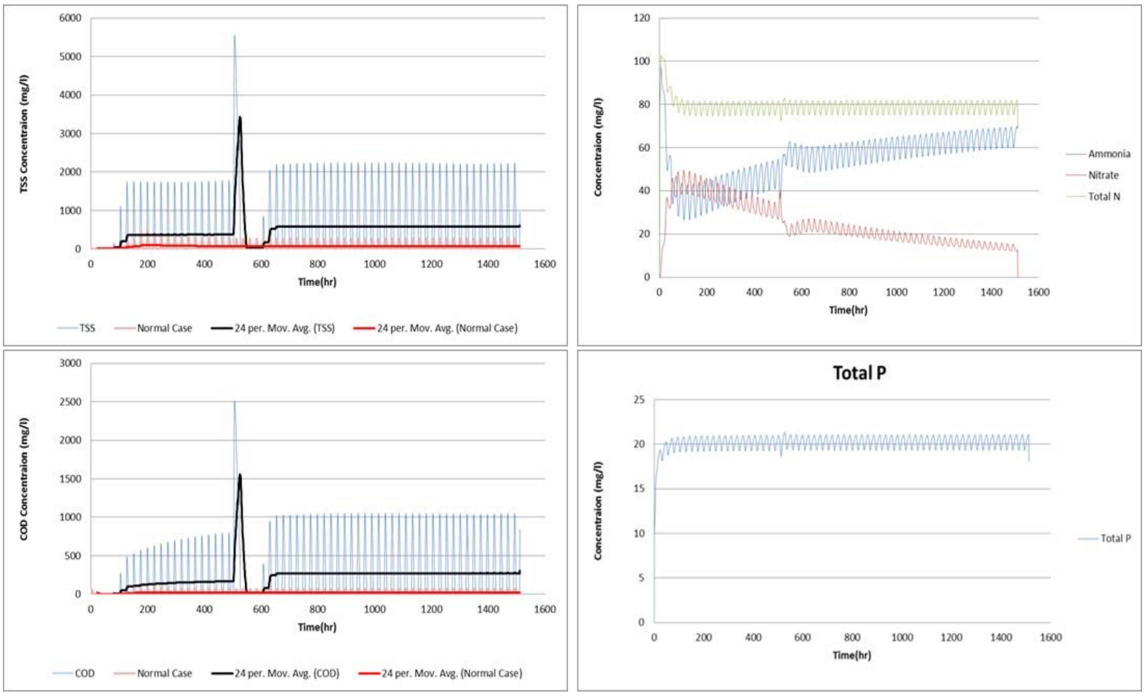


Annex B3: Results for case of Studying the effects of malfunction RAS pumps for one tank:

Annex B3.1: Failure at all simulation period

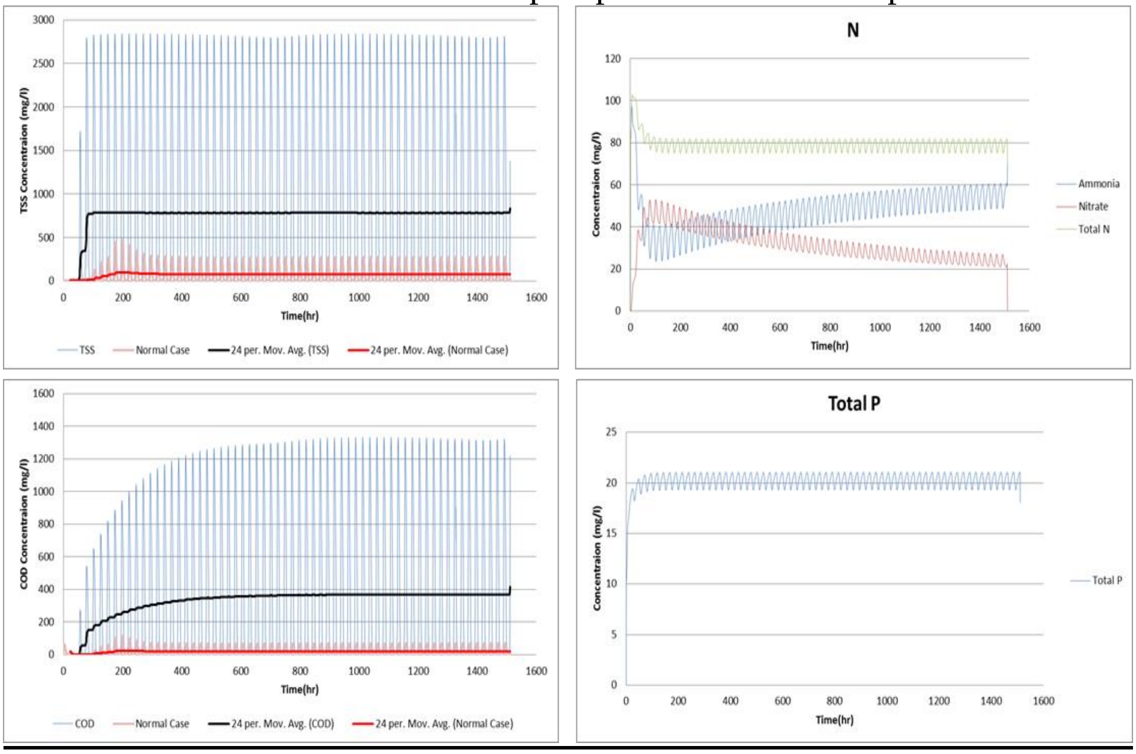


Annex B3.2: Failure after 24 hrs

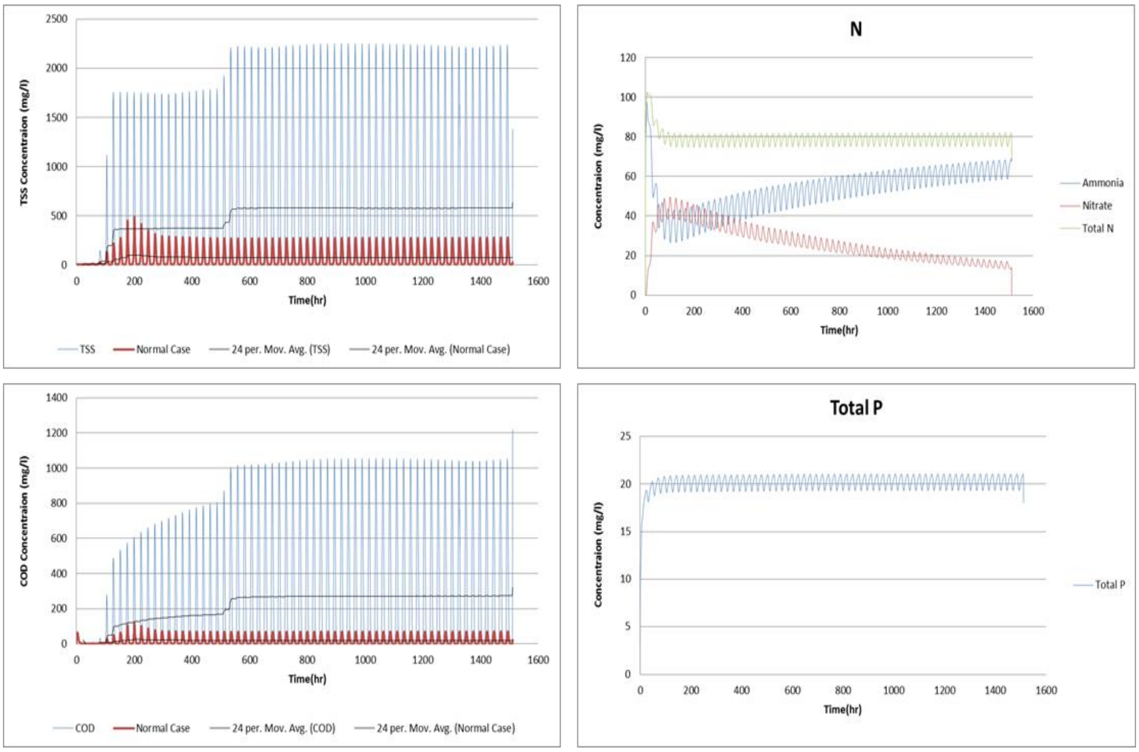


Annex B4: Results for case of Studying the effects of malfunction of WAS pumps

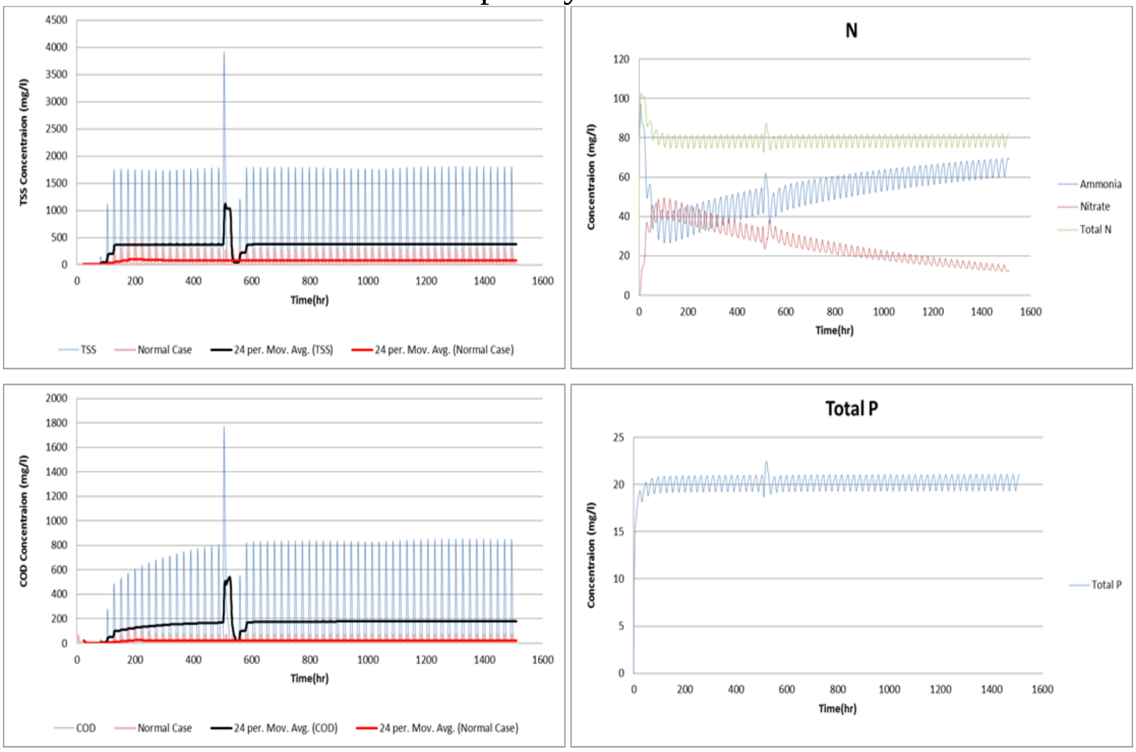
Annex B4.1: Failure of two tanks’ pumps at all simulation period



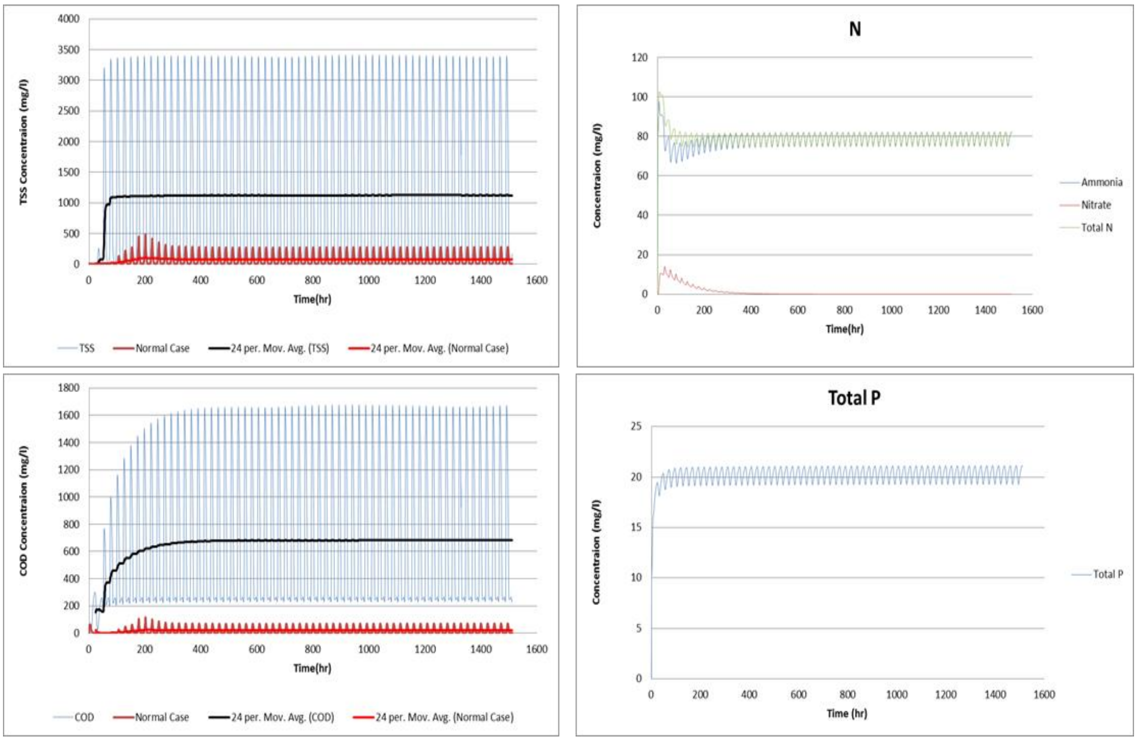
Annex B4.2: One tank failure after 500hr



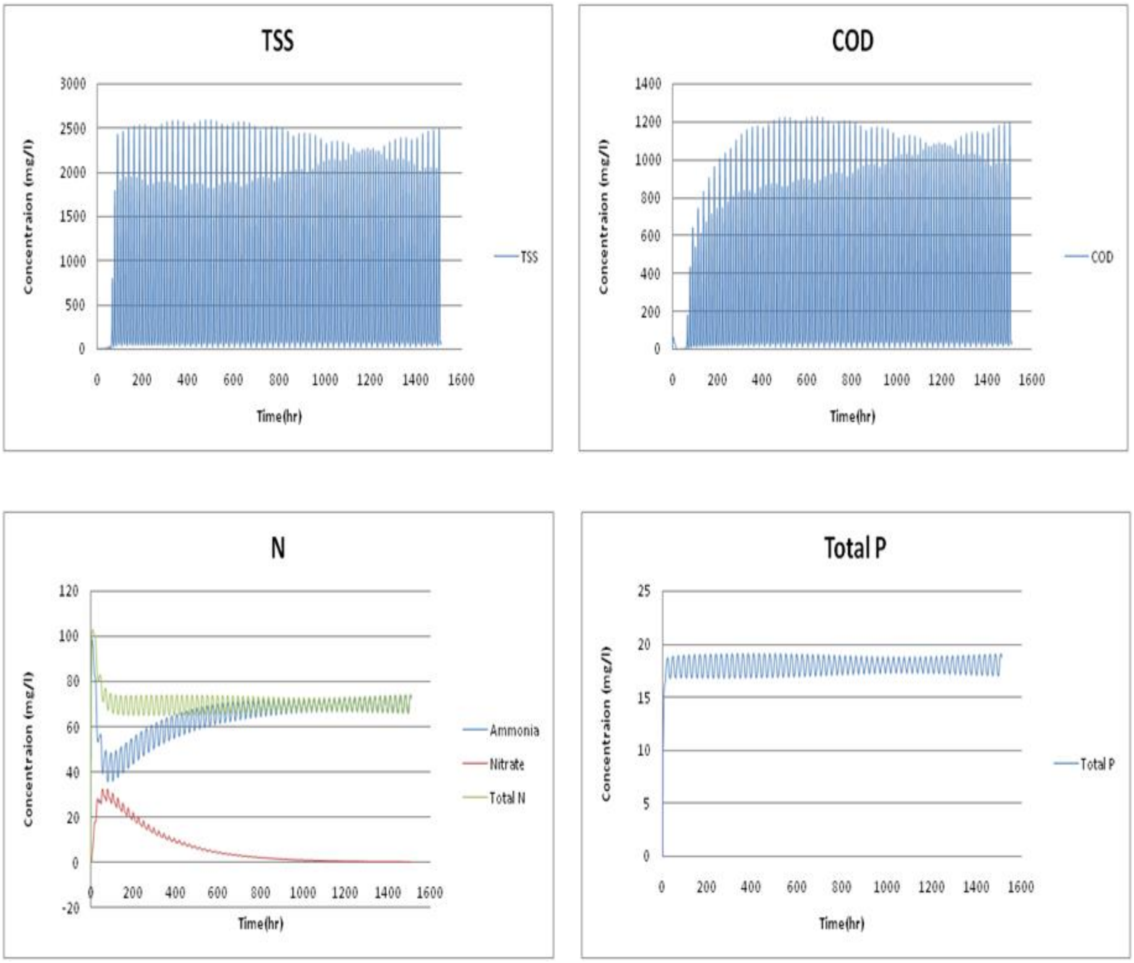
Annex B5: Malfunction of completely one line results variations.



Annex B6: Variation of the effluent components concentrations over time for flow from all industrial sectors



Annex B7: Variation of the effluent components concentrations over time for flow from some industrial sectors



جامعة النجاح الوطنية

كلية الدراسات العليا

دراسة استطلاعية لأداء محطة نابلس الغربية لمعالجة المياه العادمة والمنشأة حديثا تحت ظروف الأعمال المختلفة

إعداد

محمد عبد الفتاح ابراهيم صالح

إشراف

د. عبد الفتاح حسن

أ.د. مروان حداد

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2014

دراسة استطلاعية لأداء محطة نابلس الغربية لمعالجة المياه العادمة والمنشأة حديثا تحت ظروف الأعمال المختلفة

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الملخص

تعد مدينة نابلس اكبر مدينة في شمال الضفة الغربية. وتتكون من مستجمعين مائيين هما: المستجمع الشرقي والمستجمع الغربي. ولهذا يفضل ان يتم انشاء محطتين لمعالجة المياه العادمة. وبالنسبة للجزء الغربي فان المحطة انشأت حديثا ودخلت حيز التشغيل في حين ان الجزء الشرقي مازال في مرحلة التخطيط.

محطة نابلس الغربية سوف تقوم بمعالجة 3 ملايين متر مكعب سنويا من المياه العادمة والتي من الممكن ان يتم اعادة استخدامها في الانشطة الزراعية.

تواجه المحطة تحديين رئيسيين هما : نقص المعلومات والخبرات في تشغيل وصيانة المحطات من هذا النوع، بالاضافة الى المدى الواسع لخصائص المياه العامة في المنطقة.

تهدف هذه الراسلة الى دراسة اداء محطة نابلس الغربية تحت تاثير الاحمال المختلفة.

اعتمد البحث على برنامج محوسب لنمذجة ومحاكاة المحطة.

ومن الجدير بالذكر ان كل المعلومات اللازمة مثل المدخلات وعمليات المعالجة تم جمعها من الجهات والمؤسسات ذات العلاقة . وتمت عملية النمذجة باستخدام برنامج يسمى STOAT.

وكواحدة من المعضلات التي واجهت البحث هي مسالة القيم الاولية للتراكيز المختلفة في احواض المحطة ولهذا تم استخدام المحاكاة الديناميكية حيث تم الوصول الى نقطة التعادل الديناميكة بعد 1512 ساعة اي ما يعادل 63 يوما.

اما عن الحالات التي تم دراستها فهي : دراسة اداء المحطة في الظروف التصميمية، حالات العطل الهيدروليكي للمعدات مثل: تعطل مضخات الحمأة ومضخات العائد. بالاضافة الى دراسة بعض الاحمال الناتجة عن الانشطة الصناعية على المحطة.

تم معايرة النموذج باستخدام القيم الواردة من مختبرات المحطة.

في حالة دراسة اداء المحطة في الظروف التصميمية فانه من المتوقع ان تحقق المحطة 98% من كفاءة التخلص من الاكسجين الممتص بيوكيميائيا في حين ان الامونيا ستتحول الى نيترات بنسبة 81% ، في حين لن يحص تغيير في تراكيز الفوسفات وستبقى القيمة 20 ملغم/لتر.

ان اداء المحطة في حالات العطل الهيدروليكي يختلف من حالة الى اخرى ، لكن اسواها هو عندما تصل كفاءة المحطة الى 63%.

ستقل فعالية المحطة عند شبك المخلفات الصناعية مع المحطة حيث ستقل الى نسبة 61.5% في موسم الزيتون والى 74% في المواسم الاخرى.

وبالنهاية فان مجموعة من المشاكل التي قدتحدث نتيجة لتلك الاحمال قد تمت جدولتها واقتراح بعض الحلول لها في خطة ادارية فعلى سبيل المثال : عند تكون الرغوة في احواض التهوية فان تلك الظاهرة قد يعود سببها الى زيادة معاملات الرغوة اوزيادة الزيوت الواصلة للمحطة ، وقد تم اقتراح بعض الاجراءات العلاجية لتلك الظاهرة مثل : ازالة الرغوة باستخدام رشاشات مياه او جرعة كلور.

ويمكن استخدام وجود الحماة في الخارج من احواض الترسيب كحالة اخرى على مشاكل قد تحدث في احواض الترسيب حيث ان الاسباب المنطقية لمثل تلك الظاهرة هي : خصائص سيئة للحماة المرسبة، او زيادة في معدل الفيض او وجود كاشطات غير فعالات، اما عن الحلول المقترحة فهي تحسين قدرة السد(الهدار) او زيادة استخراج الحماة والخط المعاد.