BIRZEIT UNIVERSITY

Faculty of Graduate Studies
Institute of Environmental and Water Studies
Master Program in Water and Environmental Engineering

Assessment of Performance and Capability of Sanitation Services Providers in Management and Operation of Selected Wastewater Treatment Facilities in the West Bank, Palestine

تقييم أداء وقدرة مقدمي خدمات الصرف الصحي في إدارة وتشغيل مرافق مختارة لمعالجة المياه العادمة في الضفة الغربية، فلسطين

A Master Thesis

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June, 2022

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This Thesis was submitted in partial fulfillment of the requirements for the Master's degree in Water and Environmental Engineering from the Faculty of Graduate Studies at Birzeit University, Palestine.

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The findings, interpretations and the conclusions expressed in this study don't express the views of Birzeit University, the views of the individual members of the MSc committee or the views of their respective.

Dedication

To my family and people,,,

Acknowledgments

قال تعالى: " وَمَن شَكَرَ فَإِنَّمَا يَشْكُرُ لِنَفْسِهِ" { النمل: 40}

Praise and thanks be to ALLAH Almighty that it is upon me to complete this thesis, and prayers and peace be upon His Noble Messenger Muhammad, may ALLAH’s prayers and peace be upon him.

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Abstract

The sanitation sector in Palestine is a newly emerging and growing sector, in the shadow of the political and economic conditions that Palestine is experiencing. Wastewater treatment plants (WWTPs), key elements of the sanitation facilities, form base foundation for urban growth and community development. Lack of sanitation facilities poses environment and public health hazards caused by discharge of raw sewage into the environment.

In the study area (West Bank), despite the technical, financial and political challenges in Palestine, The Palestinian government established eighteen (18) WWTPs of variable capacities, technologies, geographical locations and service area. This study aims to investigate the efficiency and performance of WWTPs operators from administrative and technical point of view, and its impact on WWTP efficiency. For this purpose, eight selective WWTPs, serving rural and urban communities, were chosen (Al-Tireh, Al-Bireh, West Nablus, Jericho, Jenin, Missilya, Taybeh Ramon and Al-Aroub).

The study explored key questions pertinent to potential obstacles and challenges facing WWTPs operators, and identified main operational and managerial aspects that could impair WWTP operation, thus reduce WWTPs efficacy. What role a central management unit (CMOU) for all WWTPs in the West Bank could encounter under the management of the PWA management? The study applied both semi-quantitative methods (questionnaire and case study) and qualitative approaches (interviews). Data collected were analyzed using software programs (Excel, SPSS package).

From administrative perspectives, the results revealed that only 50% of the WWTPs under study provide technical training programs for WWTP technical crews during the commissioning and start-up operational stages. About 75% of WWTP facilities prepare periodic annual performance reports. Only 50% own archives for operation, maintenance and repair works. About 62.5% of WWTPs operators supported the idea of establishing a CMOU, 25% were against this idea, and the Al-Tireh committed to neutrality. This means that the administrative system of some WWTPs needs to be improved with capability upgrading.

The results showed that 50% of the WWTPs are located within the boundaries of Areas “A” in accordance with the divisions of the Oslo Political Agreement, mostly rural and small onsite WWTPs. The central urban WWTPs, serving urban communities with increased number of beneficiaries are located in areas "C" under the control of Israeli military occupation.

The technical evaluation of WWTPs under investigation revealed that all of them produce treated water (TW) suitable for agricultural purposes. However, most of them do not carry out

tests periodically in accordance to the Palestinian standards. Which could negatively affect the credibility of the plant operators towards farmers, since only 37.5% of WWTPs have a central laboratory onsite, while the rest rely on external labs. Around 50% of the investigated WWTPs discharge the treated water (TW) directly into nearby water bodies. The other 50 percentage of TW produced is utilized in multi-beneficial uses onsite and outside the fence of WWTP including agricultural irrigation. Unused TW forms water for nature usage, tributaries for the natural streams in a semi-arid region. Results analysis on sludge production and disposal revealed that 50% of the WWTPs plants practice landfilling of sludge. Compared with other WWTPs under study, Al-Aroub WWTP showed the highest sludge production rate (5 kg/m^3.day) and the least Jericho plant (0.5 kg/m^3.day).

Comparative analysis of data collected on specific capital expenditure (CAPEX) and annual operational expenditures (OPEX), the highest OPEX costs revealed Missilya plant ($1,000/cap), while the lowest for Jenin WWTP ($150/cap), while the rest showed less than $400/cap. In addition, Missilya required the most land demand for the number of people served ($5m^2$/cap), the least of which is Al-Tireh ($0.1m^2$/cap) and the rest around $1m^2$/cap. Pertinent to energy and maintenance costs, Missilya also ranked highest in terms of energy consumption (2.0 kWh/m^3), followed by Jenin (1.5 kWh/m^3) and the rest of the them less than (1.0 kWh/m^3), as well as the highest Missilya in terms of maintenance costs followed by the Al-Tireh, the least of which is Jericho plant. In terms of energy production, 50% of plants have PV production systems so that the highest production for consumption is at Missilya plant of 110%, followed by Nablus plant, which produced 60% of its daily electricity consumption through solar energy and biogas-power generation unit. Therefore, increased capacity of PV generation at WWTPs ensures sufficient energy and less reliance on off-grid energy sources.

This study concludes the need to conduct an in-depth technical study of Missilya plant to explore reasons behind high electricity consumption and annual O&M expenditures. Further, a comprehensive strategic plan identifying the feasible operational structure and financial system of the suggested CMOU warrants further investigations. The investigations from the current study will help the Palestinian Sanitation Service Providers in integrating green economy principles and integrated water resources management in their sanitation planning, design, and operation. Awareness raising programs could increase potential water reuse rates in agricultural irrigation. Biosolids recycling, another gap in the integrated water resource management (IWRM) cycle could reduce the annual OPEX and ensure economic benefits for the sanitation services providers. Finally, building on the results of this study, further investigations should consider expanding its scope to include not only WWTPs but also the sewerage systems.

الملخص

يعتبر قطاع الصرف الصحي في فلسطين قطاعًا ناشئًا ومتناميًا حديثًا ، في ظل الظروف السياسية والاقتصادية التي تعيشها فلسطين. تشكل محطات معالجة مياه الصرف الصحي، عنصرا رئيسا في مرافق الصرف الصحي ، ونقطة اساس للنمو الحضري وتنمية المجتمع. يشكل الافتقار إلى مرافق الصرف الصحي مخاطر على البيئة والصحة العامة بسبب تصريف مياه الصرف الصحي الخام في البيئة.

في منطقة الدراسة (الضفة الغربية) ، على الرغم من التحديات الفنية والمالية والسياسية في فلسطين ، أنشأت الحكومة الفلسطينية ثمانية عشر (18) محطة معالجة مياه الصرف الصحي ذات القدرات المتغيرة والتقنيات والمواقع الجغرافية ومنطقة الخدمة. تهدف هذه الدراسة إلى التحقق من كفاءة وأداء مشغلي محطات معالجة مياه الصرف الصحي من وجهة نظر إدارية وفنية ، وتأثيرها على كفاءة محطات معالجة مياه الصرف الصحي. لهذا الغرض، تم اختيار ثمانية محطات معالجة مياه الصرف الصحي الانتقائية التي تخدم المجتمعات الريفية والحضرية (الطيرة ، البيرة ، غرب نابلس ، أريحا ، جنين ، مسليا ، طيبة رامون والعروب).

استكشفت الدراسة الأسئلة الرئيسية ذات الصلة بالعقبات والتحديات المحتملة التي تواجه مشغلي محطات معالجة مياه الصرف الصحي، وحددت الجوانب التشغيلية والإدارية الرئيسية التي يمكن أن تعيق تشغيلها، وبالتالي تقلل من فعاليتها. ما هو الدور الذي يمكن أن تلعبه وحدة الإدارة والتشغيل المركزية لجميع محطات معالجة مياه الصرف الصحي في الضفة الغربية تحت إدارة سلطة المياه الفلسطينية؟ وطبقت الدراسة كلا من الأساليب شبه الكمية (الاستبيان ودراسة الحالة) والأساليب النوعية (المقابلات). تم تحليل البيانات التي تم جمعها باستخدام البرامج (Excel ، حزمة SPSS).

من وجهة نظر إدارية ، كشفت النتائج أن 50٪ فقط من محطات معالجة مياه الصرف الصحي قيد الدراسة توفر برامج تدريب فني للأطقم الفنية لمحطات معالجة مياه الصرف الصحي أثناء مرحلة التشغيل. تقوم حوالي 75٪ من مرافق معالجة مياه الصرف الصحي بإعداد تقارير أداء سنوية دورية. يمتلك 50٪ فقط أرشيفات لأعمال التشغيل والصيانة والإصلاح. أيد حوالي 62.5٪ من مشغلي محطات معالجة مياه الصرف الصحي فكرة إنشاء وحدة الإدارة والتشغيل المركزية، وعارض 25٪ هذه الفكرة ، والتزمت الطيرة بالحياد. وهذا يعني أن النظام الإداري لبعض محطات معالجة مياه الصرف الصحي يحتاج إلى تحسين مع ترقية القدرات.

أظهرت النتائج أن 50٪ من محطات معالجة مياه الصرف الصحي تقع داخل حدود المناطق "أ" وفقًا لتقسيمات اتفاقية أوسلو السياسية، ومعظمها في المناطق الريفية ومحطات معالجة مياه الصرف الصحي صغيرة الحجم. تقع محطات معالجة مياه الصرف الصحي الحضرية المركزية، التي تخدم المجتمعات الحضرية مع زيادة عدد المستفيدين، في المناطق "ج" الخاضعة لسيطرة الاحتلال العسكري الإسرائيلي.

أظهر التقييم الفني لمحطات معالجة مياه الصرف الصحي قيد الدراسة أن جميعها تنتج مياه معالجة مناسبة للأغراض الزراعية. ومع ذلك، فإن معظمهم لا يجرون الاختبارات بشكل دوري وفقًا للمعايير الفلسطينية. مما قد يؤثر سلبًا على مصداقية مشغلي المحطة تجاه المزارعين، حيث أن 37.5٪ فقط من محطات معالجة مياه الصرف الصحي بها مختبر في الموقع، بينما يعتمد الباقي على مختبرات خارجية. حوالي 50٪ من محطات معالجة مياه الصرف الصحي التي تم فحصها تقوم بتصريف المياه المعالجة مباشرة في المسطحات المائية القريبة. يتم استخدام نسبة الخمسين بالمائة الأخرى من مياه الصرف الصحي المنتجة في استخدامات متعددة الفوائد في الموقع وخارج سياج محطة معالجة مياه الصرف الصحي بما في ذلك الري الزراعي. تشكل المياه المعالجة مياه للاستخدام الطبيعي وروافد للتيارات الطبيعية في منطقة شبه قاحلة. أظهر تحليل نتائج إنتاج الحمأة والتخلص منها أن 50٪ من محطات معالجة مياه الصرف الصحي تمارس طمر الحمأة.

مقارنة مع محطات معالجة مياه الصرف الصحي الأخرى قيد الدراسة، أظهرت معالجة العروب أعلى معدل إنتاج للحمأة (5 كجم / م^3. يوم) وأقل محطة أريحا (0.5 كجم / م^3. يوم).

تحليل مقارن للبيانات التي تم جمعها حول نفقات رأسمالية محددة ونفقات تشغيلية سنوية، كشفت أعلى تكاليف تشغيلية عن محطة مسلية (1000$/cap) ، بينما أظهرت أدنى تكلفة لمحطة معالجة مياه الصرف الصحي في جنين (150 $/cap)، بينما أظهر الباقي أقل من (400$/cap) . بالإضافة إلى ذلك، فان مسلية لديها أكبر طلب على الأرض نسة لعدد السكان المخدومين (5 m^2/cap) ، وأقلها الطيرة (0.1 m^2/cap) والباقي حوالي (1 m^2/cap). فيما يتعلق بتكاليف الطاقة والصيانة، فقد احتلت مسلية المرتبة الأعلى من حيث استهلاك الطاقة (2 Kwh/m^3) ، تليها جنين (1.5 Kwh/m^3) والباقي أقل من (1 Kwh/m^3) ، فضلا عن أم مسلية الأعلى من حيث تكاليف الصيانة تليها الطيرة وأقلها محطة أريحا. من حيث إنتاج الطاقة ، تمتلك 50٪ من المحطات أنظمة إنتاج كهروضوئية بحيث يكون أعلى إنتاج للاستهلاك في مسلية 110٪ ، ثم محطة نابلس التي تنتج 60٪ من استهلاكها اليومي للكهرباء من خلال الطاقة الشمسية وطاقة الغاز الحيوي / وحدة التوليد. لذلك، فإن زيادة قدرة توليد الطاقة الكهروضوئية في محطات معالجة مياه الصرف الصحي تضمن طاقة كافية وتقليل الاعتماد على مصادر الطاقة الخارجية.

خلصت هذه الدراسة إلى الحاجة إلى إجراء دراسة فنية متعمقة لمحطة مسليا لاستكشاف الأسباب الكامنة وراء ارتفاع استهلاك الكهرباء ونفقات التشغيل والصيانة السنوية. علاوة على ذلك، فإن الخطة الإستراتيجية الشاملة التي تحدد الهيكل التشغيلي القابل للتطبيق والنظام المالي لوحدة الادارة والتشغيل المركزية المقترحة تستدعي المزيد من التحقيقات. ستساعد التحقيقات من الدراسة الحالية مزودي خدمات الصرف الصحي الفلسطينيين في دمج مبادئ الاقتصاد الأخضر والإدارة المتكاملة لموارد المياه في تخطيط الصرف الصحي وتصميمه وتشغيله. يمكن أن تؤدي برامج زيادة الوعي إلى زيادة معدلات إعادة استخدام المياه المحتملة في الري الزراعي. إعادة تدوير المواد الصلبة الحيوية، فجوة أخرى في دورة الإدارة المتكاملة لموارد المياه يمكن أن تقلل من النفقات التشغيلية السنوية وتضمن منافع اقتصادية لمقدمي خدمات الصرف الصحي. أخيرًا، بناءً على نتائج هذه الدراسة ، يجب أن تنظر التحقيقات الإضافية في توسيع نطاقها ليشمل، ليس فقط محطات معالجة مياه الصرف الصحي، ولكن أيضًا أنظمة الصرف الصحي.

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List of Abbreviations:

AL: Aerated Lagoons

AD: Anaerobic Digestion

AP: Anaerobic Pond

AFD: Agence Française de Développement (French Development Agency)

ASS: Activated Sludge System

AUFGF: Anaerobic Up-Flow Gravel Filter

BAF: Biological Aerated Filters

BOD: Biochemical Oxygen Demand

CAS: Conventional Activated Sludge

CBR: Case Based Reason

CD: Chlorine Disinfection

CMOU: Central Management and Operation Unit

COD: Chemical Oxygen Demand

CAPEX: Capital Expenditure

CSP: Contact Stabilization Pond

CW: Constructed Wetlands

DO: Dissolved Oxygen

EAAS: Extended Aeration Activated Sludge

EAP: Extended Aeration Process

EU: European Union

FP: Facultative Pond

GHGs: Green House Gass

IEA: International Energy Agency

IWRM: Integrated Water Resource Management

JICA: Japan International Cooperation Agency

KFW: Kreditanstalt für Wiederaufbau (German Development Bank)

LCA: Life Cycle Assessment

MBR: Membrane Bioreactor

MBBR: Moving Bid Bioreactor

MDGs: Millennium Development Goals

MoA: Ministry of Agriculture

MoF: Ministry of Finance

O&M: Operation and Maintenance

OPEX: Operational Expenditures

PSI: Palestinian standards Institution

PV: Photovoltaic

PM: Preventative Maintenance

PP: Polishing Pond

PWA: Palestinan Water Authority

RBC: Rotating Biological Contactors

SBR: Sequential Batch Reactor

SF: Sand Filtration

SPs: Service Providers

SPSS: Statistical Package for the Social Sciences

SSPs: Sanitation Service Providers.

SS: Suspended Solids

ST: Septic Tank

SVI: Sludge Volume Index

TF: Trickling Filter

TN: Total Nitrogen

TSS: Total Suspended Solids

TWW: Treated Wastewater

UASB: Up-Flow Anaerobic Sludge Blanket

USEPA: American Environmental Protection Agency

UV: Ultraviolet

WW: Wastewater

WB: West Bank

WSPs: Waste Stabilization Ponds

WWT: Wastewater Treatment

WWTP: Wastewater Treatment Plant

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Chapter One: Introduction

1.1. GENERAL BACKGROUND

According to World Bank reports (World Bank. 2018), globally about 2.3 billion people lack access to basic sanitation services with almost 892 million of these people practice open defecation. Despite significant gains (over 2.2 billion people gained access to improved toilets or latrines since 1990), sanitation services were among the most off-track Millennium Development Goals (MDGs). Today, only 68% of the world's population has access to basic sanitation, and only 39% of people have access to safely managed sanitation (which includes pollutants, through safe collection and conveyance, to treatment and end use/disposal). Further, 72 of people in Sub-Saharan Africa and 50 of people in South Asia still lack access to basic sanitation services (i.e., an improved toilet/latrine). The world missed the MDG target for sanitation by almost 700 million people.

The benefits of tackling the challenges of sanitation are manifold. Improved sanitation leads to lower disease burden, improved nutrition, reduced stunting, improved quality of life, increased attendance of girls at school, healthier living environments, better environmental stewardship, increased job opportunities and wages, improved competitiveness of cities, and economic and social gains to society more broadly.

1.2. WASTEWATER SECTOR IN THE PALESTINIAN CONTEXT

Most of Palestinian communities lack wastewater treatment Plants (WWTPs) due to financial, managerial and unstable local and regional political environment. Local literature sites (WAFA. 2017) (PCBS. 2017) provide general information about the current Palestinian wastewater sector. From those sites, the following are the main points:

- The number of Palestinian localities with a sanitation network reached 104 out of 557 in 2015, compared to 98 in 2013.
- 53.9% of the households in Palestine dispose of their WW through the WW network in 2015, while it found that 31.8% of the families in Palestine use cesspits, and 13.5% of the families use septic pits as a way to dispose of wastewater, and 0.8% of households use other means of wastewater disposal.

The percentage of completion in numbers given by the World Bank wastewater sector (PWA, SDG 6. 2017) as follows:

- Percentage of households connected to a public sewage network reached about 32%.
- The number of WWTPs complied with the Palestinian standard were 10 WWTPs.
- Agricultural land irrigated by treated wastewater was 1300 dunum.
- The volume of collected wastewater and treated in sewage plants reached 8.5 Mm^3/ year.

1.3. EXISTING TECHNOLOGIES OF WASTEWATER TREATMENT PLANTS

Despite this slow progress in the wastewater treatment sector, there (18) WWTPs have been implemented out of (32) WWTPs proposed on the PWA priorities, the most dominant technology in west bank is Activated sludge (ASS) with different types of technology, regardless of the size of the plant or the number of people served, as follows: (PWA. 2017)

- Activated Sludge System (ASS);
- Aerated Lagoons (AL);
- Rotating Bed Contactor (RBC);
- Constructed Wetlands (CWs);
- Membrane Bioreactor (MBR);
- Trickling Filter (TF).

Besides those WWT technologies, serving entire population/communities, many other technologies serve small number of population or at the household level [onsite]:

- Up-Flow Anaerobic Sludge Blanket (UASB);
- Septic Tank (ST);
- Contact Stabilization Pond (CSP);
- Extended Aeration Process (EAP);
- Chlorine Disinfection (CD) and Sand Filtration (SF);
- Anaerobic Pond (AP), Facultative Pond (FP), Polishing Pond (PP) and Waste Stabilization Ponds (WSPs);
- Anaerobic Up-flow Gravel Filter (AUFGF);
- Compact treatment units.
- Others…

The choice of technology for individual wastewater treatment plant depends mainly on the main treatment goal it will perform. However, many factors could influence the selection of treatment technology:

- Geographical factors surrounding the area, which limit the options available during the design phase.
- The possibility of providing the necessary services for operating of the WWTP
- The number of serviced populations, and the future growth of the population. this determines the size of the WWTP needed and thus contributes to choosing the appropriate technology for the estimated size
- Nature and type of use for treated water
- Available/ required expertise to implement, operate and maintain WWTPs.
- Available budget
- Political reasons related to the refusal of the occupation of some treatment plants.
- Others...

Table (1) summaries the under operation WWTPs in West Bank (WB), according PWA (ELAYYAN. 2021).

Table 1: Under operation West Bank's WWTPs.

No.	WWTP	Design capacity (cap/day)	Types of technology	Effluent quality
1	Al-Bireh	50,000	Activated sludge process, Tertiary treatment: disinfection (UV), Sludge treatment: filter press + centrifuge	Class A
2	Al Tireh / Ramallah	25,000	Membrane Biological Reactor	Class A
3	Anza	3,500	Activated sludge process, Tertiary treatment: filtration (sand filter) and disinfection, Sludge treatment: anaerobic sludge digestion + reeds beds	Class A
4	Beit Dajan	4,000	Activated sludge process, Tertiary treatment: disinfection (chlorine), Sludge treatment: reeds beds	Class A
5	Beit Hasan	1,900	Primary settling (Imhoff tank) Constructed wetlands (vertical + horizontal)	Class C
6	Hajjah	1,600	Primary settling Constructed wetlands (vertical + horizontal)	Class C

7	Al Aroub	8000	Activated sludge process Tertiary treatment: filtration (sand filter) and disinfection (chlorine), Sludge treatment: static thickener + forecasted dewatering + forecasted composting	Class A
8	Jenin	70,000	Primary settling Aerated lagoons Tertiary treatment: filtration (sand filter) and disinfection (chlorine)	Class B
9	Missilya	4,000	Constructed wetlands	Class B
10	Nablus west	110,000	Primary settling Activated sludge process, Tertiary treatment: filtration (sand filter) and disinfection (UV), Sludge treatment: anaerobic digestion + sludge dewatering.	Class A
11	Sarra	4,500	Primary settling (Imhoff tank) Constructed wetlands (vertical + horizontal) Sludge treatment: drying beds	Class B
12	Taybeh	7,500	Rotating biological reactor Tertiary treatment: filtration (sand filter) and disinfection (hypochlorite) Sludge treatment: drying beds	Class A
13	Tubas / Tayaseer	60,000	Primary settling Activated sludge process Tertiary treatment: filtration (sand filter and disinfection (UV) Sludge treatment: anaerobic digestion + sludge dewatering	Class A
14	Rawabi	5,000	Activated sludge (compact unit)	Class A
15	Bethlehem-Industrial Zone	100.00	MBR	Class A
16	Al-Rihan WWTP	500.00	MBR	Class A
17	Diplomatic Compound	500.00	Activated sludge	Class A
18	Jericho	36,000	Activated sludge process, Tertiary treatment: disinfection (UV), Sludge treatment: drying beds	Class A

Source: ELAYYAN. 2021

1.4. THESIS MAIN OBJECTIVES

The main aim of this study is to assess the administrative, technical, financial and social challenges and obstacles facing WWTPs, and to study the reasons for their occurrence.

The specific objectives are:

- Analyze critically the current management of WWTPs and identify the main obstacles facing the sustainability of WWTPs performance,
- Investigate technology type in achieving efficient WWTP operation,
- Comparative analysis for WWTPs operation regarding effectiveness,
  Suggest alternative management options to ensure sustainable management for the current WWTPs regardless the technology type.

1.5. SIGNIFICANCE OF THIS THESIS

The water and sanitation sector in Palestine suffers from many obstacles and challenges in general and wastewater treatment facilities (WWTPs) management in particular. Management of WWTPs faces administrative and technical challenges through due to lack of experienced staff to monitor its performance and maintenance, and to ensure periodically and regularly of the efficiency and effectiveness of WWTPs. It also faces financial challenges that weaken its ability to reach financial sustainability, and other social or even religious challenges. All this has been exacerbated by the Israeli occupation hindering the WWTPs progress. To the best of our knowledge, lack of research studies reflecting deep insights analysis and searching for possible sustainable managerial and technical options form the framework for this study. The main goal of this study is to assess selective sanitation service providers operating WWTPs and analyze their capacity regarding administrative and technical performance.

By conducting this study and analyzing the challenges and obstacles plaguing this sanitation sector, the study expects to provide feasible solutions and practical recommendations to main obstacles including:

- Enhance the administrative capabilities, communication skills and communication among the management staff of WWTPs.

- Increase the level of technical and operational performance and the skills of preparing periodic reports for the teams operating WWTPs.
- Facilitate access to an integrated financial system that ensures the continuity of the sewage plants' work, and achieving financial sustainability.
- Integrate the relevant government institutions and local community institutions, with the aim of striving for the success of the performance of WWTPs

1.6. SCOPE OF THIS THESIS

This thesis report entails the following chapters:

Chapter 1: contains general background, project area, problem definition, the main objectives, and significance.

Chapter 2: presenting the previous studies and related articles, books, journals…etc. in form of literature review including centralized and decentralized treatment system, wastewater treatment stages, wastewater characterization, wastewater treatment processes, components of wastewater treatment systems.

Chapter 3: presenting the method of how data will be collected, through questionnaire, case study and interview design. In addition to, the programs used to analyze data.

Chapter 4: showing the analyses of questionnaire, case study and interview. Presenting the analysis in Figures and Tables.

Chapter 5: presenting the results, conclusions and recommendations

The last section is references of the previous researches, books, articles…etc., then the Annexes.

Chapter Two: Literature Review

2.1 INTRODUCTION

Tremendous efforts and investment by the government to fill the gap in sanitation sector through the implementation of appropriate wastewater treatment plant with appropriate technologies. This study will present a decision-support framework for selection of wastewater treatment technologies and management teams.

Previously, receiving water bodies were highly subjected of pollutants due to discharged wastewater. WWTPs were the solution saving the environment from large portion of pollutants. As a result, they should maintain high performance at all times, despite suffering from hourly, daily and seasonal dynamics (Englande. 2015).

The sensitivity of WWTPs operation processes comes from the variances in input "influent" qualities and quantities, while the outputs "effluent" should be the same quality matching the standards. Moreover, WWTPs should have the capabilities to adapts to remove any emerging pollutants, reduction of greenhouse gases emissions…etc. (Corominas. 2018).

2.1.1 STRUCTURE OF MANAGING AND OPERATING WWTPS

To achieve highly efficient performance of WWTPs, it shall have a well management and operational structure. In addition, the management approach has to focuses on the cost sustainable performance of WWTPs along their useful life (USEPA. 2014), which may have main pillars as follows:

- Operation:

The sanitation system (collection and treatment) has to be operated as designed to adequately protect water quality and human health. The continues operation along the all-year day's during all weather conditions imposes the needs for well-trained operators ensuring proper performance.

Their responsibilities include budget and business administration, public relations, analytical testing, and mechanical engineering as well as overseeing the collection system and wastewater treatment processes (USEPA. 2014).

- Maintenance and Preventative maintenance:

Reliable service of treatment system and avoid equipment from breakdown. The breakdown can be minimized through well inspection of equipment regularly by operators.

Usage of collected and reported data through the inspections will ensure prevention of sudden failures of equipment and continuing of treatment processes, which will maintain WWTPs more efficient through the following: (USEPA. 2014), (Hernández-Chover, et al. 2020) (Okoh. 2015)

1. Proper energy consumption,
2. Processes efficiency and reduction in occasionally environmental impacts,
3. Operational cost optimization,
4. Avoid interruption of the process,
5. Minimizing the repair costs and accidental failures,
6. Reducing delays in supplying/ purchasing spare parts…etc.

- Financial:

The efficiency of WWTPs is not limited to remove the pollutant from WW through various processes. One of the main parameters that affect the efficiency of the WWTPs is the allocation of their resources into properly maximizing the return benefits (Hernández-Chover, et al. 2020) (Okoh. 2015).

2.1.2 Staff Requirements to Manage and Operate WWTPs

Operation staff:

In general, operators shall have sufficient experience especially in large WWTP, to deal with the machines specificities which demonstrate the need to implement dedicated and practical training program to complete this know-how for the technicians and operators in charge to carry out the maintenance.

The training programs must be considered as an investment to protect the devices and increase the life-time of the devices, whose replacement costs are very high.

Management Staff:

The efficient mangers have the records, reports, agenda…etc. for all working steps, in order to use it as a backup for planning for any problem may appears.

As a result, each WWTP should have information system as an archive, which will used to forecasting the coming issues (seasonal influent changes, spare parts, regular/ preventative maintenance, …etc.).

2.1.3 TECHNOLOGIES TYPE

Based on what level of treatment needed to treat the wastewater, there are three main treatment stages, as follows:

- Primary treatment:

  It achieves treated water to some extent of treatment level, based on mechanical and physical process like screening and grit removal.

  The removal rate of Biochemical Oxygen Demand (BOD) is only (30% to 40%) and Suspended Solids (SS) is (50% to 60%) in primary treatment (Metcalf and Eddy, 2003).

- Secondary treatment:

  This treatment level considered the main treatment process, as it removes the highest percent of organics (Gupta, et al. 2012).

  Secondary treatment processes can remove up to 90 % of the organic matter in wastewater by using biological treatment processes (USEPA. 2004).

  This stage of treatment mainly divided into two categories:
  - Suspended growth bioprocesses (e.g., activated sludge, aerated lagoons).
  - Attached growth bioprocesses (e.g., trickling filter, rotating biological contactors).

- Tertiary treatment:

There is some remaining pollutant after the biological process in WWTPs. So, the step of treatment can make further removal of pollutants e.g., P, N, and other biodegradable organic pollutants.

Many technological alternatives for wastewater treatment are available, ranging from advanced technologies to conventional treatment options. It is difficult to select the most appropriate technology from among a set of available alternatives to treat wastewater at a particular location.

A lot of plants, such as capital costs, operation and maintenance costs and land requirement, are involved in the decision-making process. Sustainability criteria must also be incorporated into the decision-making process such that appropriate technologies are selected for developing economies. The challenge in Wastewater (WW) management is selection of the best available technology for the particular Wastewater Treatment (WWT) objective at a particular site. It is also necessary to develop a decision-making framework that incorporates sustainability indicators to help in selecting the appropriate technologies for wastewater management

The selection of technology should be based on scenarios developed based on the regional and local societal priorities of urban, suburban and rural areas and translate them into decision (Kalbar. 2012).

Since the past two century, many WWT technologies have been developed for WW treatment, the widely used is the Conventional Activated Sludge (CAS) (Kalbar. 2012), other technologies have been developed that employ various treatment processes, both aerobic and anaerobic, highly mechanized to not highly mechanized, including:

- Trickling Filters (TF),
- Up-Flow Anaerobic Sludge Blanket (UASB),
- Rotating Biological Contactors (RBC),
- Aerated Lagoons (AL),
- Sequencing Batch Reactor (SBR), and others (Metcalf and Eddy, 2003).

Figure (1) shows the common treatment stages for WW, including sludge treatment process. Which precent the three treatment stages to produce treated water and sludge.

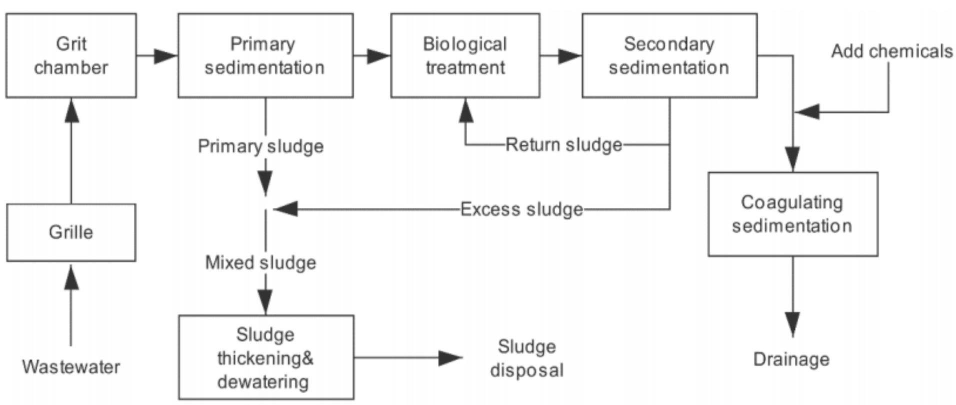

Figure 1: Flow chart of common wastewater and sludge treatments.

2.2 WWTPs Outcomes Handling

2.2.1 Reclaimed Water

American Environmental Protection Agency (USEPA) defined the reclaimed water as: "Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for a range of purposes. The term recycled water is synonymous with reclaimed water" (USEPA. 2012).

According to USEPA, Table (2) summarizes the reuse categories and their definitions (USEPA. 2012).

Table 2: USEPA Classification of Reuse Categories.

Category of Reuse		Description
Urban Reuse	Unrestricted	The use of reclaimed water for non-potable applications in municipal settings where public access is not restricted.
	Restricted	The use of reclaimed water for non-potable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction.
Agricultural Reuse	Food Crops	The use of reclaimed water to irrigate food crops that are intended for human consumption
	Processed Food Crops and Nonfood Crops	The use of reclaimed water to irrigate crops that are either processed before human consumption or not consumed by humans

impoundments	Unrestricted	The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities
	Restricted	The use of reclaimed water in an impoundment where body contact is restricted
Environmental Reuse		The use of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels
Groundwater Recharge/ Non potable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potable water source
Potable Reuse	IPR	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment
	DPR	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either collocated or remote from the advanced wastewater treatment system

Source: USEPA, 2012

Taking The Kingdom of Saudi Arabia as an example to show the role of reuse of reclaimed water, which contributes vitally to reduce the annual gap between water supply and demand that estimated around 11.5 billion cubic meters. Moreover, the using of reclaimed water reducing the energy costs of desalination processes (Dairi. 2019).

According to Palestinian standards, Table (3) presenting the classifications of treated wastewater according it's quality:

Table 3: Treated Water Classification

Class		Water quality parameter		
		BOD_5 [mg/l]	TSS [mg/l]	Fecal coliform [MPN/100 ml]
A	High quality	20	30	200
B	Good quality	20	30	1000
C	Medium quality	40	50	1000
D	Low quality	60	90	1000

Source: Dairi. 2019.

It is obvious from Table 3, that high effluent quality standards could form limitations of beneficial uses with increased operational costs for the treatment processes, all this impose burdens and cause many challenges to WWTPs owners, and operators.

2.2.2 SLUDGE

The second output of WWTPs is sludge, which produced by enrich pollutants mainly organics into the sludge. This byproduct needs treatment by stabilization, reduction, and harmless treatment, including sludge drying, aerobic, anaerobic digestion, and adding chemical agents. The treatment process is required prior to final disposal that may cost around 30% of a WWTPs operating costs. (Kalogo & Monteith. 2008)

The term "Sludge disposal" defined as “The process of reasonable storage and resource utilization” which mainly includes: (Appels, et al. 2008), (Møller, et al. 2009) and (Salsabil, et al. 2010)

- Sludge Landfill,
- Land Use,
- Composting,
- Thermochemical Treatment Technology.

In USA as case, the most common technique for sludge treatment is Anaerobic Digestion (AD), which evidently appear through the large portion of American WWTPs (48%) are treating wastewater using AD. That allowed a typical biogas composition of digested sludge is methane (CH_4) 50-70 % and carbon dioxide (CO_2) 30-50%. Only 10% of those WWTPs use biogas for heating and generating electricity to reduce the cost of energy consumption (Shen, et al. 2015).

Methods to minimize sludge production:

Flocs destruction and cells disruption can be achieved by various methods: ultrasonic disintegration, shear stress forces, alkaline pretreatment, thermal pretreatment, alkaline combined with thermal hydrolysis as well as other oxidation processes (ozone, hydrogen peroxide)

In order to reduce the WW sludge generation there is a must to take some actions like what (Salsabil, et al. 2010) stated in their paper, two feasible options for sludge pretreatment are available:

1- Aerobic digestion:

a. Using "Ultrasonic" to pretreat sludge consuming around 1650Kwh/Kg TSS removed, which reduce the total cost by 48%.
b. Using "Ozonation" to pretreat sludge consuming around 1602Kwh/Kg TSS removed, which reduce the total cost by 27%.

2- Anaerobic digestion:

c. Using ultrasonic to pretreat sludge consuming around 2601Kwh/Kg TSS removed, which reduce the total cost by 44%.
d. Using Ozonation to pretreat sludge consuming around 2496Kwh/Kg TSS removed, which reduce the total cost by 22%.

This may reduce the sludge retention time into the half time required to digest sludge by accelerating the process.

2.3 SCALE OF WWTPS

According to the world bank around 2.3 billion people lack to the basic sanitations' services, the largest fraction lives in rural area while the percent lesser in urban areas (Gambrill 2020). Which reflecting on the health issues related to diseases from wastewater, in addition to the social complication generated due to improper disposal of WW.

In order to minimize the gap generated from lacking the proper handling of WW as much as possible, and ensure sustainability of WWTPs, there are two trends around the world tackling the generated WW as follows:

2.3.1 SMALL SCALE (DECENTRALIZED)

Decentralized management of WW used to reclaim and get rid of close the source of WW, generated from single or group of households located in confined area and not served by central WW network or WWTP (Capodaglio. 2017). Decentralized or cluster wastewater treatment systems are designed to operate at small scale (USEPA. 2004). "The term decentralized also qualifies systems serving small portions (clusters) of an urban area according to hydrology, landscape, and local ecology considerations" (Opher & Friedler. 2016).

The relatively high flexible operating conditions and reduce aesthetic impact as an additional advantage of decentralized system, while some local impacts should be taking into consideration like odors, traffic…etc. (Torretta, et al. 2016).

As the local users are responsible to manage the decentralize systems, they require more efforts to rise their awareness, involvement, and participation. Local stockholders are more proactive when the decision to implement a decentralized solution made or discussed (USEPA. 2012).

In addition, pros of decentralized management are proved economically, technically and sustainable urban development in the served area. Moreover, it showed financial competitiveness, simple technology, and limited additional costs. However, the efficient operation depending on the capability of operation and maintenance (O&M) team. The reuse of reclaimed water mainly in irrigation of green areas in decentralized system has higher probability than centralized system. It has been proven that the sustainability of these facilities lies in the societal value of the public services that result from them, and accordingly, they help in growth (Suriyachan, et al. 2012).

However, "Centralized management of the decentralized wastewater treatment systems is essential to ensure they are inspected and maintained regularly" (Massoud**,** et al. 2009).

2.3.2 LARGE SCALE (CENTRALIZED)

"Traditional systems, household discharge streams are combined and transported by an extended sewer system to a (possibly) far away" is called centralized WWTP. Collection and treatment of wastewater with a centralized approach often requires more pumps, longer and bigger pipes, and more energy than decentralized ones, increasing the infrastructure cost of the system (Engin & Demir. 2006).

Conventional or centralized WWT system involve advanced collection and treatment processes that collect, treat and discharge large quantities of wastewater (Massoud**,** et al. 2009).

In general, the large-scale collection system around 0.8-0.9 of investment budget goes to the network, this percent could be more feasible in dense areas. Which is a positive point making the central system wine against the other systems from population point of view (Maure, et al. 2005).

One of the most critical issues in the new implemented project (designed for long time period, may 25 years), is the initial operation WW quantities. In addition, the more industrial and commercial growth rate country the more need for central solutions.

2.4 WWTPS SURFACE REQUIREMENTS

According Table (4), the highest surface requirements is for the Constructed Wetlands (CWs) technology, while the least one is for Membrane Bio-Reactor (MBR) and Moving Bid Bio-Reactor (MBBR).

- A "+" sign is indicated against a positive impact;
- A "x" sign is indicated against a negative impact;
- A "++" signs for a highly positive impact;
- A "xx" signs for a highly negative impact.

Table 4: Surface Requirement According Technology Type. (Seureca. 2022)

Technology	CAS	SBR	EAAS	MBBR	MBR	TF	BAF	CW
Surface requirements	+	+	+	++	++	xx	++	xx

Source: Seureca. 2022.

2.5 MONITORING

The balance calculations provide useful data about the rightness of operational measurements from WWTPs. Control schedules on balance errors can be used to analyze time series and to identify errors in full-scale WWTP data sets. The raise obtained after conducting mass balances over all possible system boundaries can be used to evaluate systematic errors and to conduct proper information satisfactions (Spindler. 2014).

2.6 RECORDS AND REPORTING

In fact, massive amounts of data weaken the databases, which are described at best as data graves and certainly cannot be considered data mines. In fact, current practices are so arranged that WWTP operators have a massive flow of data in their hands, which is extremely difficult to process and analyze in a timely enough manner to allow for a better understanding or appropriate decision making. Since the effort of data analysis is costly due to the lack of reliable data analytical tools, potentially valuable information remains unavailable and untapped. "Driving force was the transformation of data graveyards into data mines" (Corominas. 2018).

Numerical models and heuristic data the most popular and easier methods to build up a database about the problems faced during the operation of WWTPs, is Case Based Reason (CBR).

Case-based inference techniques are almost always used to collect and re-present expert knowledge, which can be framed in more complex and functional structures. Decision support systems may include specific ways of thinking that focus on providing knowledge about industry-specific organizational structures and on integrating different technologies and aiming globally to simulate the inference of industry experts (Corominas. 2018).

State library structures in CBR can be categorized on the basis of two general methods: flat memories and hierarchical memories. In flat memories, each state in memory is compared to the current state, which means more time consumption. On the other hand, in hierarchical memories, the matching process and retrieval time are more efficient due to prior discriminant searching in the hierarchical structure, considering only a few cases to assess similarity.

The dynamic CBR cycle:

(Martínez. 2006) mentioned that data is gathered as follows in order to build a library data base:

(1) from the process in order to diagnose, by means of heuristic rules, the process status. Once the status has been inferred, it can result as a new day of the current episode that has been lasting for the last days
(2) one of the following:
    a. current case, already diagnosed. (From library data base).
    b. a new case is then opened,
(3) The next step is to explore the case library to search and retrieve
(4) the historical case (or set of cases) that best match the current data.

Figure (2) shows a diagram of how to build a database, and how get a benefit from it in order to solve the coming issues.

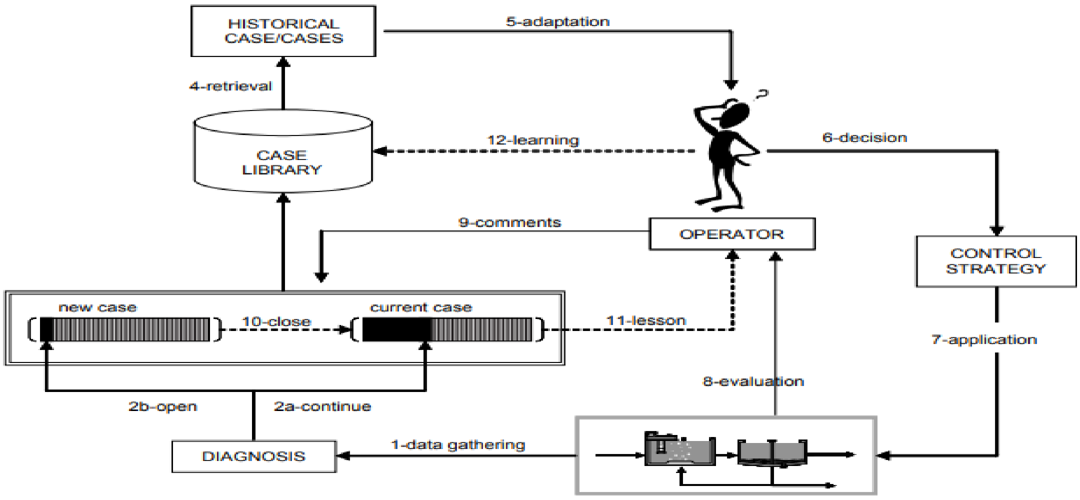

Figure 2: The dynamic reasoning cycle of CBR system (Martínez. 2006).

But still needed more prediction models to deal with expected future challenges.

2.7 ENERGY

Estimates show that the electrical energy to operate wastewater treatment is about 3–5% of the electrical load in many countries. (Taha. 2017) 0.8 kWh per cubic meter wastewater collected, transported and treated (Venkatesh & Brattebø. 2011).

One to three fifths of expenditures as operation costs paid for energy, electricity represent around six to nine tenths of the total cost in WWTPs (Sun, et al. 2019).

2.7.1 ENERGY CONSUMPTION

The energy consumption in the operational phase of the WWTPs is directly related to both the quantity and the desired quality of the treated wastewater, meaning while to the level of service provided. Which highly affecting the WWTPs capabilities.

Based on the results, annual specific energy consumption ranged from 15 to 86 kWh/Cap. The highest energy consumer in all the WWTPs was aeration, accounting for 40–75% of total energy requirements (Mamais, et al. 2015).

According Table (5), the highest consumed energy scored for the (MBR) and (MBBR) technologies, while the least one is for (CWs) and (TF), See table below:

- A “+” sign is indicated against a positive impact;
- A “x” sign is indicated against a negative impact;
- A “++” signs for a highly positive impact;
- A “xx” signs for a highly negative impact.

Table 5: Energy Consumption According Technology Type (Seureca. 2022).

Technology	CAS	SBR	EAAS	MBBR	MBR	TF	BAF	CW
Energy Consumption	+	+	+	xx	xx	++	x	++

Source: Seureca, 2022.

According to (Sun, et al. 2019), take a look at these steps in order to quantify and minimize our WWTP consumption:

- WWTPs current status of using energy, is press to apply chances for reducing energy needs.
- Reduction of energy consumption could be feasible in WWTPs if green energy/ recovery applied.
- Controlling the treatment process in prober way, will reduce energy needs.
- Through assessment of performance and corrective actions, reduction of energy consumption could be.
- As much as possible, avoid technologies consumed large energy quantities.

2.7.2 Green Energy and Energy Recovery

The fast increment in energy costs and concerns about global climate change highlight the need to improve energy sources in municipal (WWTPs).

Transporting and discharging municipal wastewater and treating it to comply with acceptable water quality standards require substantial energy, mostly electricity. Typically, energy costs account for 5% to 30% of the total operating costs of water and wastewater utilities worldwide (ESMAP. 2012).

The energy independence, which was defined as the percent ratio of green energy production to energy consumption, was estimated to be a maximum of 6.5% and to vary with on-site energy consumption in the WWTP (Chae. 2013).

To reduce the issue of large energy quantities needed, many of solutions can be applied. Energy recovery, as an example from treated sludge, or from wind and photovoltaic energy.

If captured and managed efficiently, sludge generated at WWTPs could yield substantial energy in the form of biogas, potentially turning WWTP into a net energy producer rather than a consumer (McCarty, et al. 2011). but there are a lot of barriers faced the biogas production technical, financial, social and regulatory.

The efficient operation of the sewage treatment plant can be achieved by improving the efficiency of the operating units, and using green energy (Salsabil. 2010). The International Energy Agency (IEA) has emphasized the importance of energy efficiency, cleaner use of fossil fuels, carbon capture and storage, and the use of renewable energy (IEA 2015).

The feasibility of methane production from anaerobic sludge digestion, solar and wind energy was also explored in other studies. recognized the use of anaerobic digestion in developing countries for biogas recovery to reduce methane emissions (El-Fadel. 2001).

Regarding solar energy utilization, few papers discussed, nor adequately investigated its application, mentioning that the solar energy utilization for a small-scale plant was studied and found that the dispersion of the plant component makes it feasible to utilize solar energy.

In Palestine solar Photovoltaic (PV) application is encouraged due to the high potential solar energy, where the sun hours exceed 3,000 h/y with average penetration factor 5.4 Kwh/m^2, the solar energy production premaster plan emphasized that the solar energy projects are highly encouraged by the Palestinian Energy Authority as an adequate, sustainable, cost-effective alternative source of energy in addition to environmentally friendly reducing the GHGs emissions. In addition to that utilizing of PV systems for electrification of rural and remote villages in Palestine is economically profitable whereas per Judi et al. the energy production of solar PV in Palestine reached 7.24% of the country energy balance (Juaidi. 2016).

2.8 SOURCE OF POSSIBLE POLLUTANT

Many pollutants are present within the borders of WWTPs. However, the majority of these pollutants, and in particular the organic pollutants within the wastewater, are treated through a carefully controlled treatment process. In terms of pollutants produced by treatment plants in general, the most important of which are greenhouse gases that cause global warming. The next section will present some information about it.

2.8.1 GHGS EMISSIONS

In the last years increasingly, tough restrictions have been introduced regarding the effluent quality from wastewater treatment plants. The average GHGs emissions per cubic meter of treated WW estimated around 55-63 g/m^3 (Venkatesh and Brattebø. 2011). At the same time was launched the challenge regarding the overall impact on the environment that these wastewater treatment plants have on the greenhouse gases (GHGs) emissions (Barbu. 2017). The annual GHGs emissions varied significantly according to the treatment schemes employed and ranged between 61 and 161 kgCO_{2e}/Cap (Mamais, et al. 2015).

Three major long-lived GHGSs (CO_2, CH_4, and N_2O) derived from a wide range of human activities (Greet, et al. 2019). CO_2 contribute over 74% of GHGs emissions, even methane has a short atmospheric lifetime it is 25 time more powerful than CO_2 with contribution percent around 16%. The third one is Nitrous oxide with 9% contribution which generated mainly in WWTPs in nitrification and denitrification processes (Kerr. 2009).

Consistent with the likely future scenarios, as outlined in the previous section, there is a clear hierarchy of energy and material flows in wastewater treatment plants in terms of their likely susceptibility to impact from GHGs mitigation measures: (Greenfield. 2005)

- use of non-renewable stationary energy to provide power for aeration, transport, dewatering etc.;
- generation of greenhouse gases from treatment processes; and
- transport of embodied carbon in flows from the wastewater treatment site.

As (Kerr. 2009) stated that WW sharing with methane emissions 11%, using aerobic technics will be economically feasible with BOD_5 ranging 300-700 mg/l influent WW, while anaerobic technics will be better at higher concentrations (Cakir. 2005).

Combined heat and power and household utilization were two prior options for net energy production, provided an ideal power conversion efficiency and biogas production. The joint application of household biogas uses and sludge nutrient processing achieved both high net energy production and significant environmental remediation across all impact categories, representing the optimal tradeoff for domestic wastewater treatment (Chen. 2013).

There is also the potential for producing other greenhouse gases apart from CO_2. These include methane (CH_4), and nitrous oxide (NO_2), with effective contributions to global warming of 21 times and 310 times that of CO_2, respectively (Greenfield. 2005).

The obvious requirement is that wastewater treatment plants will need to understand the source of the incoming wastewater. If its origin is entirely domestic, then the initial forcing of the GHGs is related to the net energy consumption of the plant and its source (usually obtained from fossil fuels); Secondary effects are related to whether methane was produced and released on-site, in which case the plant would be penalized for producing methane (but not if the methane was burned, whether or not the energy generated from combustion was used), and whether nitrous oxide was released.

Therefore, the modeling of GHGs emissions from WWTPs was proposed in many publications to provide an accurate estimate of how much GHGs was being emitted from wastewater treatment plants; in order to quantifying the GHGs emissions and applying a mitigating measure plan.

The more comprehensive simulation GHGs emission model is a combination between life cycle assessment (with inputs Electrical energy, Resource consumption for water treatment and Resource consumption for transport) and the plant wide model (with inputs Electricity, Chemical, Fuel oil, Flow rate and Influent characteristics) with boundary from construction until demolition (Barbu. 2017).

Figure (3) summaries the Life Cycle Assessment (LCA) of GHGs emissions through the WWTP model (Nguyen. 2020).

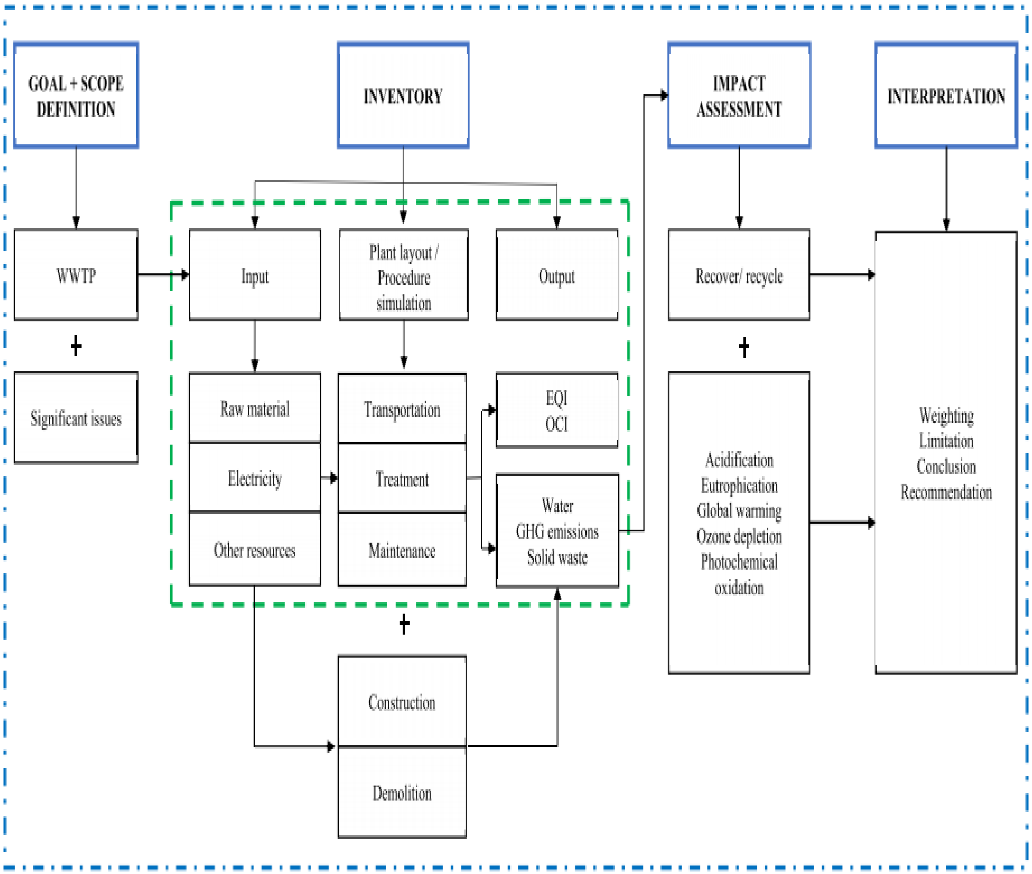

Figure 3: Frame work of the combination between LCA and plant-wide models.

In Palestine, each WWTP operator must apply a measurement model to measure the three main gases emitted by our WWTPs; In order to take into account, the reduction of greenhouse gas emissions through the application of mitigation measures plans, and to control the influencing characteristics to reduce environmental impacts.

Chapter Three: Methodology

This study adopts a qualitative and quantitative research methodology. The later entails direct interviews with the relevant stakeholders, including operators, service providers (SSPs), as well as policy and decision makers in the field of water and sanitation sector. In addition to questionnaire developed and distributed to collect data and information on status of managerial capacity pertinent to administrative, operational and financial aspects.

After data analysis using the SPSS software, “R” programming language and Excel software, results will be critically analyzed and compared between the different SPs. Field visits will be conducted to the WWTPs under study to verify and collect data and reflections of chief operators and performance reports including daily challenges and obstacles faced over the years.

Monthly and annual reports on the performance of WWTPs will be collected to analyze data to evaluate the compliance and identify the efficiency and effectiveness of WWTPs. Figure (4) summarizing the research methodology graphically.

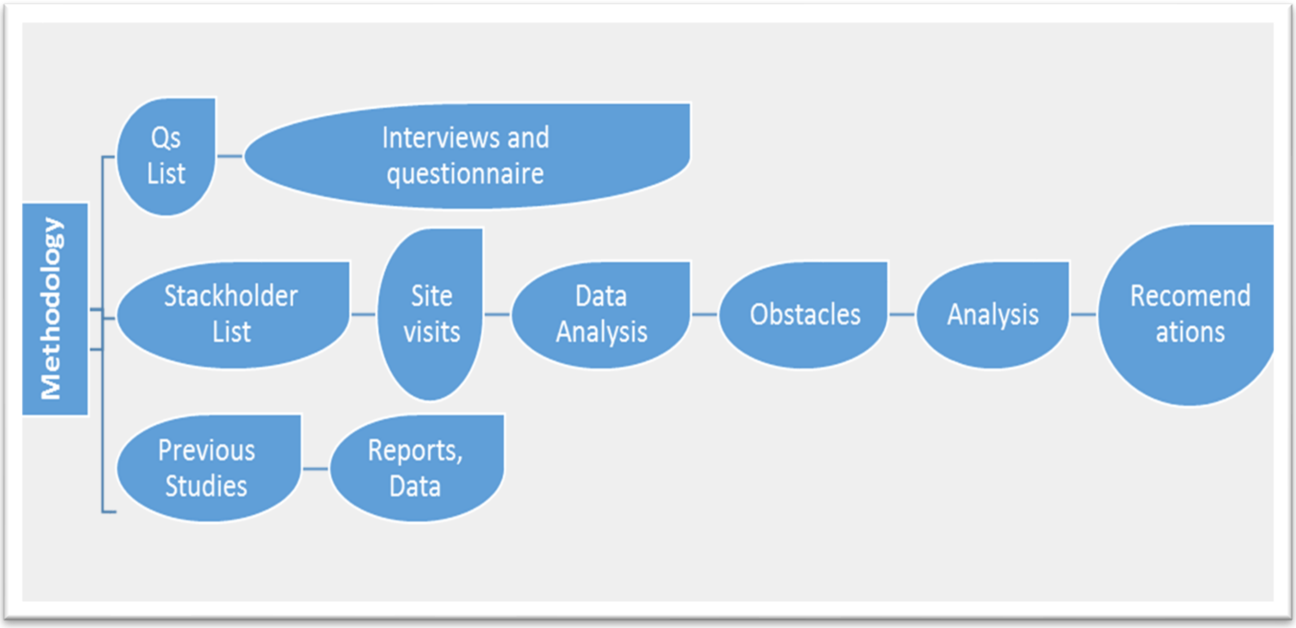

Figure 4: Thesis Methodology Chart.

3.1 STUDY AREA

To achieve the main goal of the study, selective water and sanitation service providers operating eight-(8) wastewater treatment facilities include:

- Ramallah/Al-Bireh Governorate (Al-Tireh MBR, Al-Bireh and Al-Taybeh WWTP).
- Nablus Governorate (Nablus Western WWTP)
- Jenin Governorate (Missilya WWTP, Jenin WWTP).
- Jericho Governorate (Jericho City WWTP).
- Hebron Governorate (Sa'ir WWTP).

WWTPs include sewage collection system (sewerage network), transport (main trunk and pump), WWTPs and wastewater reuse schemes. Due to time constraints, the scope of this study concentrates on evaluation of performance within the WWTPs with emphasis on treatment and safe disposal of treated water. Therefore, the sewerage system is beyond the scope of this study.

The selected WWTPs are diverse considering the geographical location, the surrounding environment, and technologies used for wastewater treatment. In order to study the effect of specific standards on the quality and efficiency of the performance of service providers in managing, O&M these WWTPs, and to compare each other, with an indication of the effect of the difference in the surrounding environment and the technology used.

3.2 BRIEF ABOUT WASTEWATER TREATMENT PLANTS INCLUDED

3.2.1 NABLUS WEST WWTP

It's located in the western part of Nablus City at the lowest part of the city Beit Leed village. The construction budget allocated from KFW through an agreement signed since 1998, while the construction finished at 2013 due to political issues to get the permit from Israel occupation as it lies in area "C" (AbuJaffal. 2020).

Figure 5: Nablus West WWTP Location.

It is working since Nov,2013 and serves around 120,000 Cap, producing daily average of treated water 14,000 m^3.

A Conventional Activated Sludge (CAS) plant, that provides nutrients carbonaceous, nitrogen, and phosphorous removal, sludge stabilization, and anaerobic digestion. Later on, filtration and chlorination unit processes were installed as part of reuse pilot projects funded by KFW. Current average flow treated at the plant is 14,000 m^3/day. The full layout of it is attached in ANNEX No.3.

Figure 6: Nablus West WWTP Layout.

3.2.2 JENIN WWTP

It's located in the Jenin City, serves the city itself and the refugee camp. The construction budget allocated from The Netherlands, it was built and operated since 1972, while it also rehabilitated in 2014, to enhance the effluent quality and removal efficiency. Its capacity around 10,000m³ daily serving about 35,000 Cap.

An aerated-lagoons-wastewater treatment plant, rehabilitated in 2013 to remove nutrients (carbonaceous, nitrogen, and phosphorous) from wastewater. Consists of Preliminary treatment (screen and grit-chambers) followed by aerated lagoons in two trains. Each train has two aeration ponds and one stabilization pond. Sludge handling facilities do not exist. Biosolids accumulate at the bottom of the ponds (ELAYYAN 2021).

3.2.3 MISSILYA WWTP

It located in Missilya village, Jenin district. It was starting operation in 2019, producing daily treated water around 120m³. The construction cost was allocated from AFD (CDG. 2018).

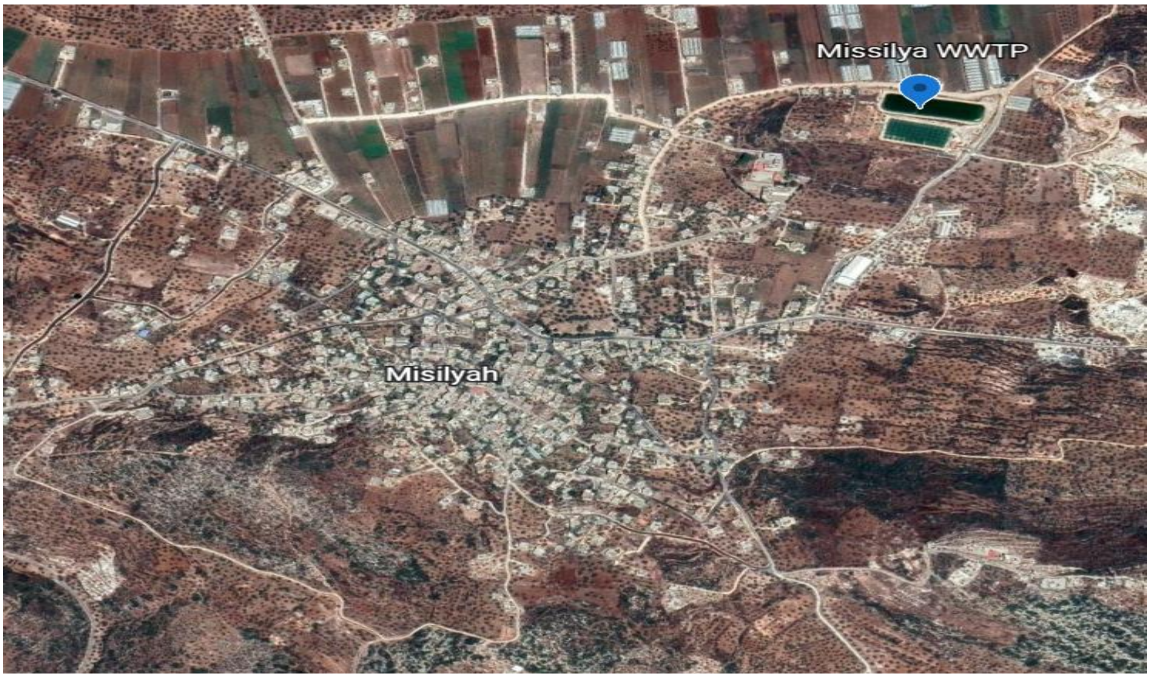

Figure 7: Missilya WWTP Location.

The plant was designed to 2025 horizon serves around 3,635 Cap. A Low cost WWTP. Vertical and Horizontal Constructed Wetlands and storage pond provides nutrient removal (C, N, P removal). Sludge accumulate and removed every 15-20 years (CDG. 2018).

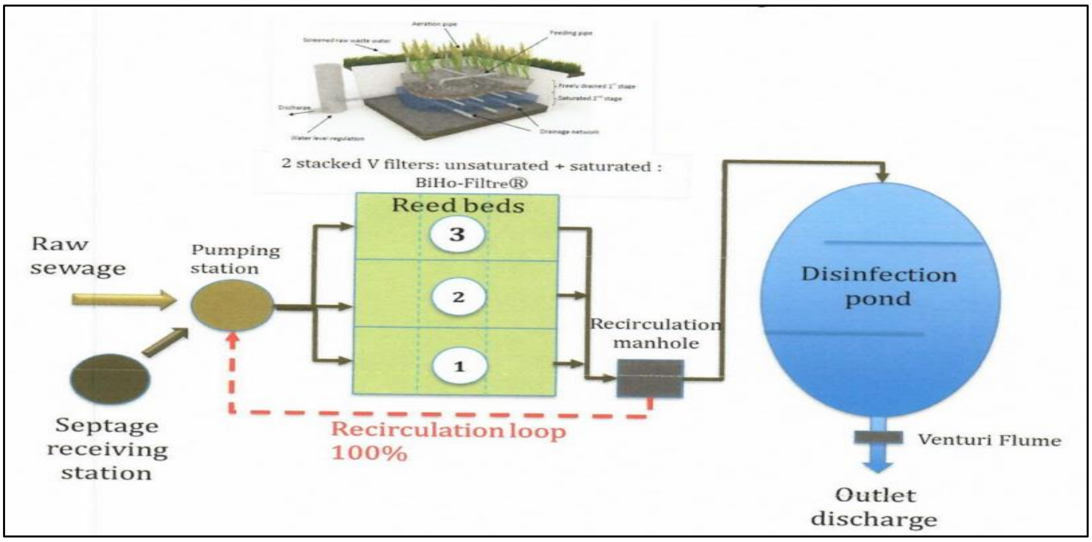

Figure 8: Missilya WWTP Layout.

3.2.4 JERICHO WWTP

Located in southern east Jericho city serving Jericho, Doyok, Nuwe'emeh, Sultan camp, Oqbat Jabr Camp communities, it was starting operation in 2014, producing daily treated water around 2000m³ (current), while its capacity around 9900m³. The construction budget was allocated from JICA, Japan.

The plant was designed to 2025 horizon serves around 36 000ap. Extended aeration Activated Sludge - Oxidation Ditch. Aerobic sludge digestion in aeration tank. Thickened and dewatered by drying beds. Has photovoltaic system (CDG. 2018).

3.2.5 AL- BIREH WWTP

Located in South East Al Bireh city serving 93% Al Bireh City, Am'ari Camp, Qaddura Camp, and Al Awdeh Camp, it was starting operation in 2000, producing daily treated water around 5750m³. The construction budget was allocated from KFW, Garman.

The plant was designed to 2020 horizon serves around 50 000Cap. Extended Aeration Activated Sludge. Aerobic sludge digestion, thickening, belt filter press for dewatering. Then Mixed with solid waste and transported to Zahret Al-Fenjan sanitary landfill (CDG. 2018).

3.2.6 AL-TIREH WWTP

Located in Northwest Ramallah city serving Northwest Ramallah City (Al Tireh Suburb), 39%, it was starting operation in 2014, producing daily treated water around 2000m³. The construction budget was allocated from Ministry of Finance (MoF), Palestine.

The plant was designed to 2020 horizon serves around 25 000Cap. Extended Aeration Activated Sludge. MBR with aerobic stabilization in the aeration tank. MBR WWTP. Sludge dewatering by centrifugation with polymer dosing. Then transported to Zahrt Al-Fenjan sanitary landfill (CDG. 2018).

3.2.7 AL-TAYBEH WWTP

Located in Al-Taybeh village north-west Ramallah city serving Taybeh and Ramon villages, it was starting operation in 2014, producing daily treated water around 150m³, while its capacity around 450m³. The construction budget was allocated from EU.

The plant was designed to 2035 horizon serves around 7 500Cap. Rotating Biological Contactors - with sludge drying beds. No info about disposal (CDG. 2018).

3.2.8 AL-AROUB WWTP

Located in North Hebron city between Saier and Al-Aroub refugees camp serving Al Aroub Camp and Shuyoukh Al Aroub, it was starting operation in 2016, producing daily treated water around 1500m³. The construction budget was allocated from Spanish Cooperation, Spain.

The plant was designed to 2035 horizon serves around 8000Cap. Activated Sludge. Screening (4 mm); Preliminary treatment; Biological reactor; Secondary Clarifier; Sludge thickener; Sand filters; Disinfection. Then transported to Al-Menyah sanitary landfill (CDG. 2018).

3.3 QUESTIONNAIRE DESIGN

A simple questionnaire was designed (ANNEX No.1), which aims to verify the data provided to us, in order to reach the highest possible accuracy in the research and analysis process, which leads to real results even if they are of a negative result, or contrary to what was expected. Therefore, the questionnaire was divided into several paragraphs, which are as follows:

Paragraph 1: General information about the treatment plants:

This paragraph is an opening paragraph, and it breaks the ice between the researcher and the person responsible for filling out the questionnaire, and this will lead to a higher degree of transparency in answering the following paragraphs.

Paragraph 2: The size of treatment plant and its investment costs:

This paragraph was chosen to be the second paragraph of the questionnaire, because its answers are often known to most of those interested in the sanitation sector and those who follow its development, and this paragraph also emphasizes giving psychological comfort to the questionnaire-filler to be more confident that giving accurate information to the researcher will be valid.

This paragraph includes several questions related to the treatment plants capacity, the area of land it is built on, the number of serviced residents, future expansion plans, and the resulting investment costs.

Paragraph 3: Consumption of electrical energy:

Here, the researcher delved into his questions within this paragraph, as one of the most interesting topics is the amount of energy consumption for treatment purposes. This paragraph addressed, through a set of questions, the measurement of the amount of energy consumed in all the processes of the treatment process in the plant, in addition to the possibility of having systems Production of energy in the treatment plant, whether through photovoltaic energy or biological energy resulting from methane gas.

Paragraph 4: Reusing the products of treatment plants:

Through this paragraph, the effectiveness of the reuse system for TWW and stabilized sludge was verified, and its reflection on the treatment plant revenues and expenses because of its important role in influencing their sustainability.

Paragraph 5: Performance of employees in WWTP:

Through this paragraph, the number of employees in the treatment plant was known, with their different academic qualifications and job positions, and the extent of the officials' interest in raising their efficiency was measured by studying the training provided to them. The financial impact of the salaries of the employees in the treatment plant was also measured and its reflection on the operational costs of the WWTPs

This paragraph also includes a part that aims to measure the extent of administrators' interest in the treatment plants performance by following up on the characteristics and quality of its inputs and outputs. As well as providing the necessary maintenance, both preventive and emergency.

Also, it included a part related to the extent of the administrators’ interest in WWTP, as this is shown through performance reports that are done periodically, as well as reports of archiving the problems encountered by the treatment plants and the mechanisms for their solutions, which contributes to facilitating the task of the technical staff, especially in the event of some of the teams are replaced by employees who are not within the same level of technical and administrative experience. It also addressed the follow-up of the administrative staff of the treatment plant by measuring the extent of their knowledge of the needs of their treatment plant, and their communication with the relevant authorities and government agencies.

Finally, it was discussed to put forward an alternative idea for the management of WWTPs in the West Bank, and to measure the extent to which the administrative in the treatment plants interact with this idea.

3.4 TIME SERIES DATA (CASE STUDY)

In order to go deeply through assessment of capabilities of WWTP operators, it’s important to analyze all data related to WWTP performance like reports and archives, to conclude the real situation of each WWTP.

As an example, this study will take Nablus West WWTP as a case study, and analysis the collected (88) reports about its performance since Jan, 2015 until April, 2022.

Applying a time series analysis using MS-office “Excel” and SPSS program, to looking through its performance regarding to the standards, and the variances in it along the whole operation period approximately. Then, expectation can be build based on the results.

3.5 INTERVIEW DESIGN

The last method of collecting data depending on personal interviews (semi-structural) with each WWTP operation manager, and with the related person from PWA.

These interviews will be done virtually using ZOOM software, the researcher will invite each nominated person in Table (6), then each one will answer two parts of questions, one of them will be general information about the challenges and obstacles facing their plant, while the other part will be based on the results of questionnaire in order to explain that results.

Generally, the interview questions (ANNEX No.2), were divided into main four-axis. That axis’s are managerial, technical, financial and social. Each of them has its answers from interviewee point of view. The main goal of conducting these interviews is to bridge the gap of information that couldn’t be covered in the questionnaire.

Table 6: List of interviewers.

NO.	Name	Position	Entity
1	Mr. Adel Yasin	General director of strategic planning and sanitation	PWA
2	Ms. Asmaa Salah	Executive Director	Joint Services Council of AL-Taybeh-Ramon
3	Mr. Elias Abu-Mohr	Al Aroub WWTP manager	Applied Research Institute (ARIJ)
4	Mr. Ibraheem Abu-Sebaa	Head of the water and sanitation department	Jericho municipality
5	Mr. Malik Ishtiah	WWTPs manager	Ramallah municipality
6	Mr. Noor-Eden Abu-Gazala	Jenin WWTP manager	Jenin municipality
7	Mr. Rabee Rabaiah	Executive Director	Joint services council of Maithaloon
8	Ms. Roa Al-Taweel	Head of engineering department and WWTP manager	AL-Berih municipality
9	Mr. Yousef Abu-Jafal	Operation manager of Nablus West WWTP	Nablus municipality

3.6 DATA ANALYSIS

Statical analysis of data was done through using of SPSS software and MS-Excel software, generate the Figures and Tables present results of questionnaire and case the case study, besides the programming language “R”. While, the descriptive analysis used to analyze and conclude results from interviews.

Chapter Four: Results and Discussion

Each one of the eight (8) WWTPs responded and filled the questionnaire, the analysis and questionnaire results are presented below:

4.1 General Data

Through the results presented in Table (7), revealed that the most widespread technology in the sample is EAAS , and that the majority (40%) of WWTPs sites are within the boundaries of areas (a) in accordance with the Oslo Agreement 1993, while only 25% of the WWTPs are within the boundaries of areas C (Al-Bireh and West Nablus WWTPs) which is under the control of the Israeli security occupation, that means its needed prior to Israeli permits, hence it noted that whenever the area of coverage for the serviced area The WWTP's location is heading towards areas of C.

The majority of WWTPs have enough space to create a future expansion of 75%, due to the fact that when the land was acquired, the future developments of the WWTPs were taken into account, while only 25% of these WWTPs did not have enough space to expand, namely:

- Al-Aroub WWTP: It is designed to accommodate the Arab camp only, and if other areas are connected with it, it needs additional land.

- Taybeh-Ramon WWTP: This WWTP does not have the land on which it is built, as it is privately rented, and in the event of expansion the area of rented land can be increased.

All treatment plants produce treated water suitable for agricultural reuse (according to the operators of these plants), while 37.5% own their own laboratory, which conducts tests for both wastewater and treated water, and these WWTPs are only the central WWTPs (Jericho, Al-Bireh, West Nablus), through the Palestinian Ministry of Agriculture.

The only plant that collects methane gas and exploits it as a source of electricity is the West Nablus plant, since the technology used allows it, while the rest of the plants cannot, for the following reasons:

- Lack of methane gas extraction and assembly unit.

- The number of beneficiary populations is much less than 70,000 Cap and therefore does not work efficiently.

- Some WWTPs produce sludge in very low quantities.

Sludge is treated in its final form and transported to landfills (50%) of the WWTPs, and Jericho WWTP alone stores it in land belonging to the WWTP (helped by the availability of large areas, relatively high temperature reduces the size of sludge naturally), and there are three plants that make up 37.5% of the sample, their production of which is neglected, as follows:

- Missilya plant: Sludge accumulates over the filter basin by (1 cm/year), and after the accumulated layer is 20 cm thick, only 15cm is removed. That is, at the rate of removal once every 15-20 years.

- Taybeh-Ramon plant: The amount of wastewater reaching the plant represents 27% of the plant's capacity, making the plant's production low as sludge is recycled and deposited during the treatment process.

- Jenin plant: It does not have sludge disposal systems where it is deposited in treatment basins.

37.5% of the plants use chemicals (mainly polymers) in the treatment process, for the purposes of draining water from sludge, namely Nablus west, Al-Bireh and Al-Aroub.

Half of the sample of plants produces solar power, while the other part of the sample lacks PV power generation systems.

In terms of the technical capabilities of the operational teams, 62.5% of the WWTPs perform monthly Preventive Maintenance (PM) work, and one plant does not carry out periodic maintenance at all (Jenin Industrial WWTP), indicating that the plant has a malfunction with the technical staff specialized in maintenance. While the remainder is carried out at semi-annual or annual intervals, this indicates that these WWTPs need to intensify the PM patrol. It is noteworthy that 50% of the WWTPs archive this data and return to it in time of need, and the other half do not store this data and therefore deprive themselves of a real database on the maintenance work of their plants.

75% of the WWTPs operator's administrative system makes monthly performance reports on the WWTP's performance, while a Missilya plant alone does not make these reports at all, making it difficult to track the WWTP's performance during the run-up period, while the rest make semi/annual performance reports and these can also be intensified for better follow-up of its performance. 50% of WWTPs administrators make monthly needs reports, while the other half make semi-annual reports. These reports are published only at the Nablus west WWTP, which publishes these reports through its own website, which owns it from the rest of the WWTPs.

One of the ways to exchange information between WWTP operators, is to conduct regular field visits between them, 37.5% of them do not making such visits, and a similar percentage of WWTP operators making half/year visits, and the rest visiting over longer periods (more than a year).

One of the most important means of developing the capabilities of the teams working in the WWTPs, is through the conduct of appropriate training for them, as all plant operators trained teams before the operation of the plant except the Jenin industrial WWTP, which was not trained its crew before operation, and with regard to training during its operation 50% of the WWTPs are trained teams during half/annual periods, while the remaining percentage does not conduct any training at all or train during long-term periods building on the grant programs available, this means that there is a clear failure to improve and develop the capabilities of a large part of the plants teams.

A large percentage of WWTP operators communicate with government agencies from relevant ministries and authorities, as 62.5% of them communicate over periodic periods ranging from one month to one year, in the sense that one plant (Al-Bireh) does not communicate with them at all, which make their staff weakness, while the rest continues only as needed this weakens the relationship between these parties. Also, 62.5% of WWTP operators supported the idea of establishing a central government management and operating unit for all WWTPs, while only 25% did not support this idea, Al-Tireh plant is neutral.

Table (7): Frequencies of some WWTP characteristics.

VARIABLE	CATEGORIES	COUNT / PERCENTAGE
TECHNOLOGY TYPE	EAAS	3 (37.5%)
	CAS	1 (12.5%)
	MBR	1 (12.5 %)
	CW	1 (12.5%)
	AL	1 (12.5%)
	RBC	1 (12.5%)
LOCATION	A	4 (50%)
	B	2 (25%)
	C	2 (25%)
AVAILABILITY OF EXPANSION AREA	YES	6 (75%)
	NO	2 (25%)

T.W COMPLY WITH AGRICULTURAL REUSE STANDARDS	YES NO	8 (100%) 0 (0%)
INSIDE WWTP (OWNED) LAB	YES NO	3 (37.5%) 5 (62.5%)
CH4 COLLECTION SYSTEM	YES NO	1 (12.5%) 7 (87.5%)
SLUDGE FINAL LOCATION	Dumping Storaging Composting Negligible	4 (50%) 1 (12.5%) 0 (0%) 3 (37.5%)
CHEMICAL ADDITIVES USAGE	YES NO	3 (37.5%) 5 (62.5%)
SOLAR PANELS AVAILABILITY	YES NO	4 (50%) 4 (50%)
PERIODICAL PREVENTATIVE MAINTENANCE	None Monthly Half-Yearly Yearly More Than One Year	1 (12.5%) 5 (62.5%) 1 (12.5%) 0 (0%) 1 (12.5%)

HISTORICAL MAINTENANCE REPORTING DATA AVAILABILITY (ARCHIVING)	YES	4 (50%)
	NO	4 (50%)
PERFORMANCE REPORTING	None	1 (12.5%)
	Monthly	6 (75%)
	Half-Yearly	1 (12.5%)
	Yearly	0
	More Than One Year	0
PUBLISHING OF PERFORMANCE REPORTS	YES	1 (12.5%)
	NO	7 (87.5%)
NEEDS REPORTING	None	0 (0%)
	Monthly	4 (50%)
	Half-Yearly	0 (0%)
	Yearly	4 (50%)
	More Than One Year	0 (0%)
WEB-SITE AVAILABILITY	YES	1 (12.5%)
	NO	7 (87.5%)
VISITS TO OTHER WWTPS	None	3 (37.5%)
	Monthly	0 (0%)
	Half-Yearly	1 (12.5%)

	Yearly More Than One Year	2 (25%) 2 (25%)
PRE-OPERATION TRAININGS	YES NO	7 (87.5%) 1 (12.5%)
THROUGH-OPERATION TRAININGS	None Monthly Half-Yearly Yearly More Than One Year	2 (25%) 0 (0%) 1 (12.5%) 3 (37.5%) 2 (25%)
COMMUNICATING WITH RELATED GOVERNMENTAL AUTHORITIES	None Monthly Half-Yearly Yearly More Than One Year	1 (12.5%) 2 (25%) 1 (12.5) 2 (25%) 2 (25%)
GOVERNMENTAL CENTRAL MANAGEMENT UNIT	Favor Against Neutral	5 (62.5%) 2 (25%) 1 (12.5%)

4.2 WWTPs AND ITS AREA OF LAND RELATIONS

This section shows the relations between each WWTP of the sample and its current area, capacity and costs.

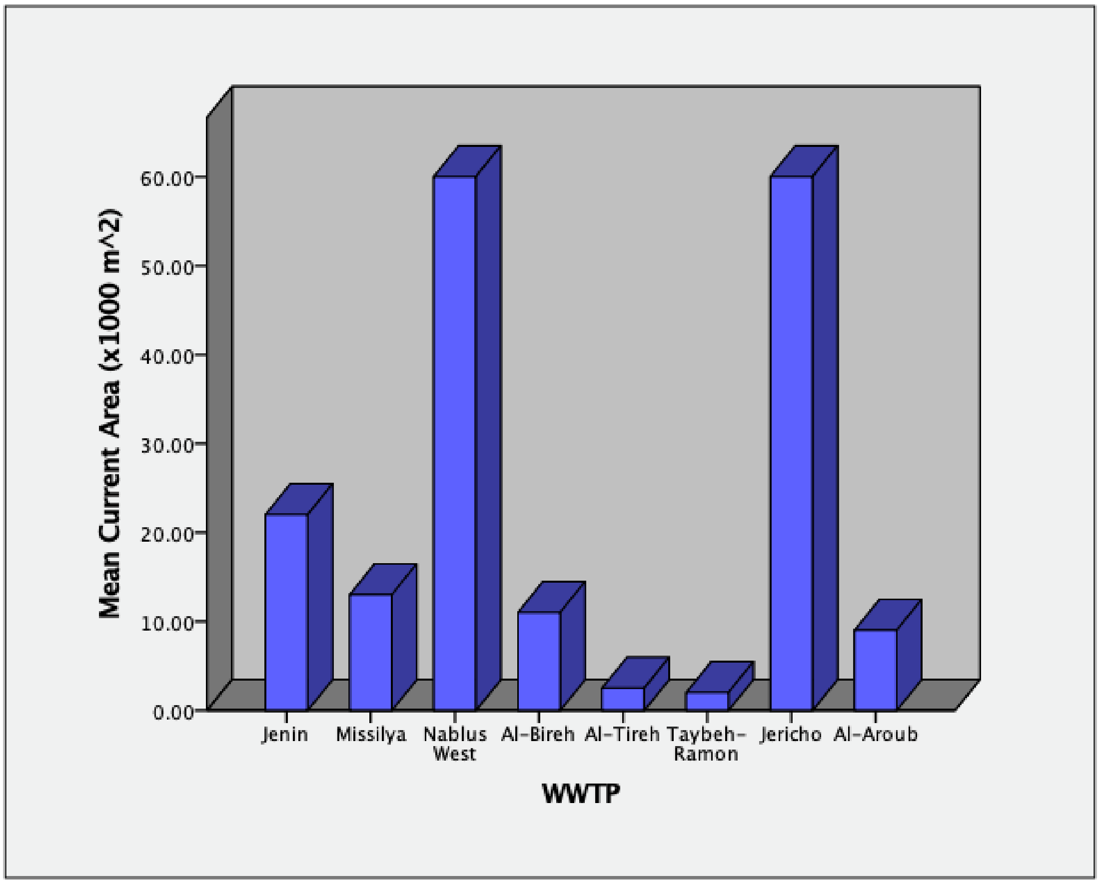

Figure 9: Current Area of each WWTP of sample, WB.

Figure (9) shows that both of Nablus West and Jericho WWTPs have the largest area of land (about 60,000 m² each), as they are the largest in size and have large future expansion area, while Taybeh-Ramon WWTP is the smallest area of land regarding its capacity and type of technology which doesn't need large are, in addition to haven't expansion area.

However, Figure (10) shows the required area of land for each cubic meter of WWTP capacity. It's obvious that Missilya WWTP has the largest area (around 110m² / cubic meter), which greater than Jenin WWTP (AL technology, around 2.2m²/ m³). That generally speaking should be the largest area percent, meaning that Missilya has a construction issue causing it has large area percent. However, the smallest area percent (around 0.8m² / cubic meter) achieved by Al-Tireh WWTP, due to advanced MBR technology which needs smaller area.

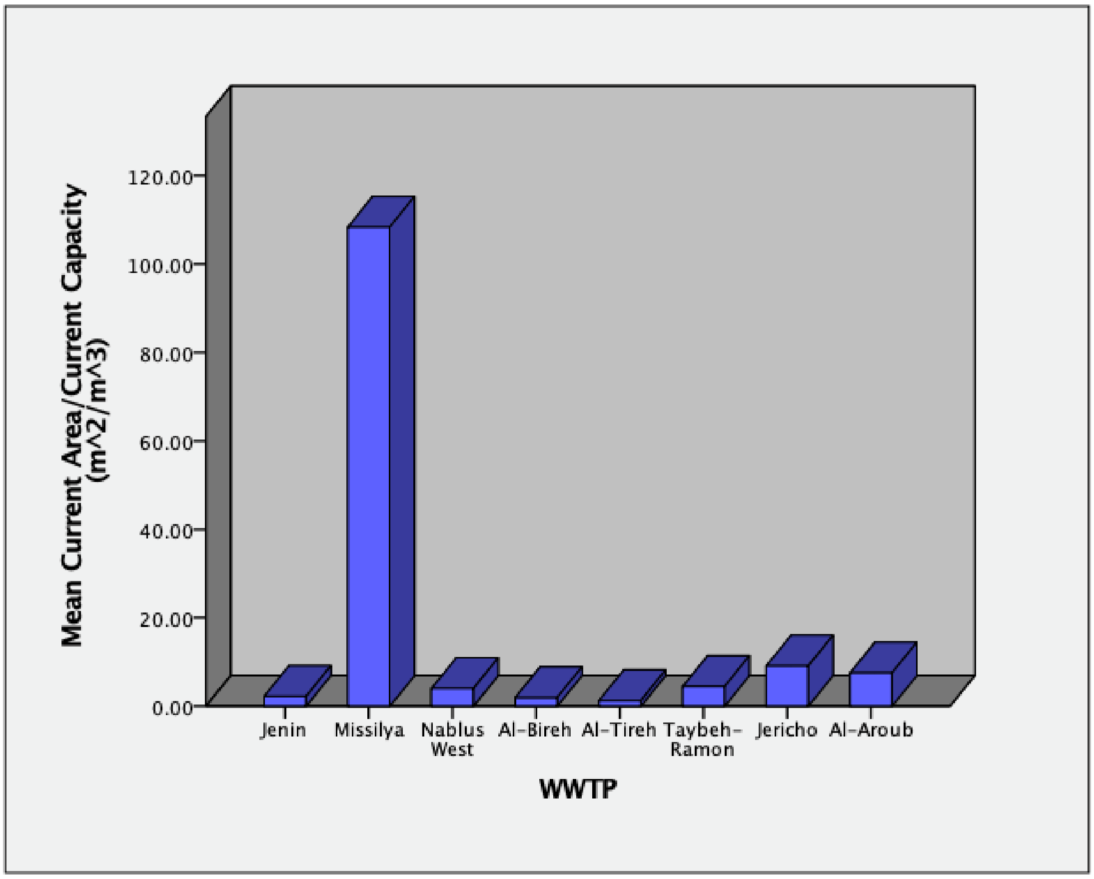

Figure 10: Area of land required per cubic meter of WW for each WWTP, WB.

Figure (11) more specific than the previous one, in presenting the effect of land area on the WWTP by taking into consideration the location through valuating it by the current price of it. Missilya WWTP has the largest price of land regarding to its capacity (around 1500$/m³) as it located in area "A" and considered a residential area. while both of Jericho and Taybeh-Ramon WWTPs almost have no cost because they don't own the land, they are renting it. While Jenin WWTP has the smallest percent (around 175$/m³). All precises were considered as the current price.

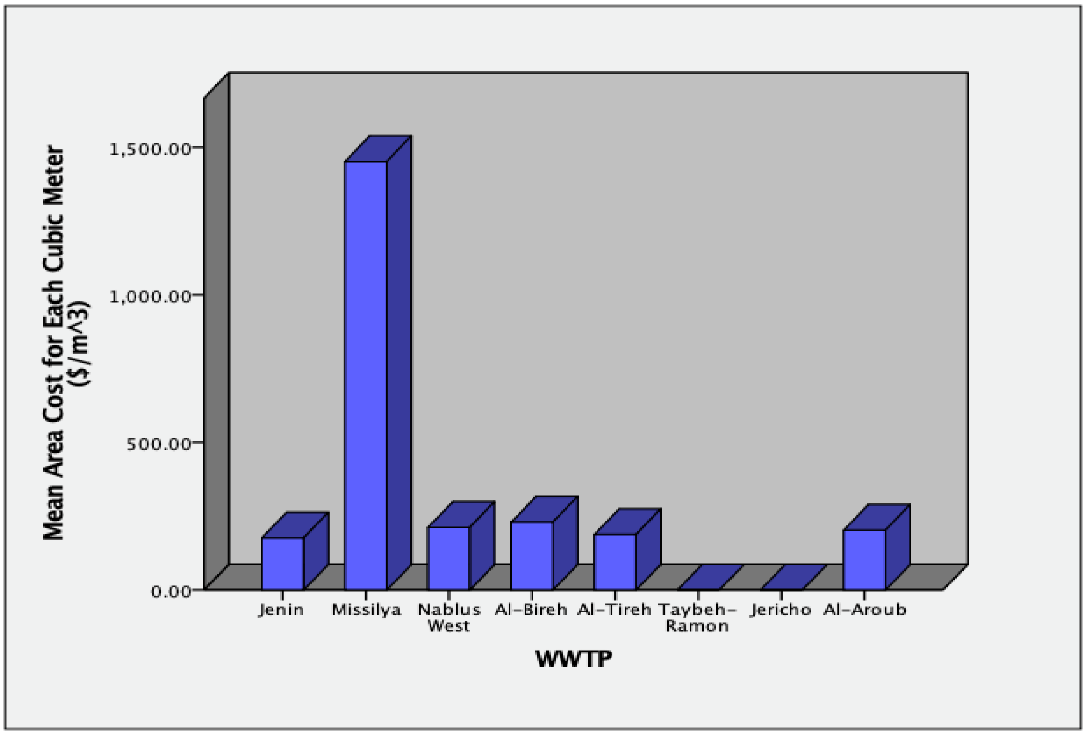

Figure 11: Cost of Land per cubic meter of WW, WB.

4.3 BENEFICIARIES – WWTP RELATIONS

This section showing the numbers of connected people for each WWTP, Capita share of construction cost and the effect of technology on the capita share of construction cost.

Figure (12) shows the number of beneficiaries (connected people) for each WWTP of the sample. It clear that Nablus west WWTP is the largest (around 115,000 Cap), while Missilya WWTP is the smallest regarding to connected people. Also, they can be divided into three categories regarding to that numbers:

- Largest: Nablus West WWTP.
- Moderate: Jenin, Al-Berih, Al-Tireh and Jericho WWTPs.

- Smallest: Missilya, Taybah-Ramon and Al-Aroub.

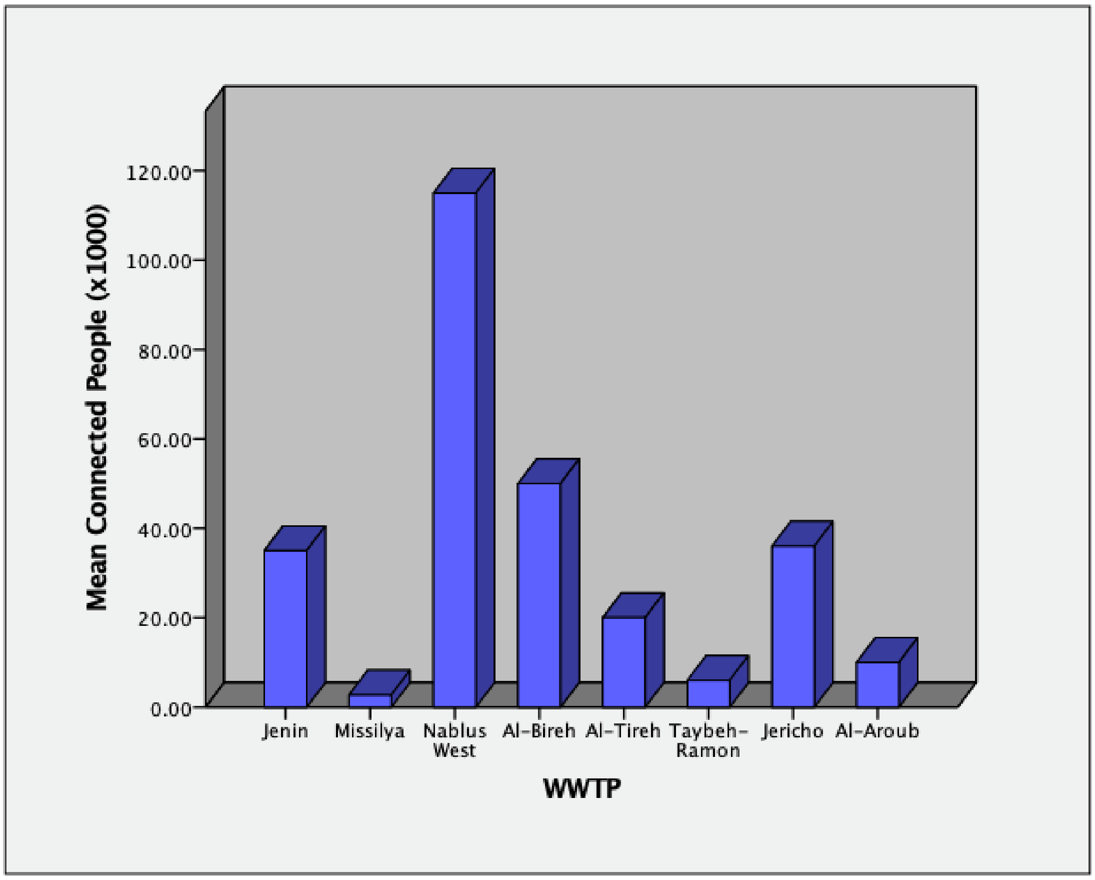

Figure 12: Number of populations served for each WWTP, WB. It's obvious that

To specify the real needs of area for each WWTP of study sample, see Figure (13) which shows the area of land required for each person connected to the WWTP.

Al-Tireh has the lowest area requirement ($0.2m^2/cap$); due to the technology type which needs smaller area. In addition, five of them are less than $1.0m^2/cap$. While the largest is for Missilya WWTP requires around $5.0m^2/cap$ which a very high area requirement in comparison to the other sample; because of the completely natural treatment process used which needs high areas. But when looking to Jericho WWTP will see its percent quite high (around $2.0m^2/cap$); because it works right now only of 30% of its capacity and this area requirement will decrease when its occupied capacity increases

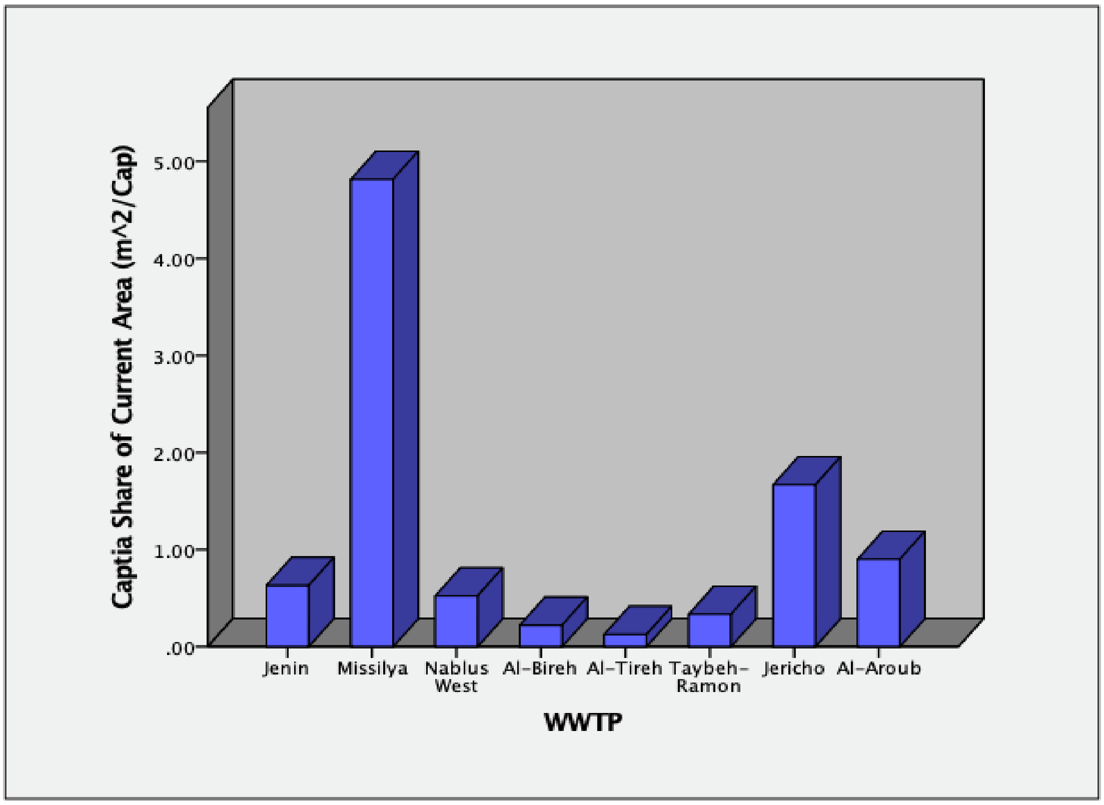

Figure 13: Capita Share of WWTP Area of Land, WB.

Figure (14) showing the share of each one who served by the WWTP from its construction cost. It's clearly to see that Missilya is the largest one (around 1000$/cap) which huge number regarding to other complicated technology have lesser share like e.g., Nablus west or Al-Tireh WWTPs. The second one is Jericho WWTP and it has the large number due to very low percent of connection (around 30% of its capacity). While, the lowest percent is for Jenin WWTP due to its very simple technology.

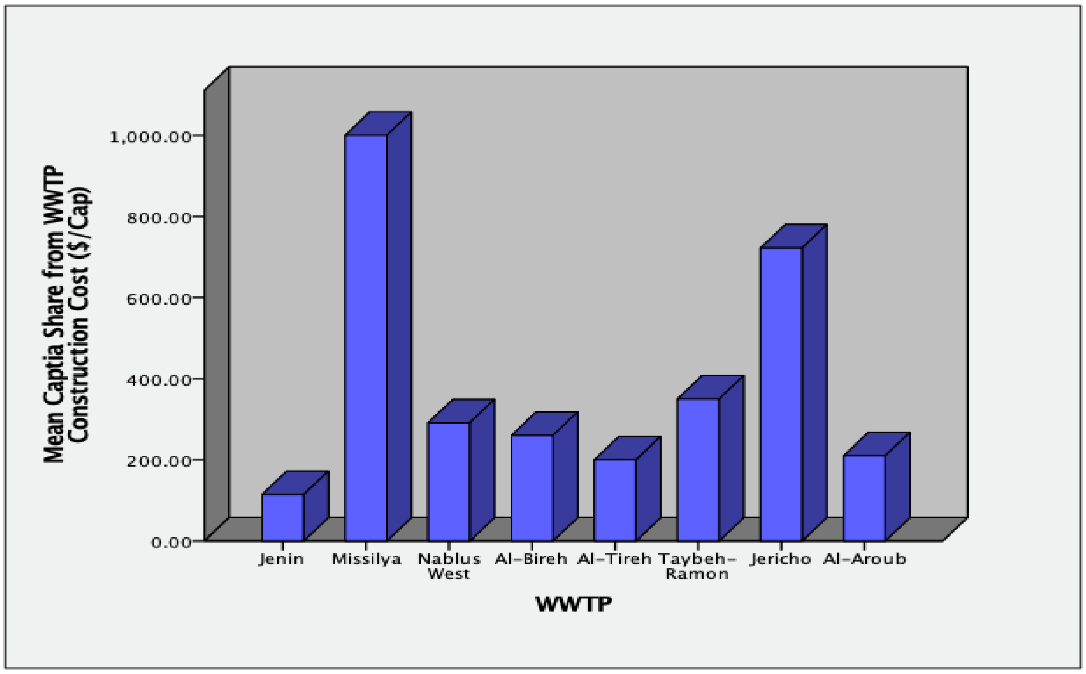

Figure 14: Capita share of the construction cost of the WWTP, WB.

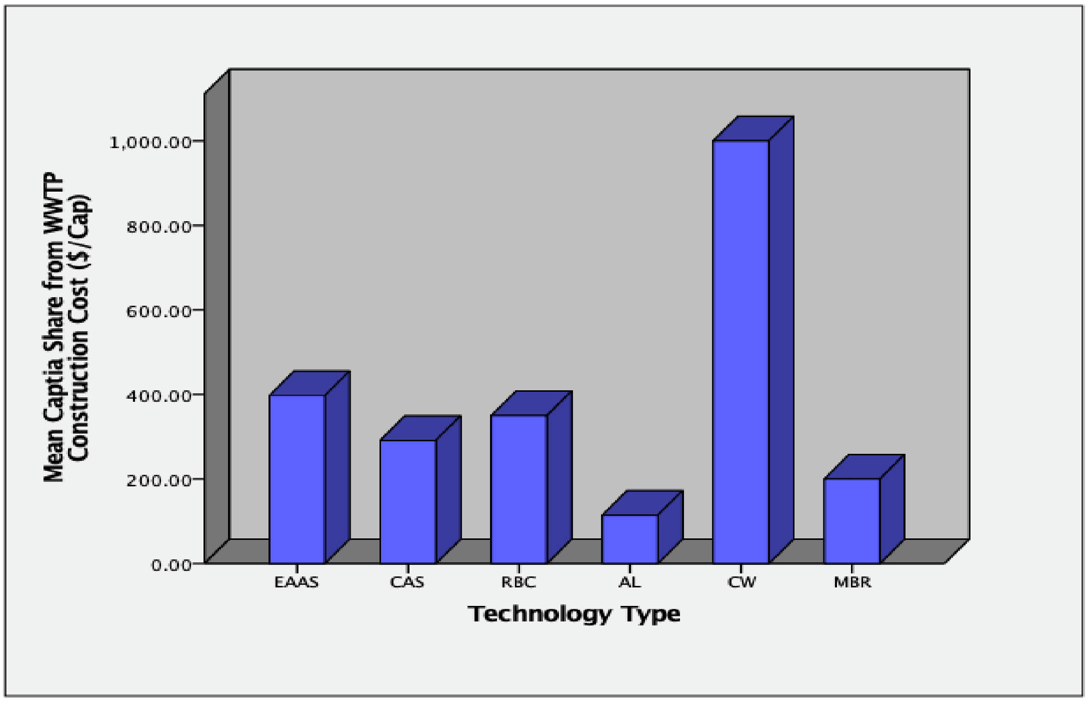

Figure 15: Technology effect on the capita share of construction cost, WB.

Figure (15) confirming what shown in Figure (14), which is CW technology in Missilya WWTP has the largest capita share of construction cost, while the lowest in AL technology in Jenin WWTP.

4.4 FUTURE EXPANSION OF WWTP

Figure (16) shows the current capacity for each WWTP of the sample, and the planned future capacity. It obvious that the largest current capacity is for Nablus West WWTP, while the lowest is for Missilya WWTP.

In future extension point of view, it clear that Nablus West planned to the largest extension at 2025 by doubling its capacity to become 30,000 m³. In addition, Al-Tireh planned to extend its capacity by additional 2500m³ in 2022, and Al-Berih aimed to increase its capacity by 5000m³ in 2010 but it does not have the permits from Israil Occupation until now. Jericho WWTP also aims to increase its capacity by one third of the current capacity but they did not know when they need because (as masoned before) the percent of occupation around 30% only of the current capacity.

However, 3-WWTPs have no planning for extension, the reasons are as follows:

- Jenin: they do not have any plans for extension (may due to the simple technology).
- Taybah-Ramon: they have percent of occupation around 27% of the current capacity, so they have enough space until 2035 (when the renting contract will finish).
- Al-Aroub: it has plan to serve only Al-Aroub Camp population, and it has enough capacity to serve them.

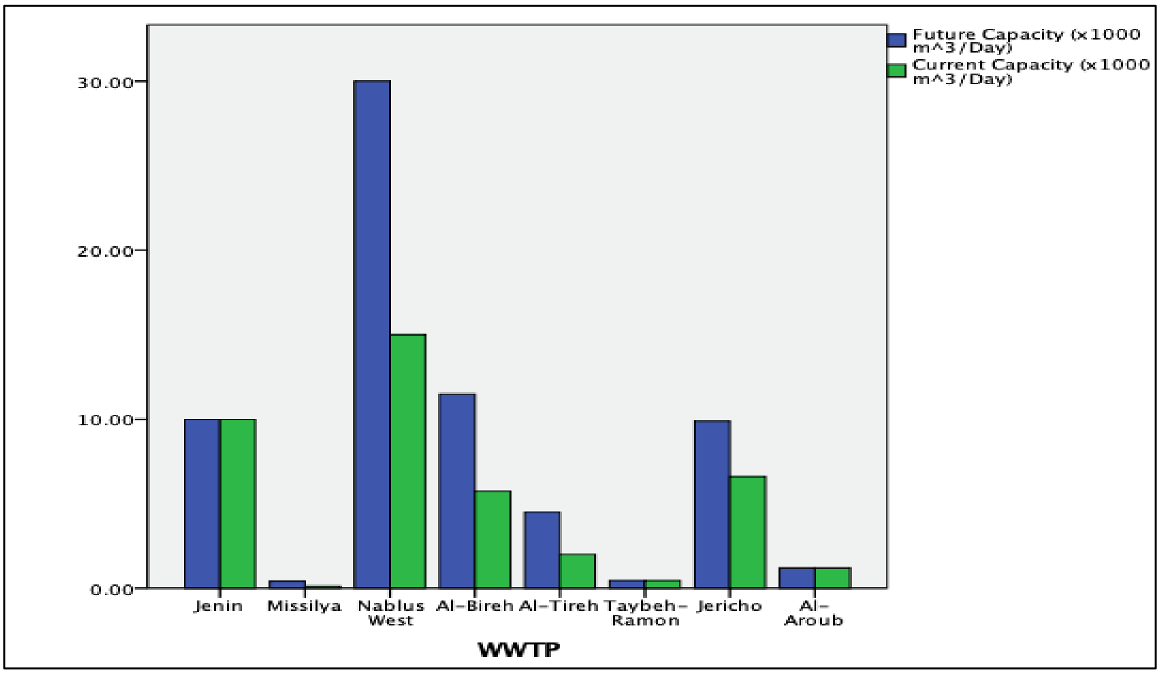

Figure 16: Future plaining for WWTPs extensions, WB.

4.5 ENERGY

This part will go deeply into electrical consumption and production, although, will shows the effect of the capacity and the number of beneficiaries on the electrical consumption.

Figure (17) shows who much the daily electrical consumption for each WWTP of the sample as an average consumption.

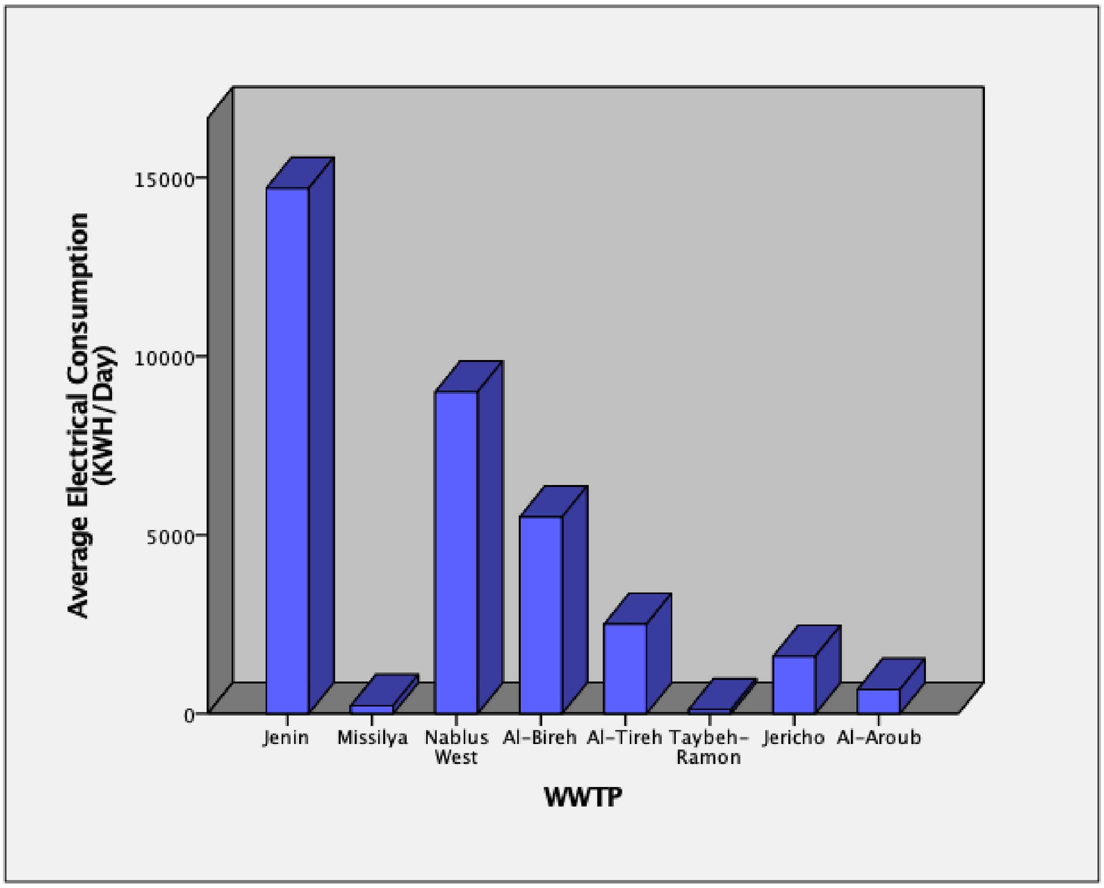

Figure (17): Average WWTP Daily Electrical Consumption, WB.

Concluding from Figure (17) that Jenin WWTP is the largest electrical consumer, while the lowest consumer is Taybeh-Ramon WWTP. Three of them have average daily consumption less than 1000KWh because their small capacity in comparison to the remaining four-WWTPs, which have consumption range from (2000-10,000) KWh. However, the next two figures will make the comparison more realistic, as the electrical consumption depends on many factors e.g. (capacity, technology, population…etc.).

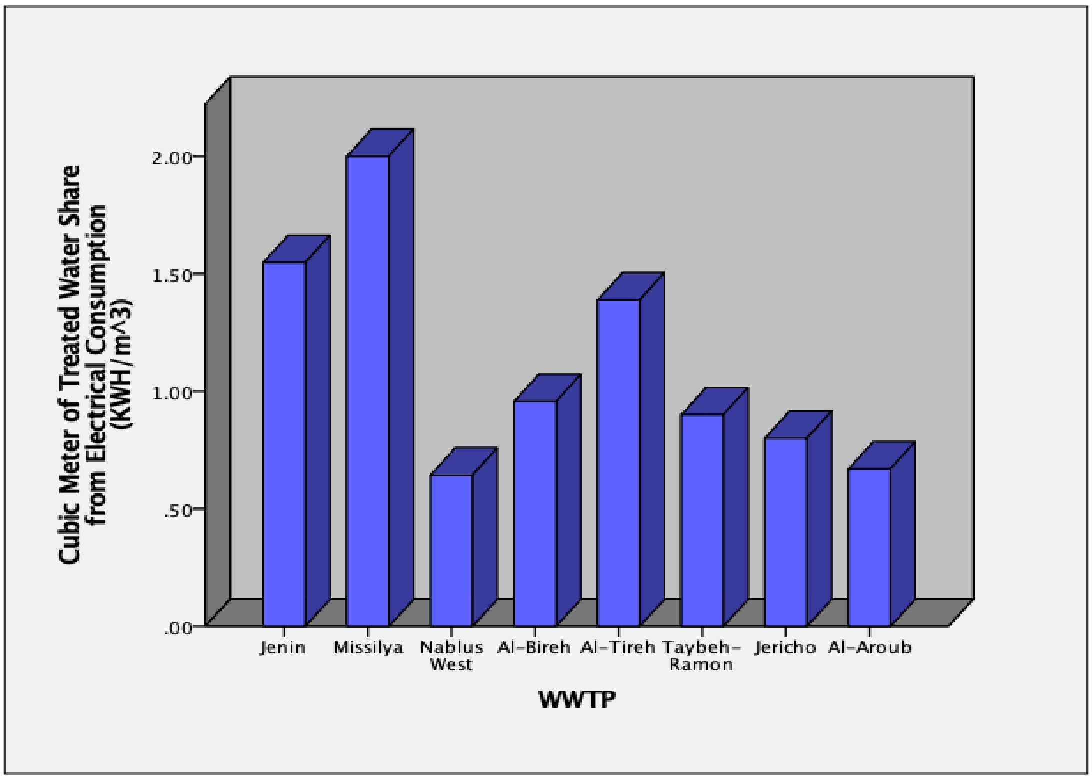

Figure 18: Cubic meter electrical consumption for each WWTP, WB.

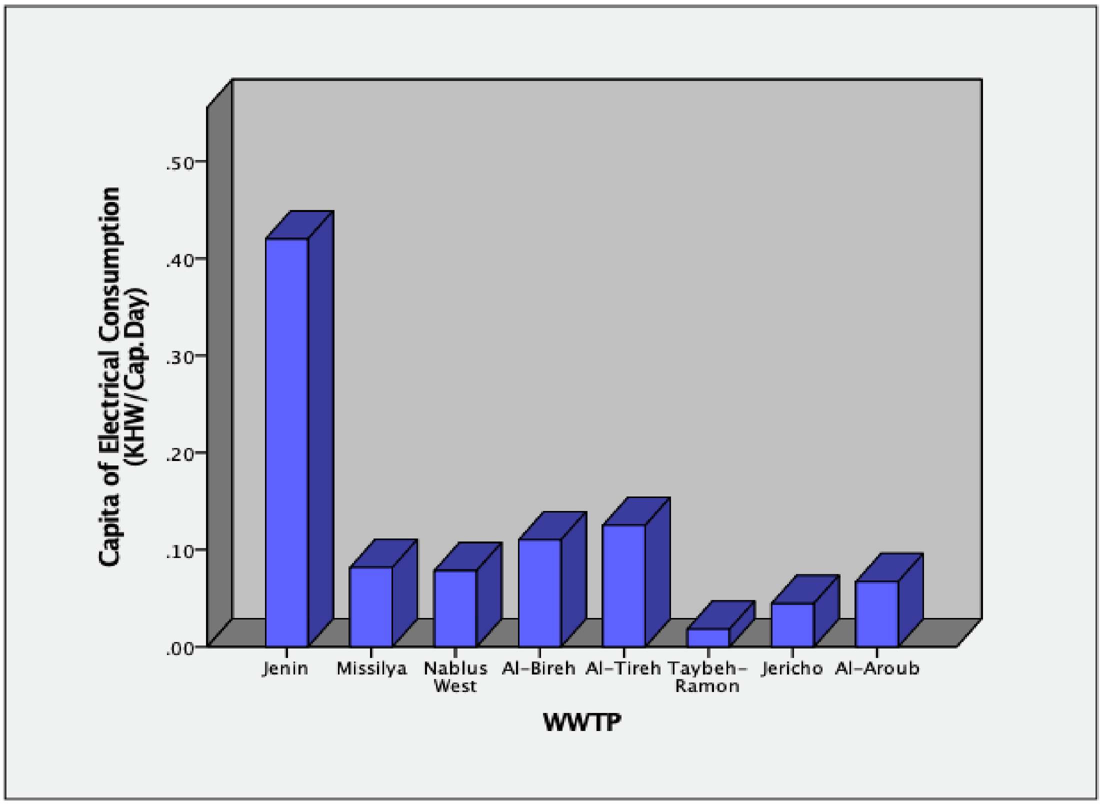

Figure 19: Electrical Consumption required per Cap for each WWTP, WB.

From Figure (18) that largest electrical consumer is Missilya WWTP (around 2KWh/m³) regarding to its capacity, then Jenin WWTP and Al-Tireh WWTP with an average consumption (around 1.4 KWh/ m³), While the lowest consumer is Nablus West WWTP with an average around (0.6 KWh/m³). The rest of them varies in range from (0.7-1.1) KWh/m³.

Figure (19) shows that one WWTP has average capita share of electrical consumption more than 0.13KWh/Cap.day (Jenin WWTP). Also, two of them have the lowest share less than 0.05KWh/Cap.day, while the rest of them have an average share between (0.05-0.13) KWh/ Cap.day. The two figure above show very realistic results regarding to the number of population and capacities.

Four WWTPs from the study sample producing electricity using PV panels (Missilya, Nablus West, AL-Aroub and Jericho WWTPs). Which reduce their electrical consumption up to certain level (e.g., Missilya WWTP has around 10% excess of produced electricity over its consumption). In addition, Nablus West WWTP also produce electricity from methane gas since beginning of 2018. These solutions will minimize the daily electrical consumption leading to reduce the total operation expenditures. Also, in national level, the produced electricity in these WWTPs will reduce the burden on the national electrical gird, causing enhance on the overall service level.

Figure (20) shows the daily electrical consumption minus the daily production of electricity, which presented in the figure by term “shortages”.

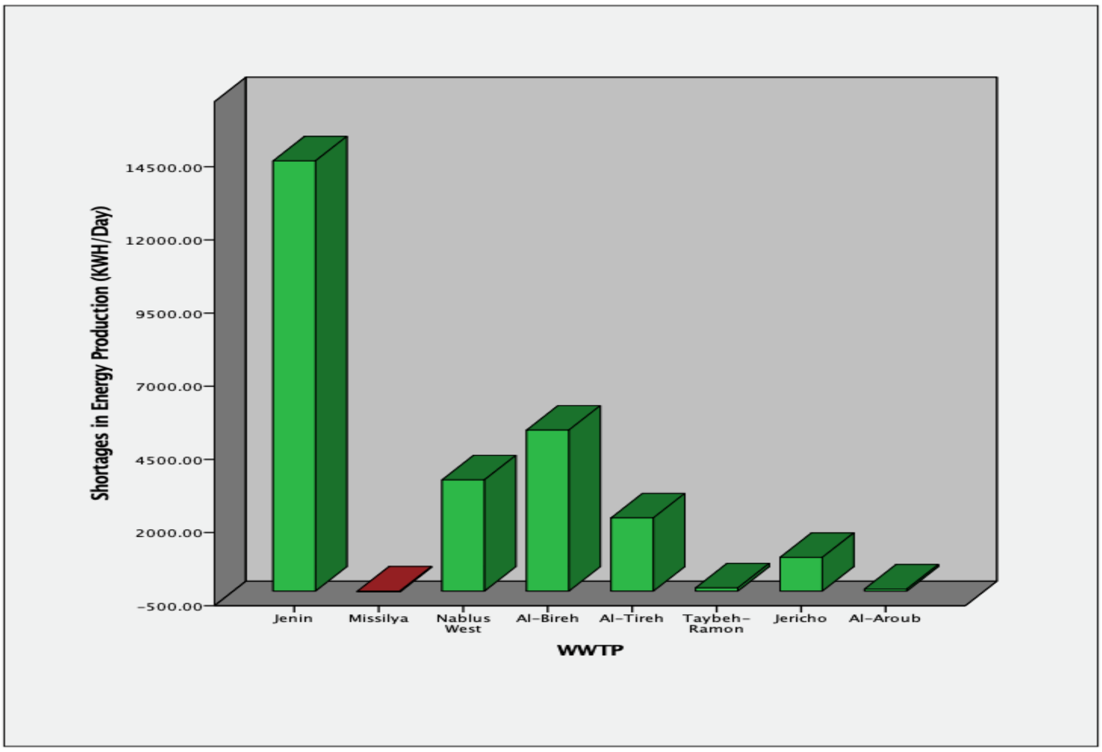

Figure 20: Deference Between Daily Produced and Consumed Electricity (KWh), WB.

From Figure (20) it can conclude that four WWTPs (Jenin, Al-Bierh, Taybeh-Ranon, Al-Tireh) have no any produced electricity, which increase there O$M costs. Missilya WWTP has excess in production, while the other three have percent of produced electricity which can be clearer in Figure (21).

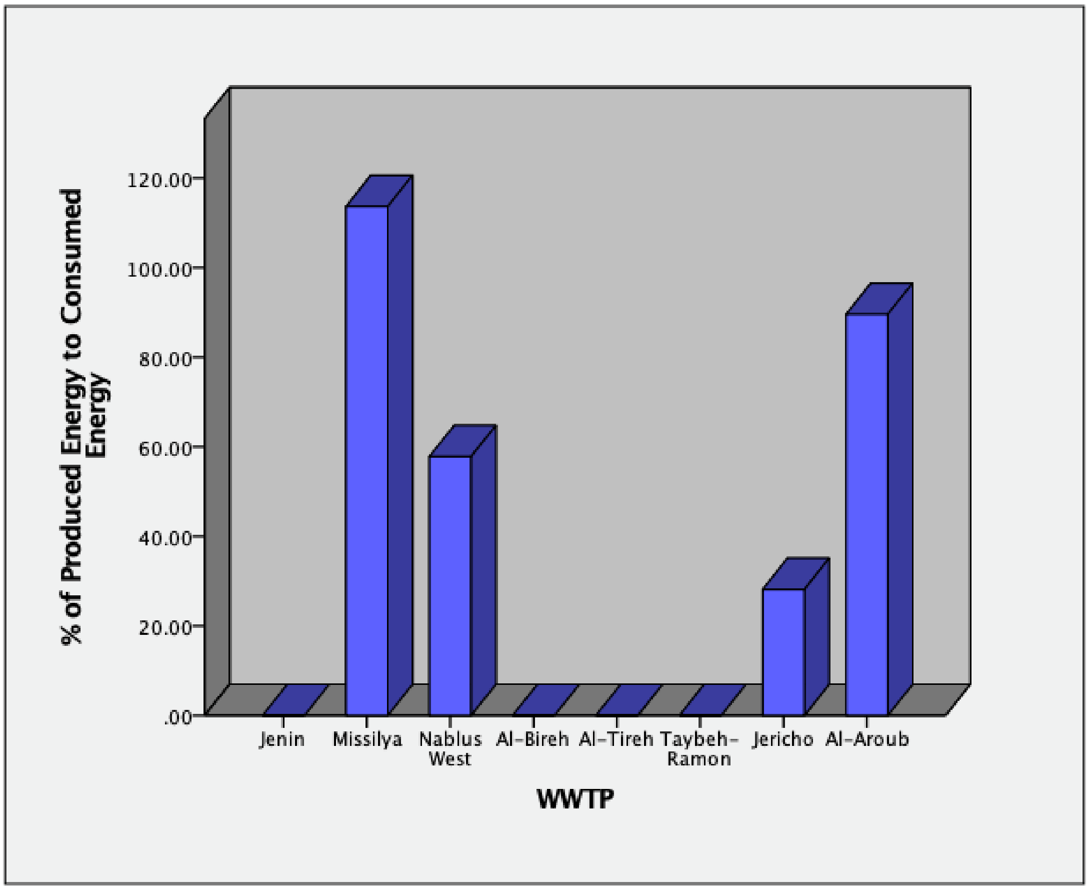

Figure 21: Electricity Production Ratio Regarding to Daily Consumption, WB.

As mentioned in Figure (21) Missilya WWTP has production percent around 110%, which means it has an energy excess, while Al-Aroub the second largest percent around 90% of its consumption that means it has to enlarge its PV system to cover the remaining 10%.

But when looking to Jericho WWTP percent (around 35%), it's disappointing because the weather in Jericho helps largely to maximize the PV system production.

The biggest producer of electricity even its percent less than others (around 60%) is Nablus West WWTP, it produced daily 700KWh from PV system and 4.5 MWh from CHP unit. However, this high production did not cover more than 60% of its consumption because it's the largest WWTP of the study sample. As a result, Nablus West should increase PV system productivity to cover the remaining 40% (around 4MWh/day).

For more clarification, Figures (22) & (23) show which WWTP produced electricity from PV system and CHP unit and which not.

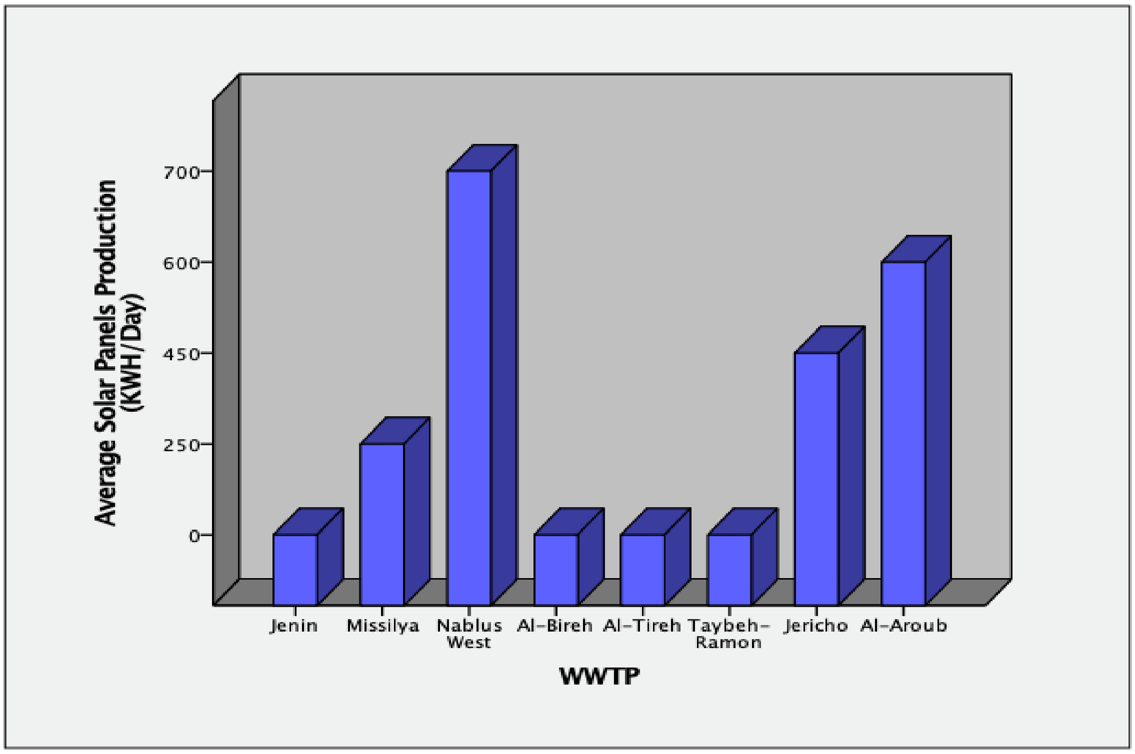

Figure 22: PV System Production, WB.

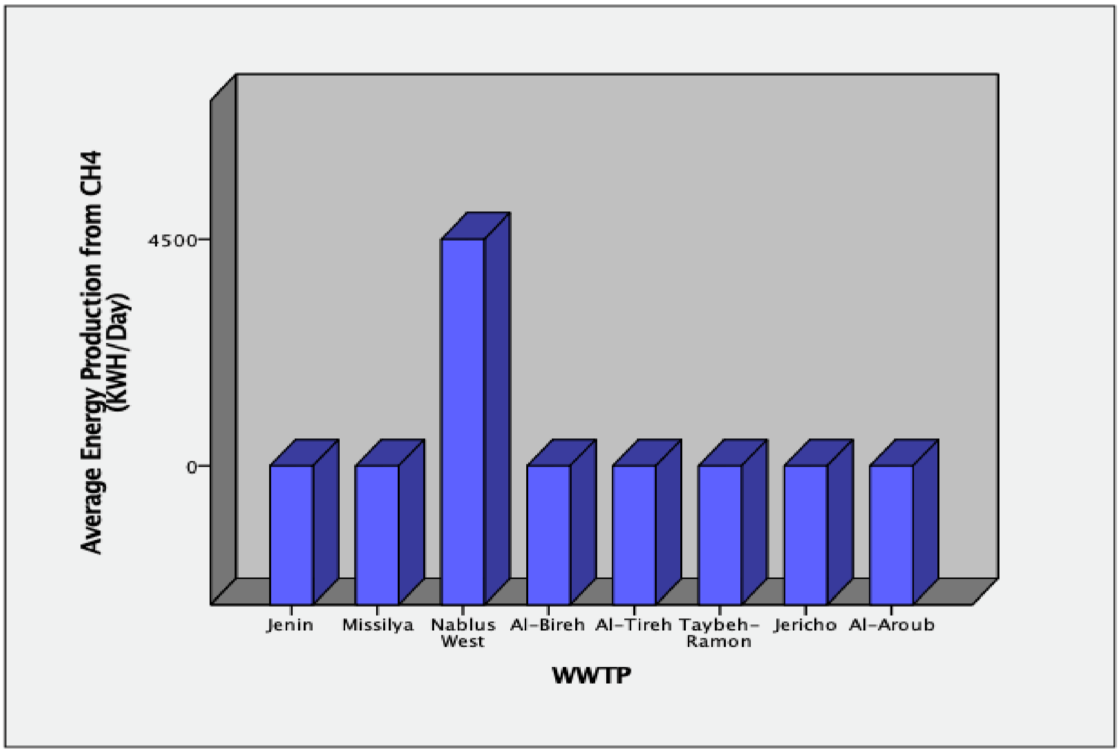

Figure 23: CHP Units Production, WB.

4.6 TREATED WATER AND ITS FINAL LOCATION

One of the most important issues facing the WWTPs managers is where operators will go of the TW. Figure (24) below shows the current handling of treated water in each WWTP.

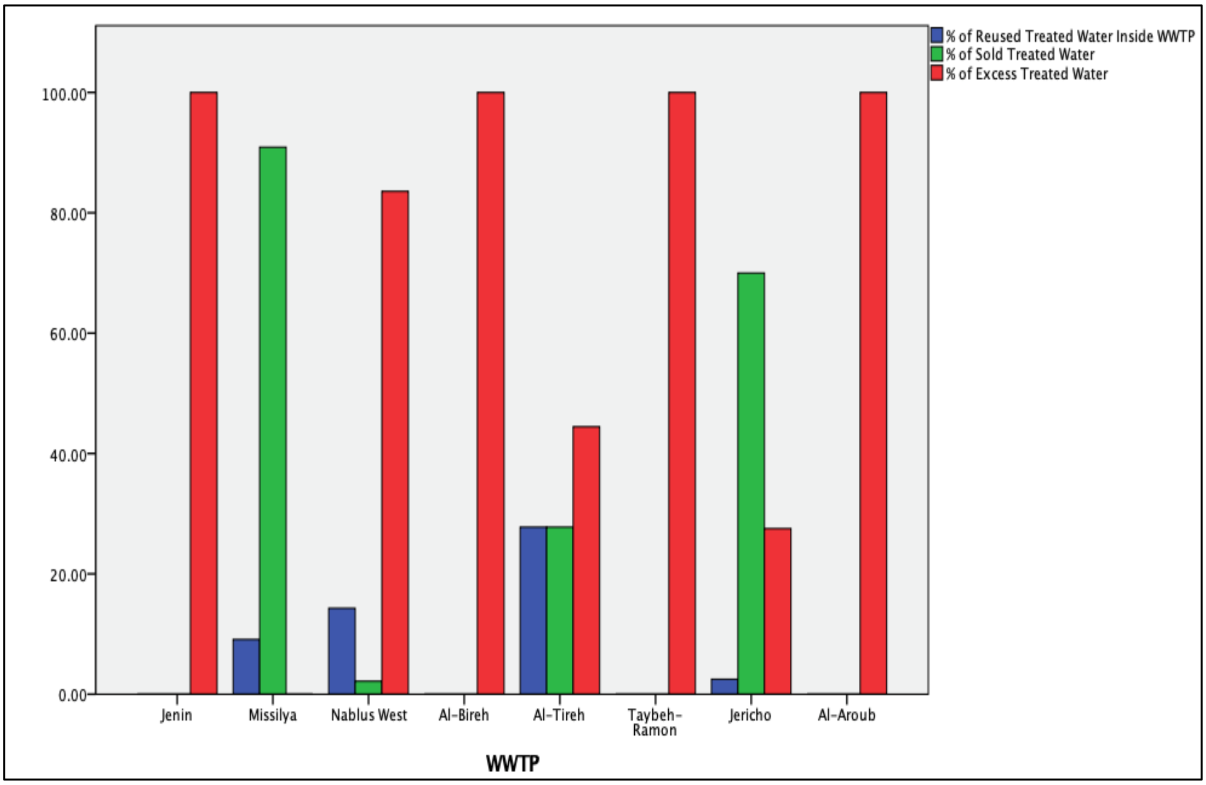

Figure 24: Final Handling with TWW in Percentage, WB.

Firstly, it clear that half of study sample have no intervene; because all of treated water discharged into wadi. However, Missilya WWTP the only one does not has any excess TW, it using small part inside itself while the other part selling it to the farmers. The second largest one of reuse TW is Jericho of around 75% selling and 10% reusing inside itself, while the third one is Al-Tireh with equal percent of reuse inside and selling around 30%, the excess is discharged into wadis. But the largest quantity discharged into wadi in Nablus West WWTP (around 82%). The low re-used quantity, leads to unsustainable WWTPs. The reuse of TWW can achieve source of fund for the financial system of WWTPs, in addition to, provides water quantities for agricultural uses which minimize the burden on drinking water quantity (that not enough for residential purposes) specially in summer season.

Figure (25) shows the daily revenue of soled TW. It's clear that five of the have no revenue; because as mentioned before four of them only dumping TW to wadi and Missilya WWTP selling TW for free. The rest can be arranged in descending order as follows:

- Jericho WWTP: 210$/day.
- Al-Terih WWTP: 150$/day.
- Nablus West WWTP: 60$/day.

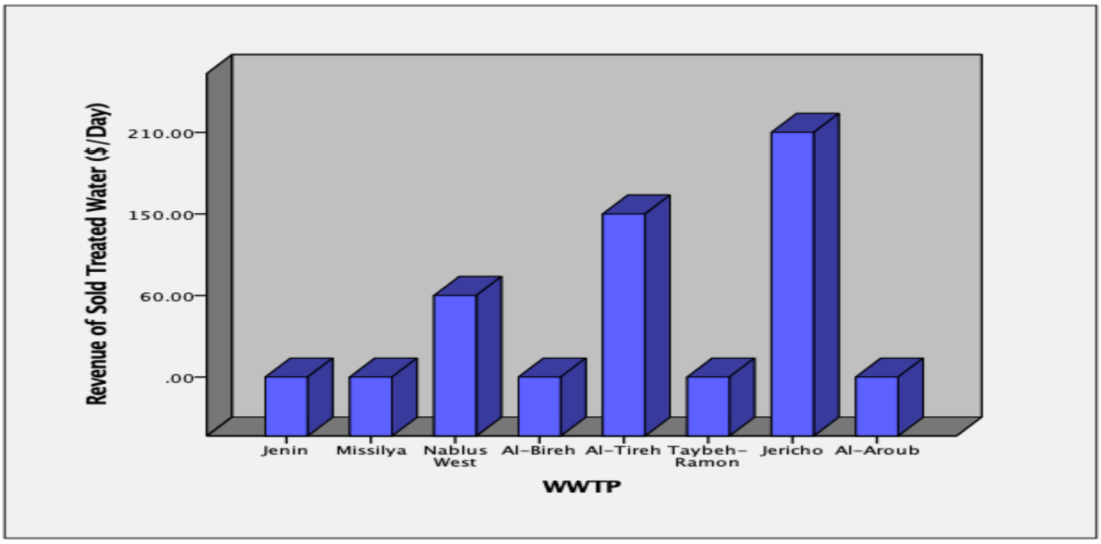

Figure 25: Average Daily Revenue of Sold TWW, WB.

4.7 Produced Sludge and its Final Location

One of the biggest issues facing the WWTPs in WB is sludge handling in a unexpensive and proper ways. So, this section will provide a clear image about what happening to sludge inside West Bank WWTPs and showing its effects on them.

Figure (26) presents the sludge quantities produced among the eight-WWTPs included into the study sample.

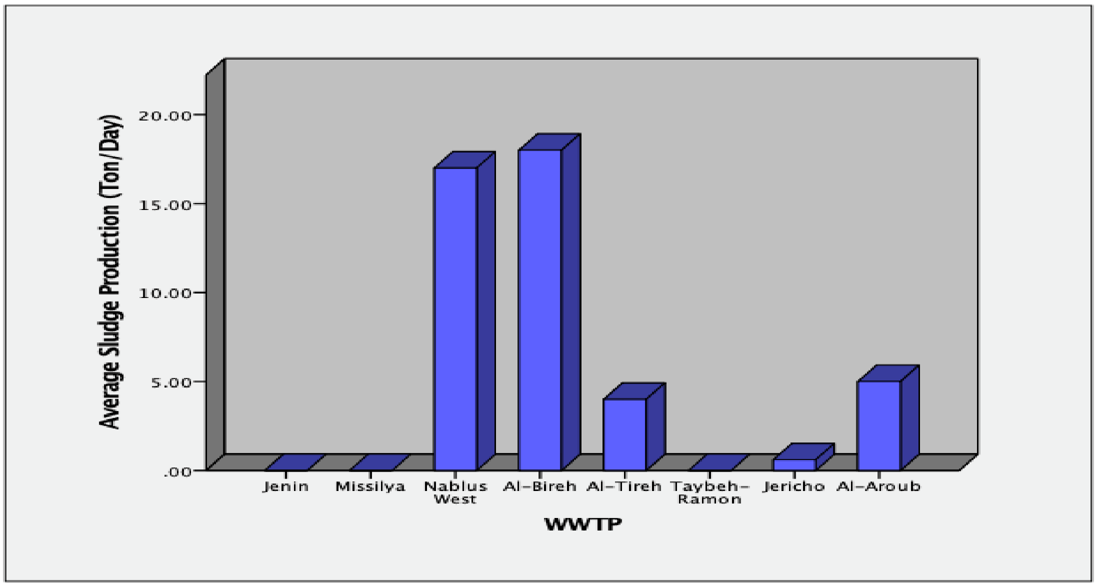

Figure 26: Daily Sludge Production (ton/day), WB.

As shown in Figure (27), regardless the capacities, Al-Bierh and Nablus West WWTP are the largest sludge producers with an average around (17-18 ton/day). However, three WWTPs (Jenin, Missilya and Taybeh-Ramon) producing very low sludge quantities or recycle it into their treatment processes.

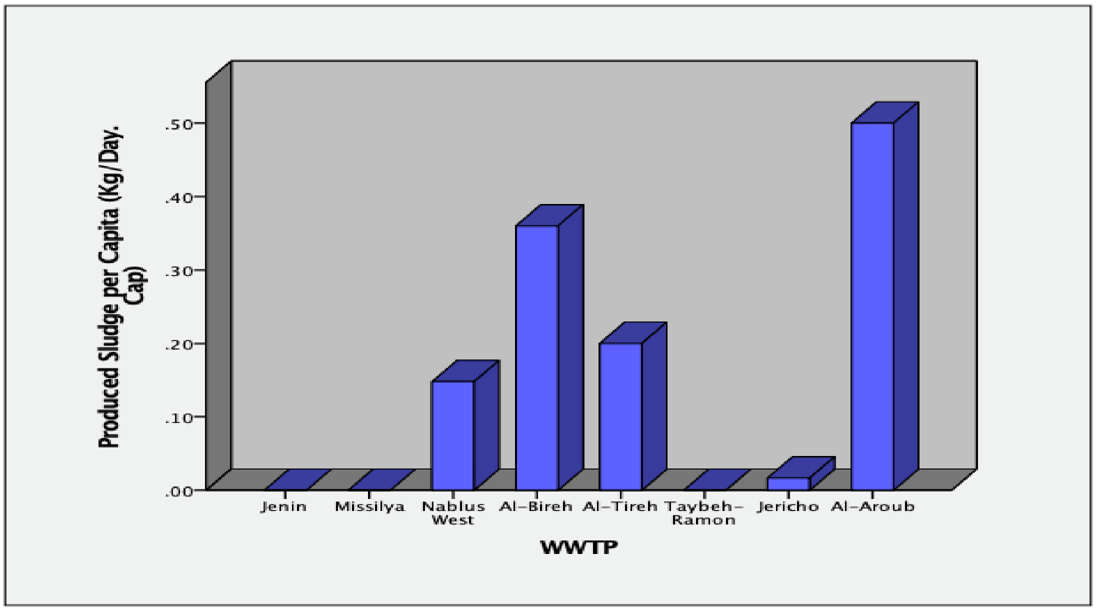

Figure 27: Per Capita Daily Sludge Production, WB.

To reflect the effect of WWTP size and served people, Figure (27) presenting who much sludge produced for each one of them. It's clear that Al-Aroub WWTP is the biggest sludge producer (around 0.5Kg/Cap.day) regarding to its connected people number which means that influent has more concentrations of pollutant than other WWTPs with same technology, while the lowest one of the producing sludges WWTPs is Jericho WWTP (around 0.03 kg/Cap.day) which very low in compression to other WWTP with same technology because it -as mentioned before- works with around 30% of its capacity. By looking to the other three sludge producers, it founded them into close range of production (0.15-0.35kg/Cap.day).

Moreover, Figure (28) confirming the presented information in the previous one more accurately regarding to the current treated WW, this figure will show the produced sludge for each cubic meter of treated WW.

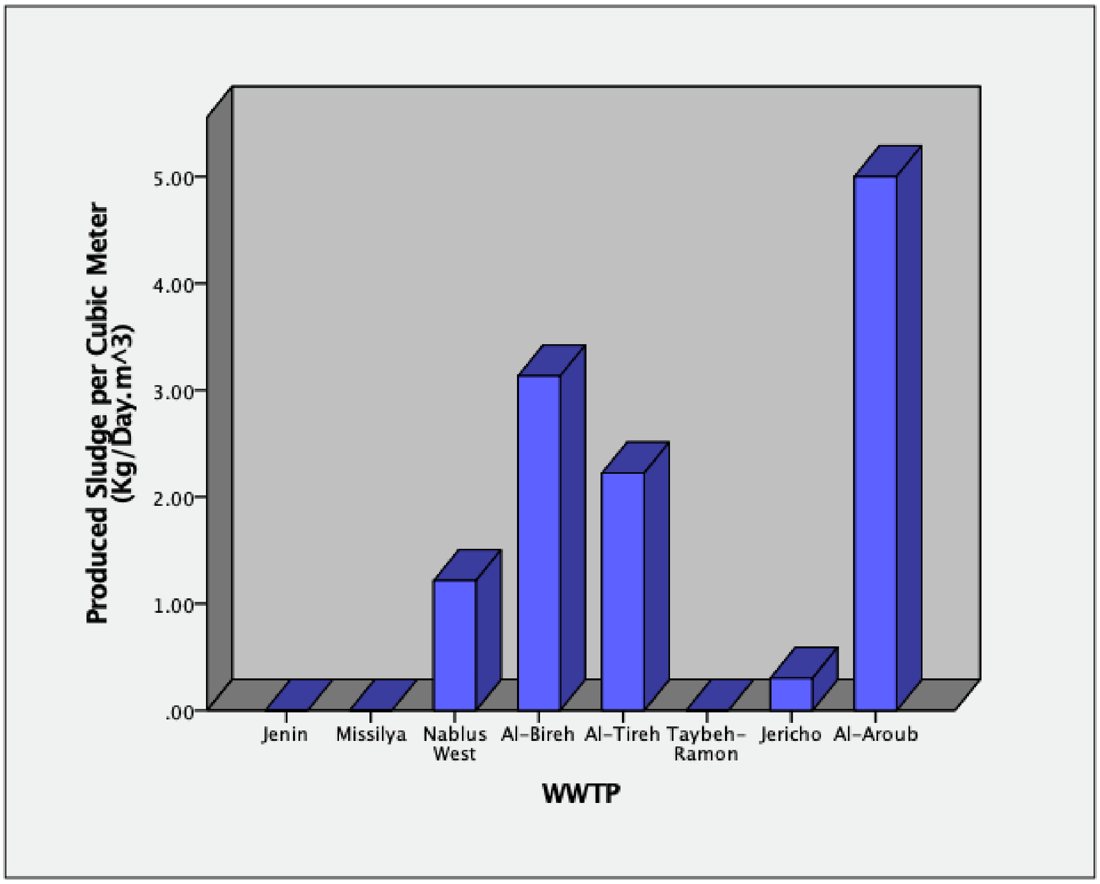

Figure 28: Produced Sludge Quantities per each Cubic Meter of TWW, WB.

The values shown in Figure (28) very close to the values in Figure (27), the biggest producer is Al-Aroub WWTP while the lowest is Jericho WWTP.

The study sample consisting of eight WWTPs, five of them producing sludge, all of the producers dumping it into landfills approximately except Jericho WWTP which storing it into its draying beds. The others have negligible sludge production, which is considered an advantage for those WWTPs, as a result no dumping costs for them. On the other side, the quantity produced can be used enhance the soil characteristics after treatment processes according PSI. Take a look to the dumping costs for them in Figure (29).

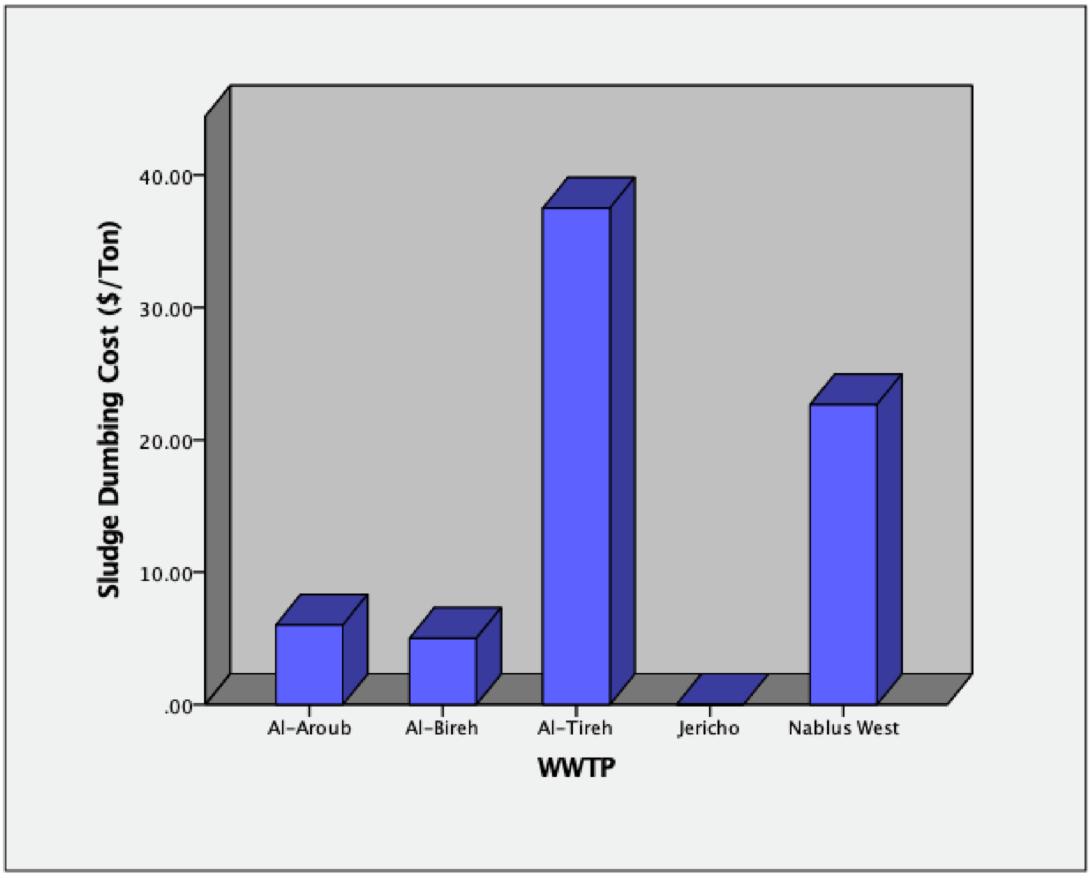

Figure 29: Sludge Dumping Cost, WB.

Jericho has no dumping cost because it has enough area to store it. In addition, benefit from the high temperature there causing volume reduction of sludge. While Al-Aroub and Al-Bireh WWTPs paid around 8.0$/ton, but Nablus West WWTP paid about 23$/ton and Al-Tireh WWTP has the largest average around 38$/ton. The variances above due to the following causes:

- Distances between WWTPs and Landfills.
- Landfills rules and their tariff.

4.8 Maintenance Costs

One of the most important factors in operating of treatment plants is the maintenance works, due to its effect on the working teams, expenditures and allover treatment processes. The previous table shows the intervals and reporting systems of maintenance works, while this section will present the costs of both preventative and emergency costs.

Figure (30) present average monthly maintenance costs for each WWTP.

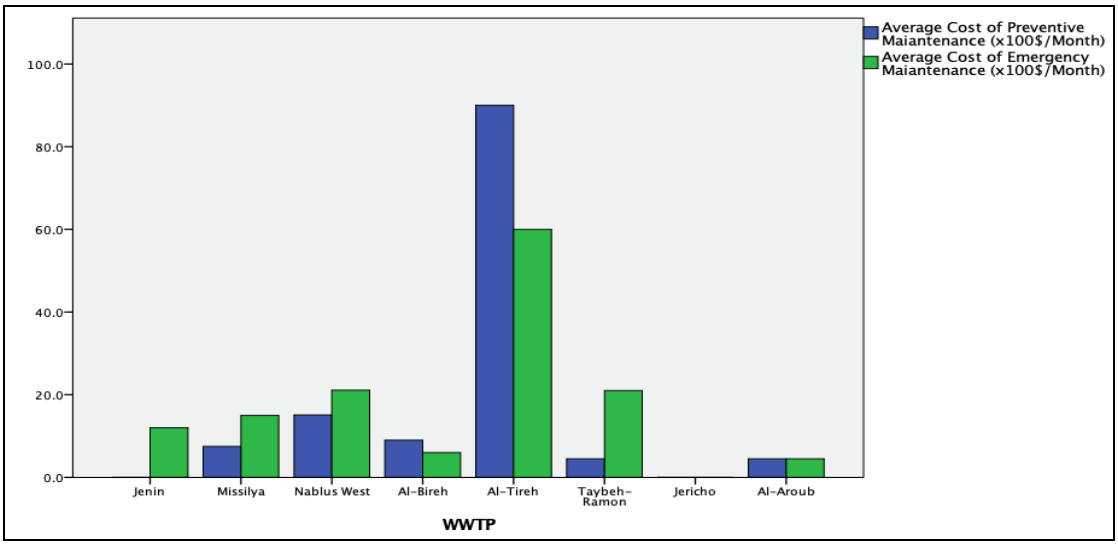

Figure 30: Maintenance Costs ($/month), WB.

The highest both costs present in Al-Tireh WWTP, while the lowest one is Jericho WWTP; because it's very small costs. However, Jenin WWTP did not do any preventative maintenance only emergency. The remaining five have an average (500-1800) $/month and (500-2200) $/month for preventative and emergency maintenance respectively.

Many factors affecting these values like, technology type, size, influent characteristics …etc., but for making comparison between them, Figure (31) simplify the numbers by presenting the costs per each cubic meter of their capacities.

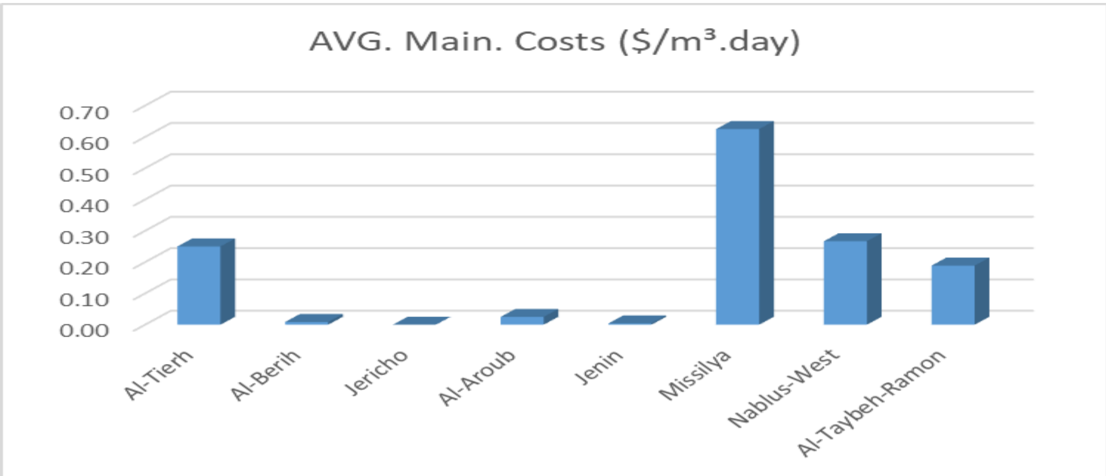

Figure 31: Avg. of total maintenance costs ($/m^3. day), WB.

The highest costs expended in Missilya WWTP (0.63$/m^3. day), due to large pumping works through the process. While the lowest for who did the maintenances is Jenin WWTP, as very small mechanical and electrical equipment used.

4.9 WWTP WORKING TEAM

The working team in WWTPs in main factor playing the main role of successing them, Figure (32) shows the distribution of the staff according to their specialization.

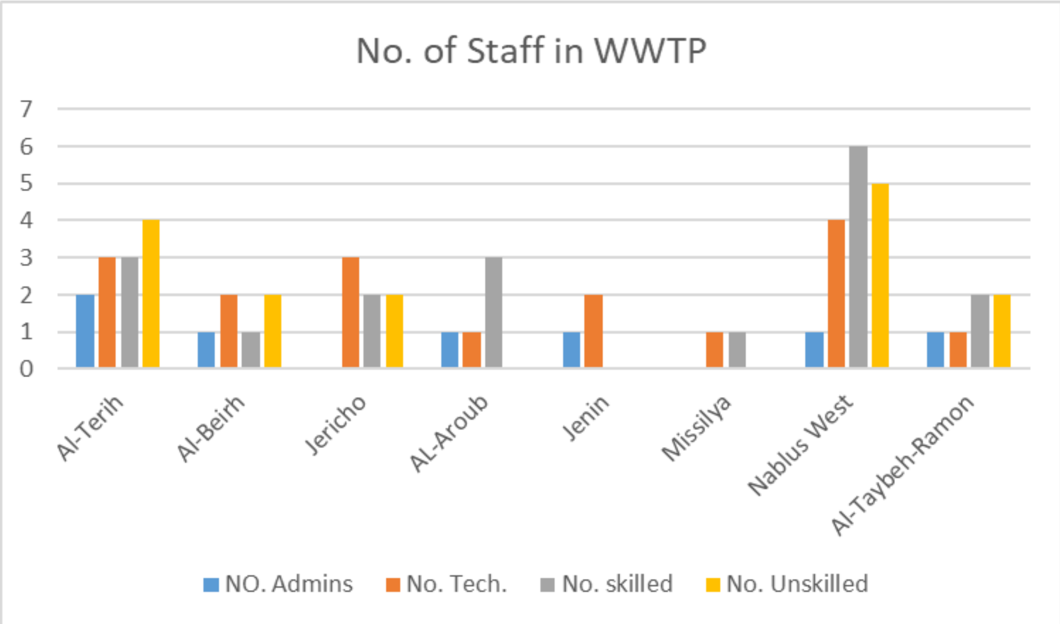

Figure 32: Number of working staff in WWTPs based on their Specialization, WB.

The highest number of staff in Nablus West WWTP as it’s the largest one, while the lowest in Missilya and Jenin WWTP as they are the simplest in technology. The distribution of staff requirements among all of the WWTPs shown in Figure (33), it’s clear that the lowest number required in managerial staff while highest in the technical and skilled labors.

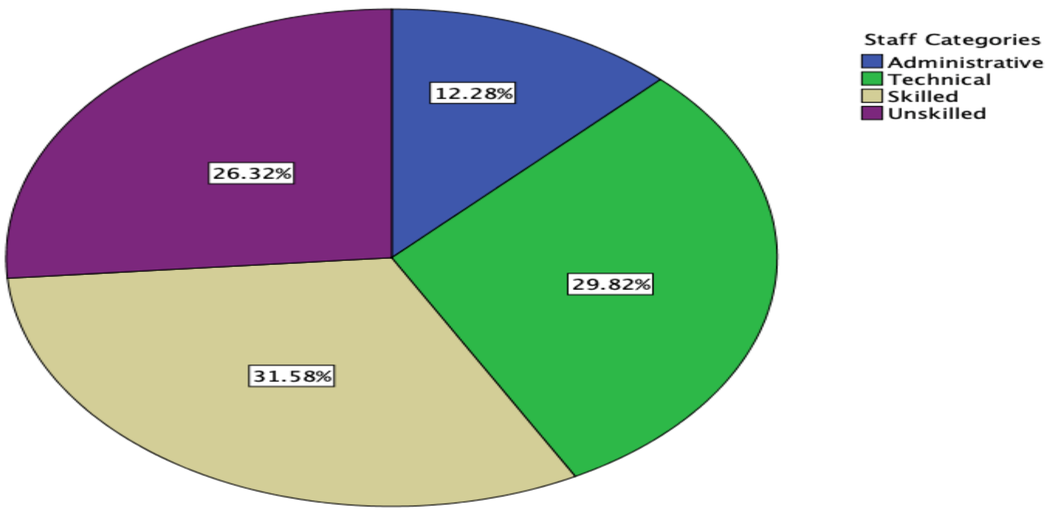

Figure 33: distribution of staff requirements in WWTPs, WB.

Moreover, the salaries of the staff considered one of the costs for WWTPs, as shown in Figures (35) & (36) for each WWTP salaries cost and average employees' salaries.

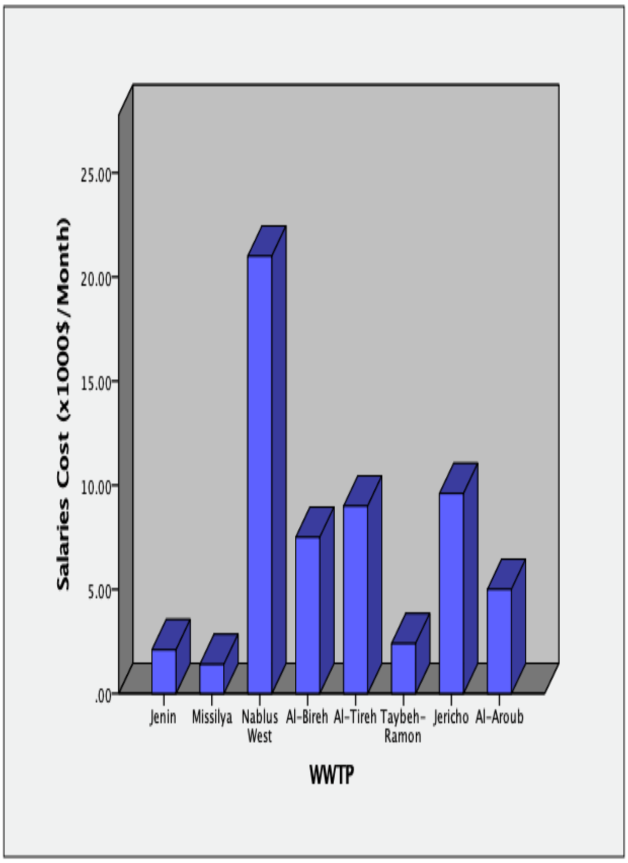

Figure 35: Salaries(1000$/month), WB.

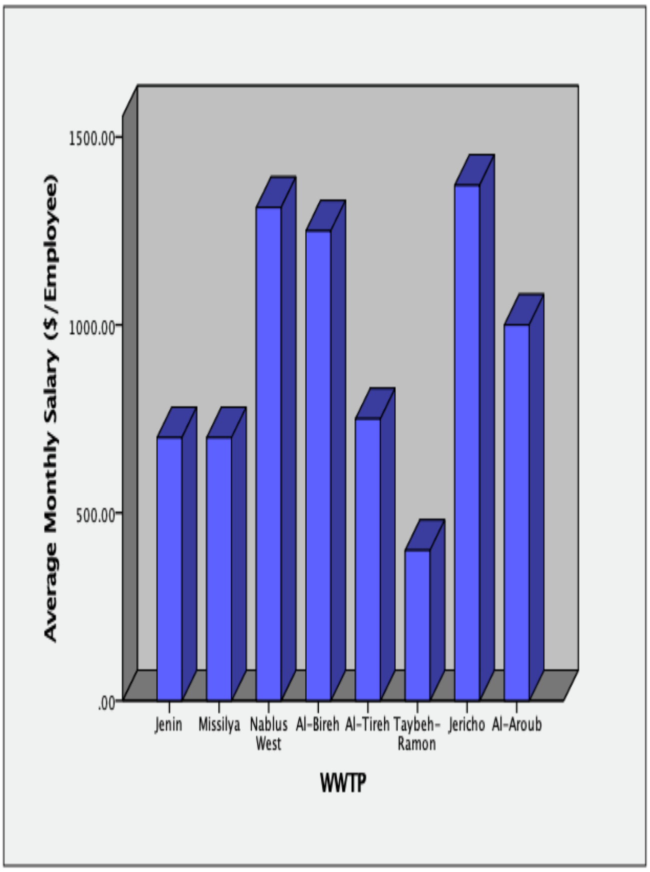

Figure 34: Avg. salaries ($/employee), WB.

Nablus West WWTP has the highest salaries and average, while Taybeh-Ramon WWTP is the lowest. However, the averages of Jenin, Missilya, Al-Tireh WWTPs are almost the same, and Nablus West, Al-Bierh and Jericho also the same even they have different numbers of staffs which means their unjustness in salaries distribution among the staffs in the WWTP.

4.10 OTHER

This section will present some other subjects in WWTPs, like, chemical additives costs, lab tests.

Figure (36) showing the daily costs paid for chemical additives used to enhance the treatment process mainly for water extraction from sludge.

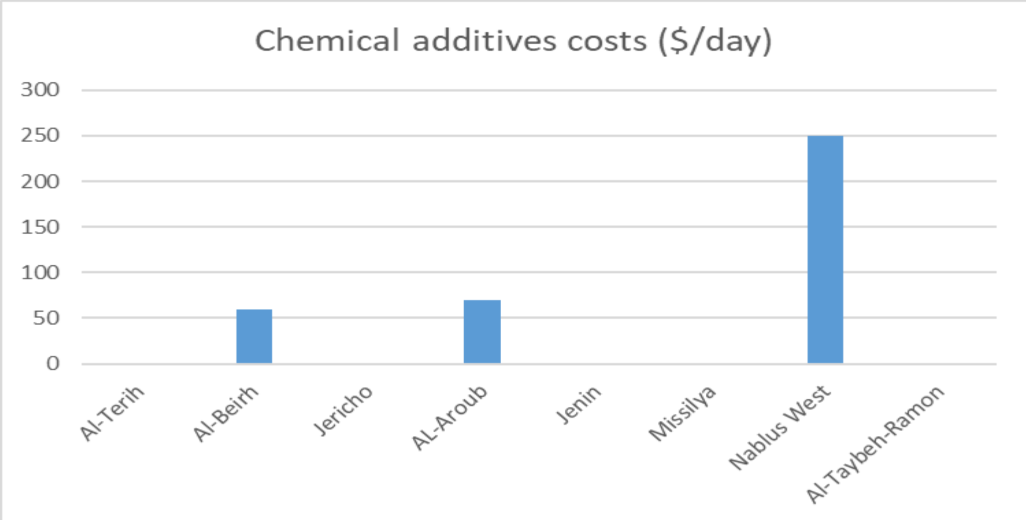

Figure 36: Costs of Chemical Additives used ($/day), WB.

Only Three WWTPs using additives in treatment process, the highest cost in Nablus West WWTP (250$/day).

Another important subject for ensuring the efficiency of WWTPs is making tests, Figure (37) present the numbers of tests conducting by WWTP labs and outside tests.

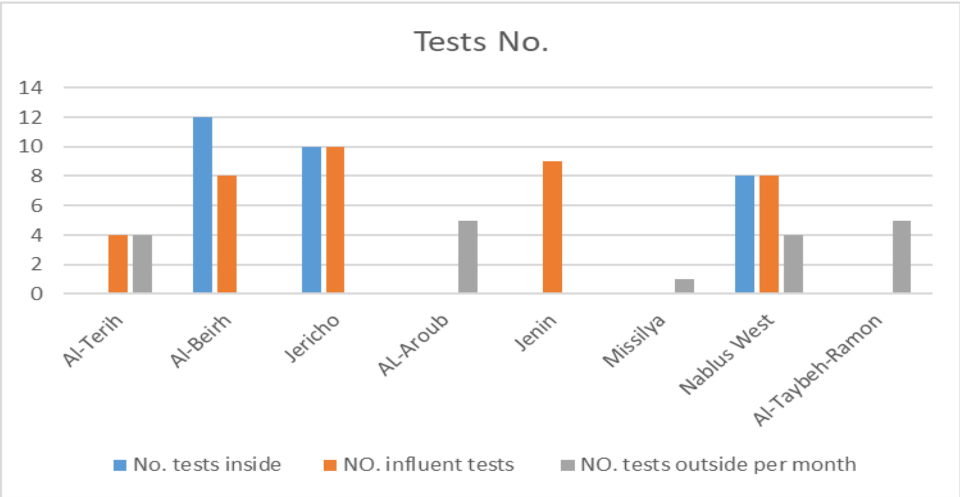

Figure 37: No. of Tests Conducted by WWTPs, WB.

The largest WWTPs only have their own Lab and making more than eight tests per month for both TWW and influent WW, but Nablus West needs additional outside test means that its own lab should be enhanced to do those tests.

While the other depends on outside tests without doing tests for influent WW which may affect the controlling on the treatment process. Figure (38) shows the costs of tests conducted outside WWTP lab.

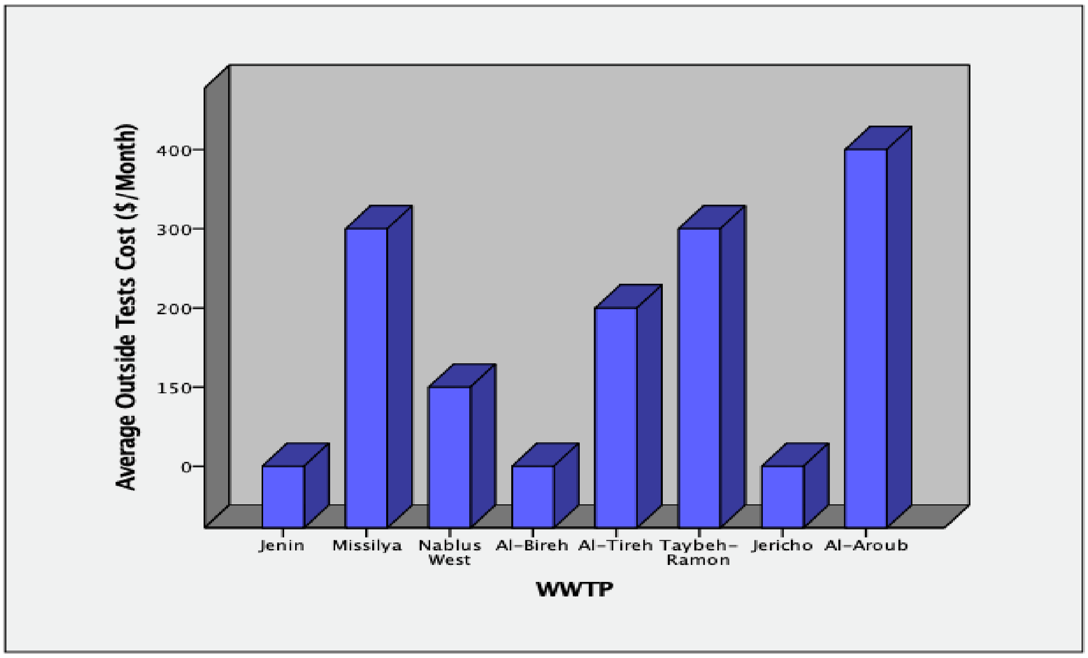

Figure 38: Monthly costs of tests, WB.

Al-Aroub, Taybeh-Ramon and Missilya WWTPs have the largest costs (300-400) $/month, while the other who are doing outside tests have average (150-200) $/month.

Table (8) shows the type and time period for tests done by the WWTPs operators according to their answers in the questionnaire.

Table 8: Tests and time periods for each WWTP.

WWTP	Test Name	Period
Al-Tireh	BOD_5, COD, TSS, TN	Monthly
Al-Bireh	BOD_5, COD, TSS, TN, PO_4, pH, Temp., conductivity, SVI, DO.	Daily/Monthly
Jericho	BOD_5, COD, TSS, TN, PO_4, pH, Temp., conductivity, SVI, DO.	Daily/Monthly
Al-Aroub	pH, Temp., SVI, DO	Weekly
Jenin	BOD_5, COD, TSS, TN, PO_4, pH, Temp., conductivity, DO.	Yearly (by MoA)

Missilya	BOD_5, COD, TSS, TN, PO_4, pH, DO.	Three Months
Nablus West	BOD_5, COD, TSS, TN, PO_4, pH, Temp., conductivity, SVI, DO.	Daily/Monthly
Taybah-Ramon	BOD_5, COD, TSS, TN, pH.	Monthly

However, according Palestinian Standards Institution (PSI) in (PS 742-2015, Treated wastewater - from treatment plants for agricultural purposes) related to tests done by the operators and monitoring authorities, the following table present the required number of tests and their repetition period as below (PWA. 2013).

Table 9: Quality Control.

WWTP	Repetition of samples collection
Type	Operators
Mechanical (Mechanical Treatment Process)	A- Routine tests: 8 samples monthly (composite sample). B- Physical and chemical characteristics: 3 samples daily (individually). C- Intestinal worm eggs: 4 samples monthly (composite sample). D- E-coli: 8 samples monthly (individually). E- FC: 8 samples monthly (individually).
Natural (Natural Treatment Process)	A- Routine tests: 4 samples monthly (composite sample). B- Physical and chemical characteristics: 3 samples daily (individually). C- Intestinal worm eggs: 4 samples monthly (composite sample). D- E-coli: 8 samples monthly (individually). E- FC: 4 samples monthly (individually).
Note: Routine tests are: pH, DO, Turbidity, Temperature, NO_3, BOD_5, COD, TSS, T-N.	

Source: PS742, 2015.

Comparing Tables (8) & (9), it's obvious that none of the WWTPs do any of (C, D, and E) tests. However, only Nablus west, Jericho and Al-Bierh WWTPs are doing the routine tests according the PS 742-2015.

- A "*" signs for a very small value ;

- A "**" signs for a small value ;

- A "***" signs for a medium value ;

- A "****" signs for a highly value ;

- A "*****" signs for a very highly value.

Each value has positive (++) impact or negative (--) impact.

Table (10) summarize and compare to some extent between the WWTPs.

Table 10: Summary of WWTPs analysis results.

			WWTP Name								Effect of Determinant		
Determinant	**Name**	Notes	Al-Tierh	Al-Bierh	Jericho	Al-Aroub	Jenin	Missilya	Nablus West	Taybeh-Ramon	(Positive (++)/ Negative (--))	Higest	Lowest
	Area	Per m3	*	*	***	***	*	*****	**	**	(--)	Missilya	Al-Tierh, Al-Bierh, Jenin
		Per Cap	*	*	****	***	**	*****	**	**	(--)	Missilya	Al-Tierh, Al-Bierh
		Price $/m3	***	***	*	***	***	*****	***	*	(--)	Missilya	Jericho, Taybeh-Ramon
	Construction cost	$/Cap	**	***	****	**	*	*****	***	***	(--)	Missilya	Jenin
	Electricity	Consumption (KWh/m3)	****	***	**	**	****	*****	*	***	(--)	Missilya	Nablus West
		Consumption (KWh/Cap.day)	***	***	**	**	******	***	***	*	(--)	Jenin	Taybeh-Ramon
		% of production	*	*	***	****	*	*****	***	*	(++)	Missilya	Al-Tierh, Al-Bierh, Jenin,Taybeh-Ramon
	Treated Water	% of reused inside WWTP	*****	*	***	*	*	***	****	*	(++)	Al-Tierh	Al-Bierh,Al-Aroub, Jenin,Taybeh-Ramon
		% of Sold (m3/day)	****	*	*****	*	*	*****	**	*	(++)	Missilya, Jericho	Al-Bierh,Al-Aroub, Jenin,Taybeh-Ramon
		Revenue ($/day)	****	*	*****	*	*	*	***	*	(++)	Jericho	Al-Bierh,Al-Aroub, Jenin,Taybeh-Ramon,Missilya
	Sludge	Production (Kg/Cap.day)	***	****	**	*****	*	*	***	*	(--)	Al-Aroub	Jenin,Taybeh-Ramon,Missilya
		Production (Kg/m3.day)	***	****	**	*****	*	*	***	*	(--)	Al-Aroub	Jenin,Taybeh-Ramon,Missilya
		Dumpting Cost ($/ton)	*****	***	*	***	*	*	****	*	(--)	Al-Tierh	Jericho, Jenin,Taybeh-Ramon,Missilya
	Maintenance	Cost ($/m3.day)	***	**	*	**	*	*****	***	***	(--)	Missilya	Jericho, Jenin
		Period	*	*	***	****	*****	*	*	*	(--)	Jenin	Al-Tierh, Al-Bierh,,Nablus West, Taybeh-Ramon,Missilya
	Staff	Requierd Number	****	***	***	***	**	**	*****	***	(--)	Nablus West	Jenin,Missilya
		Avg. Salaries ($/month)	***	***	***	**	**	*	*****	**	(--)	Nablus West	Missilya
	Chemical Additives	Cost ($/day)	*	***	*	***	*	*	*****	*	(--)	Nablus West	Al-Tierh,Jericho, Taybeh-Ramon, Missilya, Jenin
	Test	Number	***	*****	*****	*	***	*	*****	***	(++)	Nablus West	Al-Aroub, Missilya
		Costs	***	*	*	*****	*	****	**	****	(--)	Al-Aroub	Al-Bierh, Jericho, Jenin
No. Stars Gained (Positivly)			17	9	21	8	7	15	15	7	1st: Jericho. 2nd: Al-Tierh,Taybeh-Ramon.		
No. Stars Gained (Negativily)			40	38	33	47	31	45	45	30	3rd: Jenin.		
Net			-23	-29	-12	-39	-24	-30	-30	-23	4th: Nablus West,Missilya.		
Order of Preference			2nd	5th	1st	6th	3rd	4th	4th	2nd	5th: Al-Bierh. 6th: Al-Aroub.		

4.11 CASE STADY ANALYSIS (NABLUS WEST WWTP)

This section presents the analysis of the collected monthly reports (88 report) from Nablus West WWTP, the figures below will show the changes in each factor through the operation period in form of quarters of years and seasonally.

The analyzed factors are the influent quantities, laboratory test results and energy consumption and production along eight years. All factors' values depend on the values published in the mentioned reports.

4.11.1 INFLUENT QUANTITIES

Figure (39) shows the trend of WW entering the treatment plant.

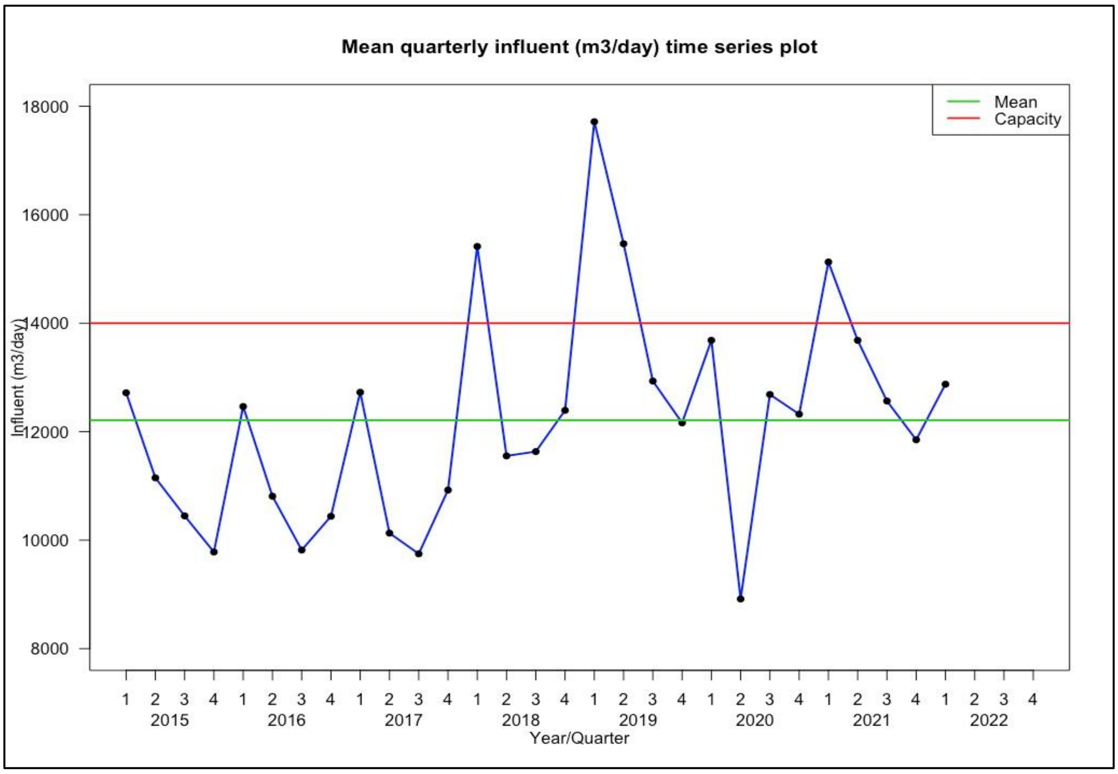

Figure 39: Influent quantities (m³/day), Nablus West case study.

Generally, the WW quantities increasing by time, especially in the first two quarters of each year, while it also exceeded the design capacity (14,000 m³/day) of the WWTP since the beginning of 2018 until now, but it treats all of the excess quantities to date. However, it decreases to the lowest values in the second two quarters.

4.11.2 BIO-CHEMICAL OXYGEN DEMAND (COD)

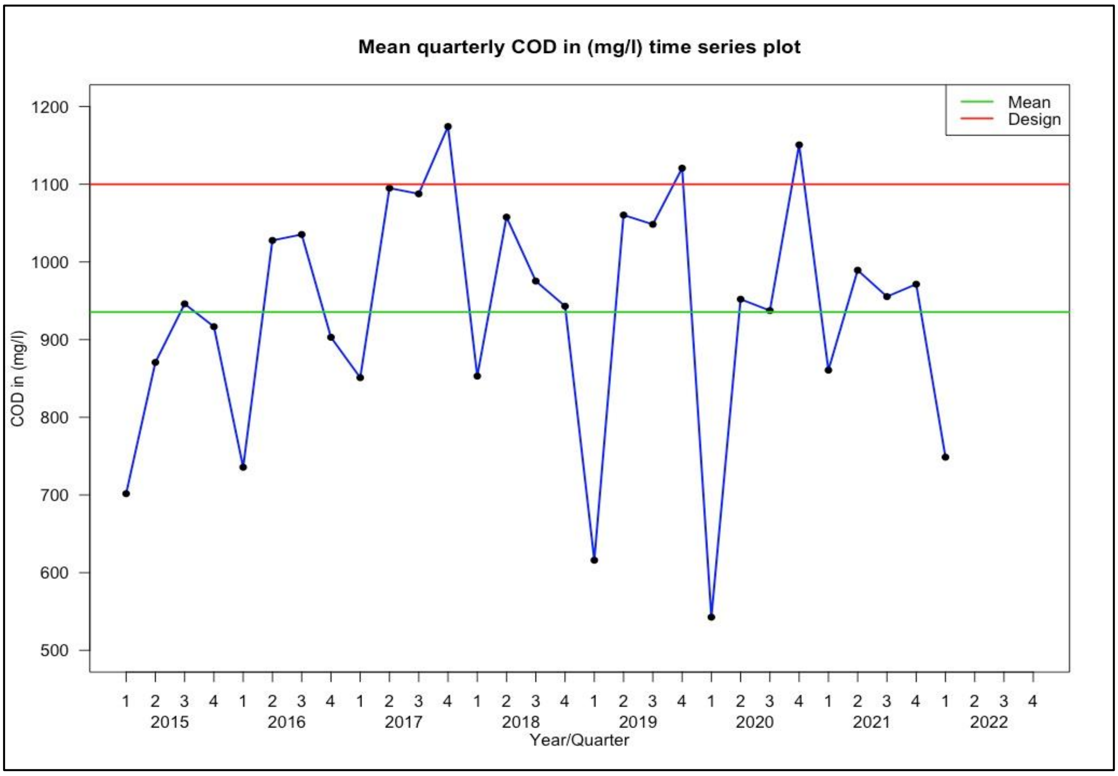

Figure 40: Inlet COD (mg/l), Nablus West case study.

The lowest values of COD concentration during the begging of each year, while it increases gradually to reach the highest values in the third and fourth quarters. Also, the COD concentrations exceeds the design limit (1100 mg/l) since the middle of 2017, especially in the last quarter of each year in general. Generally, it tends to exceed the design limit over time.

The efficiency of removing the COD presents in Figure (41), which showing its concentration in the effluent. It's clearly shown that the first two operational year have less removal efficiency of COD, by looking to the effluent concentration of it, which more than the standards limit, while it became more efficient by the time even the influent concentrations become more and more than the design confederations.

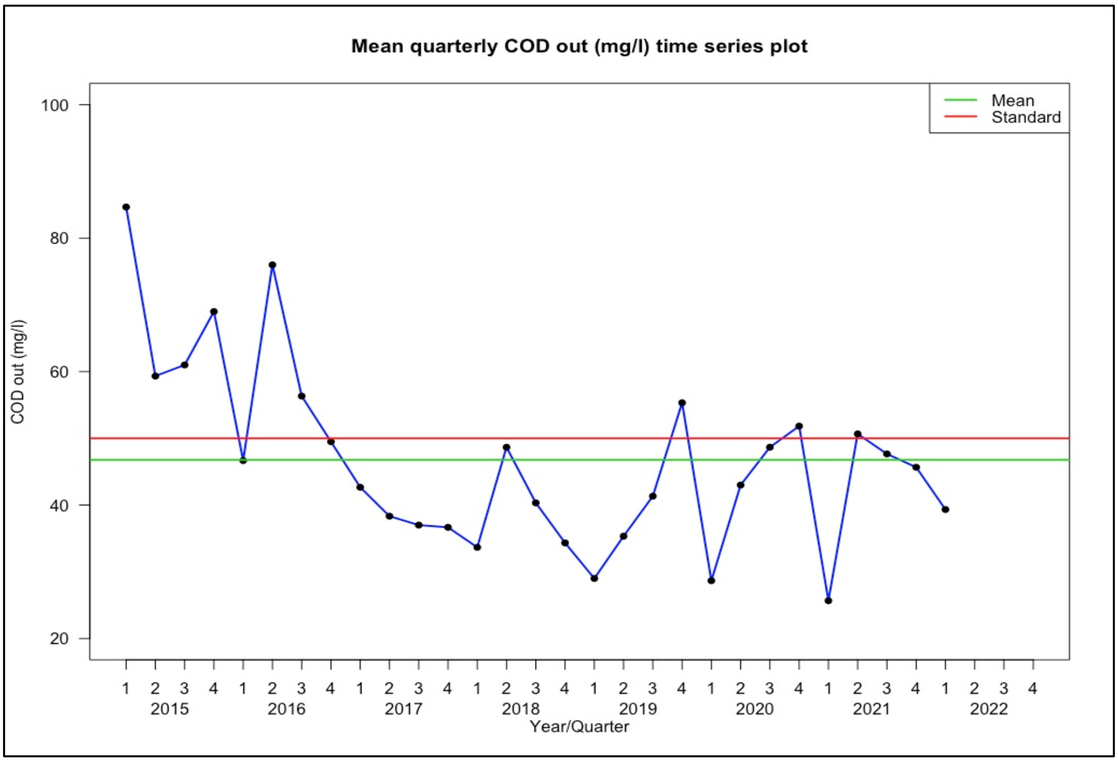

Figure 41: Outlet COD (mg/l), Nablus West case study.

4.11.3 BIOLOGICAL OXYGEN DEMAND (BOD_5)

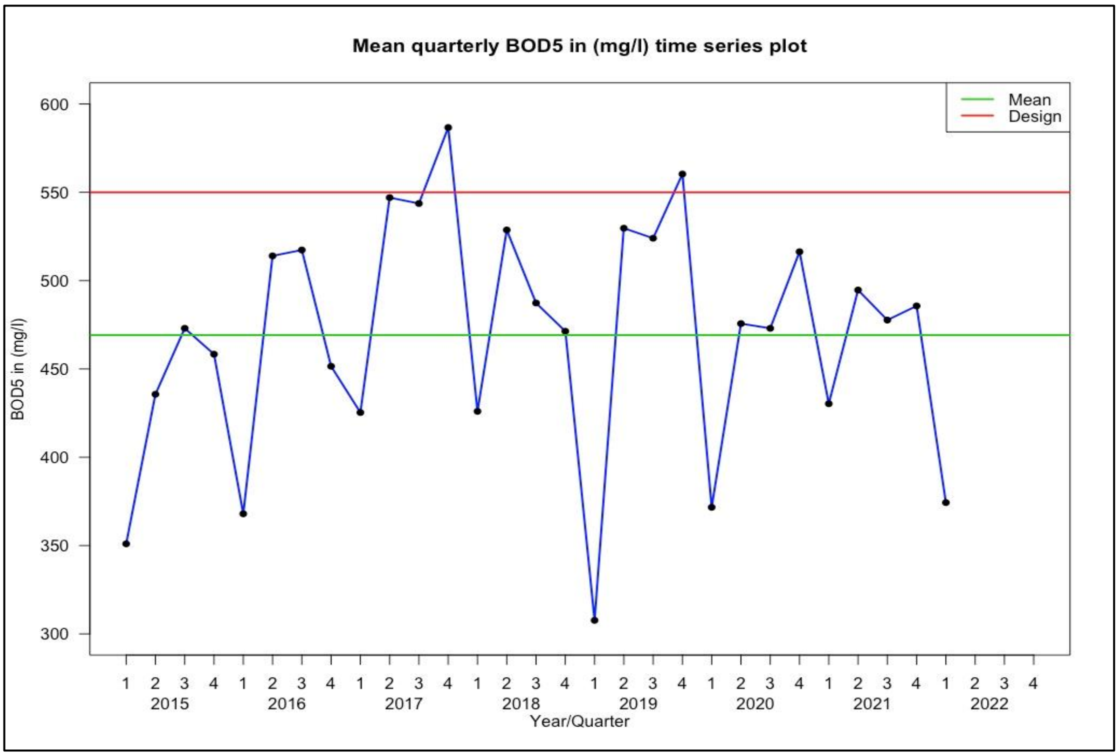

Figure 42: Inlet BOD_5 (mg/l), Nablus West case study.

As shown in Figure (42), the BOD_5 concentrations in the influent increases over time, as the first year have only on value above the average, but the next years have two or three values exceed the average. Also, when looking to the design limit, there is some values exceed it, which means the treatment plant should prepares to receive high values in the next years.

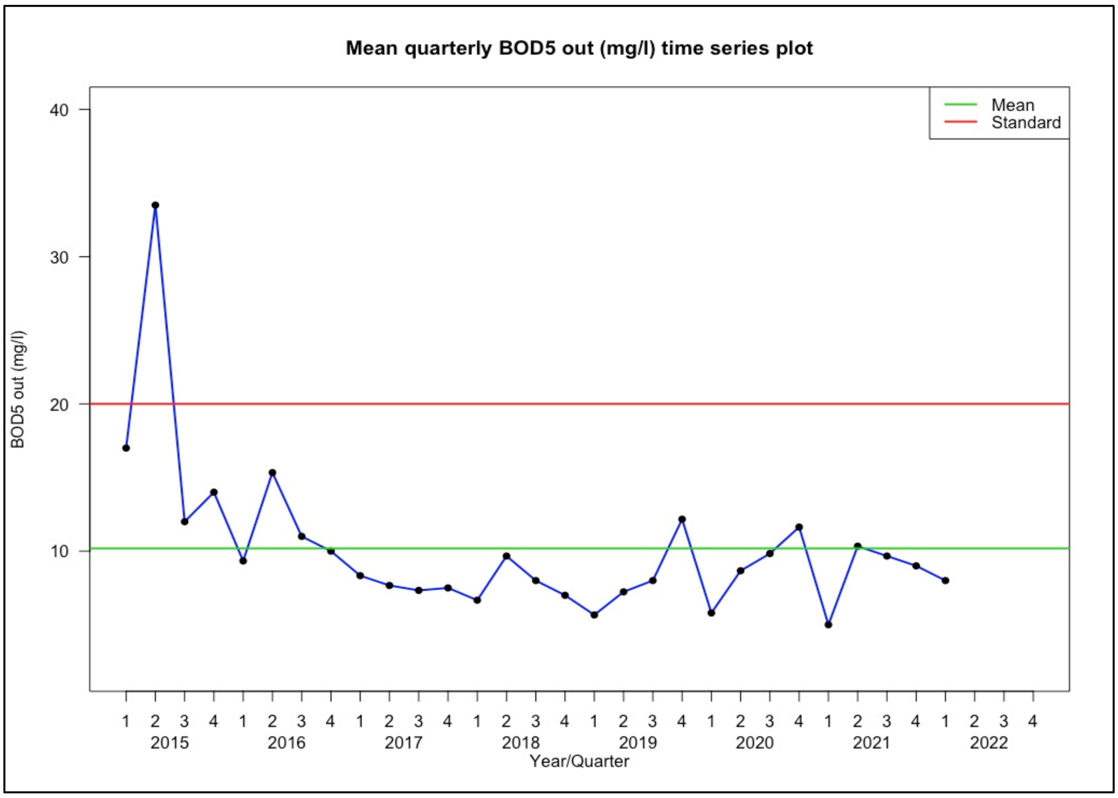

Figure 43: Outlet BOD_5 (mg/l), Nablus West case study.

The BOD_5 removal efficiency presented in Figure (43), which showing its concentration in the effluent. It's clearly shown that the first operational year has less removal efficiency of it, by looking to the effluent concentration of BOD_5, which more than the standards limit, while it became more efficient by the time even the influent concentrations become more and more than the design confederations.

4.11.4 TOTAL SUSPENDED SOLIDS (TSS)

Generally, TSS concentrations in the influent of Nablus WWTP exceeds the average value and close to the design limit, although it exceeds it in some years as in 2017 especially in the two middle quarters, as shown in Figure (44).

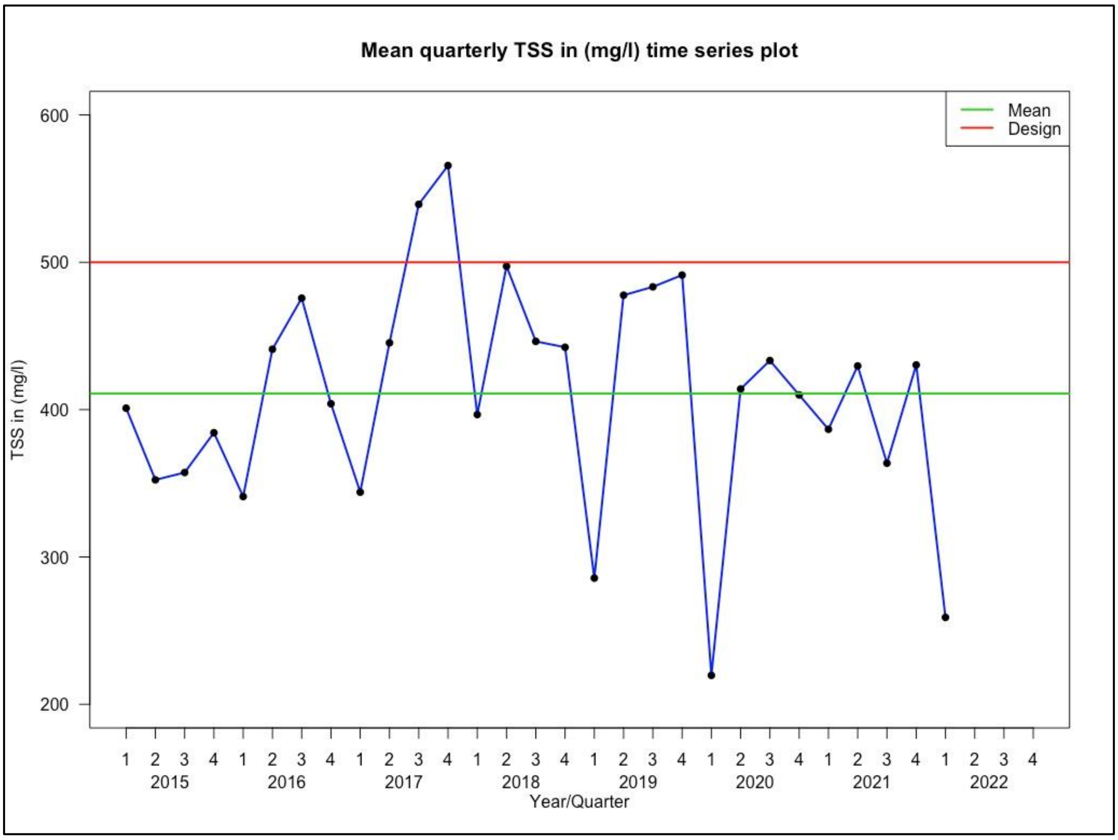

Figure 44: Inlet TSS (mg/l), Nablus West case study.

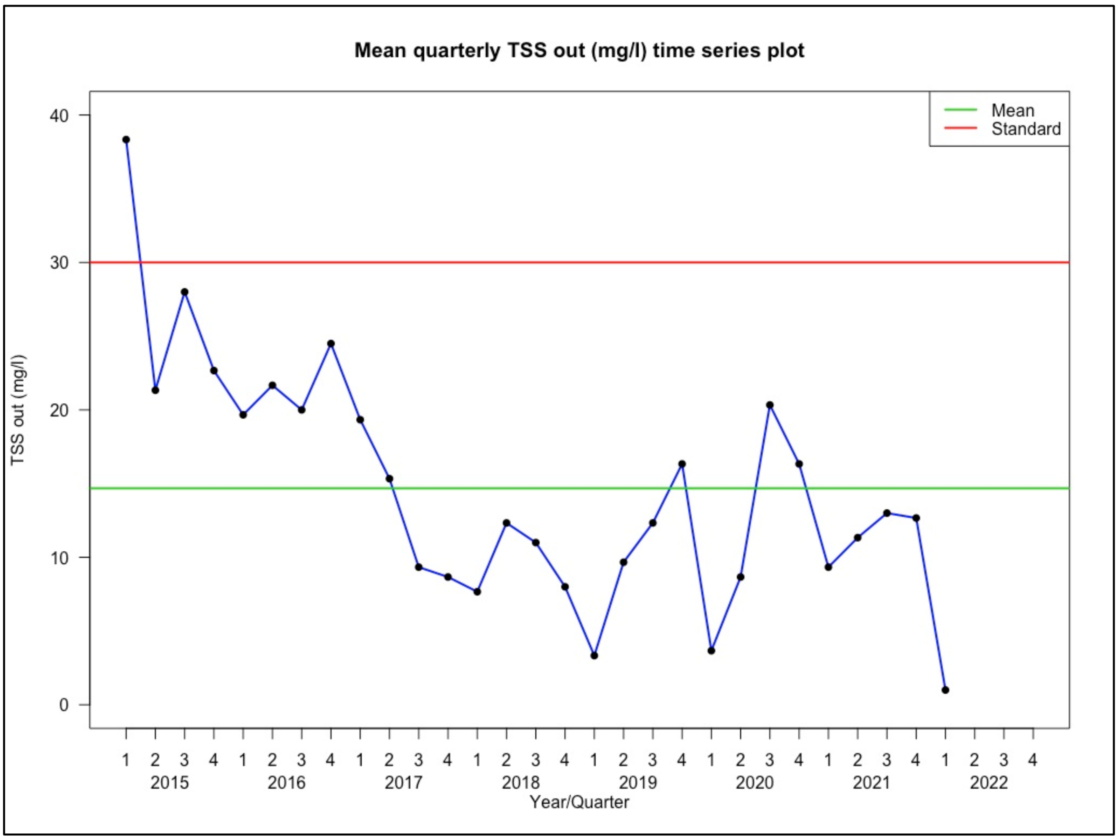

Figure 45: Outlet TSS (mg/l), Nablus West case study.

The TSS removal efficiency presented in Figure (45), which showing its effluent concentration. It's clearly shown that the first operational year has less removal efficiency of it, by looking to the effluent concentration of BOD, which exceeds the standards limit, while it became more efficient by the time even the influent concentrations become more and more than the design considerations.

4.11.5 NITROGEN CONCENTRATIONS

Figure (46), shows the ammonium concentrations in the influent, during the first half whole operational period the NH_4 values are exceeded the average while it became less than the average in the second half. Also, when looking to yearly bases, the fourth quarter has the lowest value in each year, while the third one has the largest, in general.

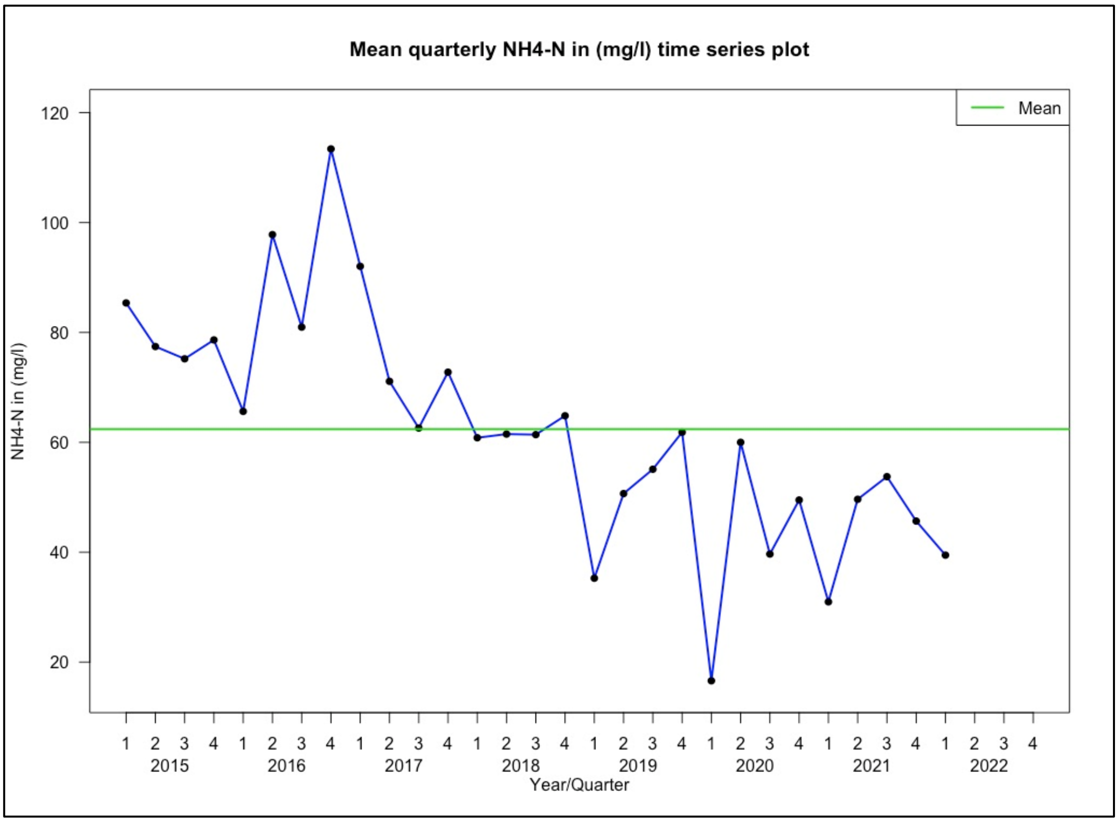

Figure 46: Inlet NH_4-N (mg/l), Nablus West case study.

The NH_4 removal efficiency presented in Figure (46), which showing its effluent concentration. It's clearly shown that the first operational year has the lowest removal efficiency of it, by looking to the effluent concentration of NH4-N, which beyond the standards limit (5mg/l), while it still produces effluent concentrations of NH_4 more than the standard limit.

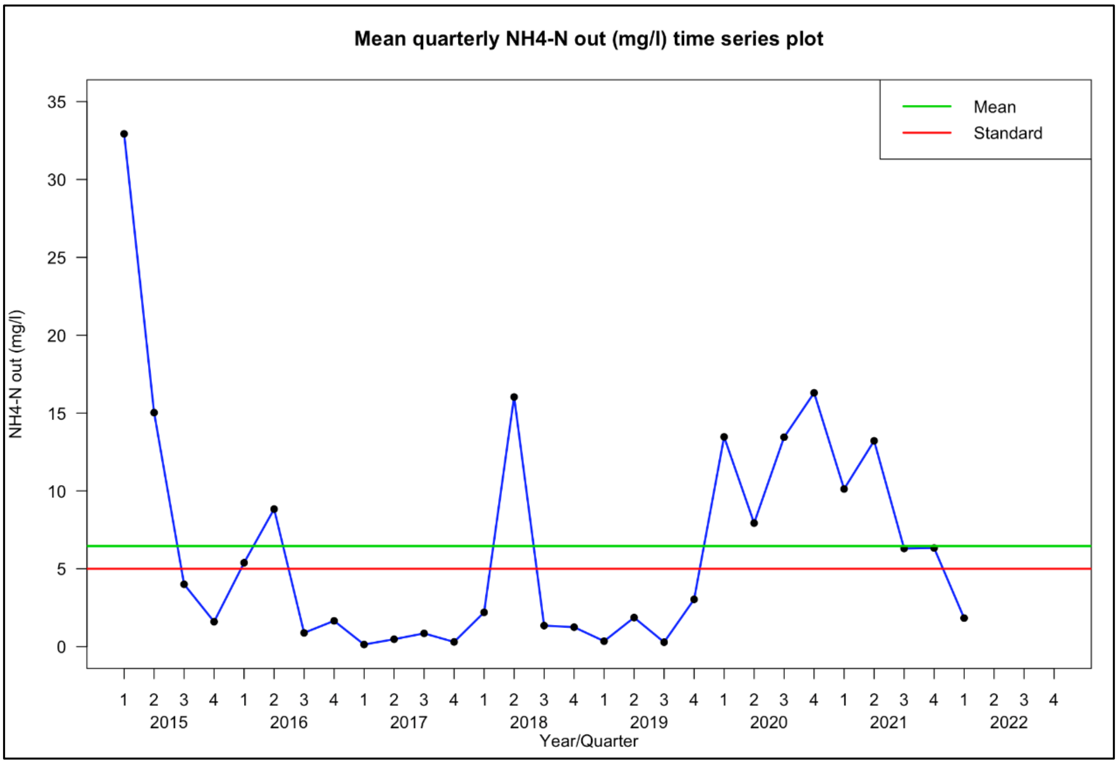

Figure 47: Outlet NH_4-N (mg/l), Nablus West case study.

Unfortunately, the very little amount of influent concentration of nitrate (NO_3-N) values (readings) prevents them from being read legibly through figure. However, Figure (48) shows the effluent concentrations of it.

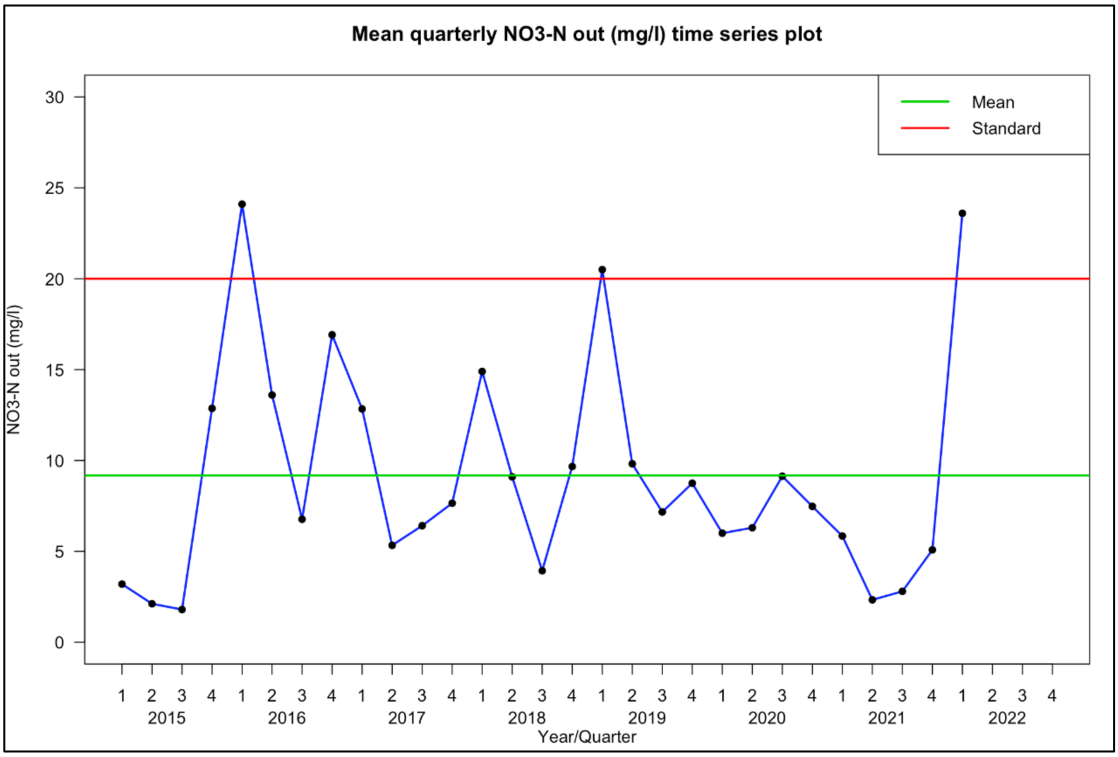

Figure 48: Outlet NO_3-N (mg/l), Nablus West case study.

Its value increased in the first and last quarters (Winter and Autumn) until exceeds the standard thresholds in some years, while it has lowest concentrations in the middle of the year.

Figure (49) shows the total nitrogen (TN) concentration in the effluent, which is looks like sine wave frequent around the average, but has some value exceed standard thresholds in the second quarter of some years.

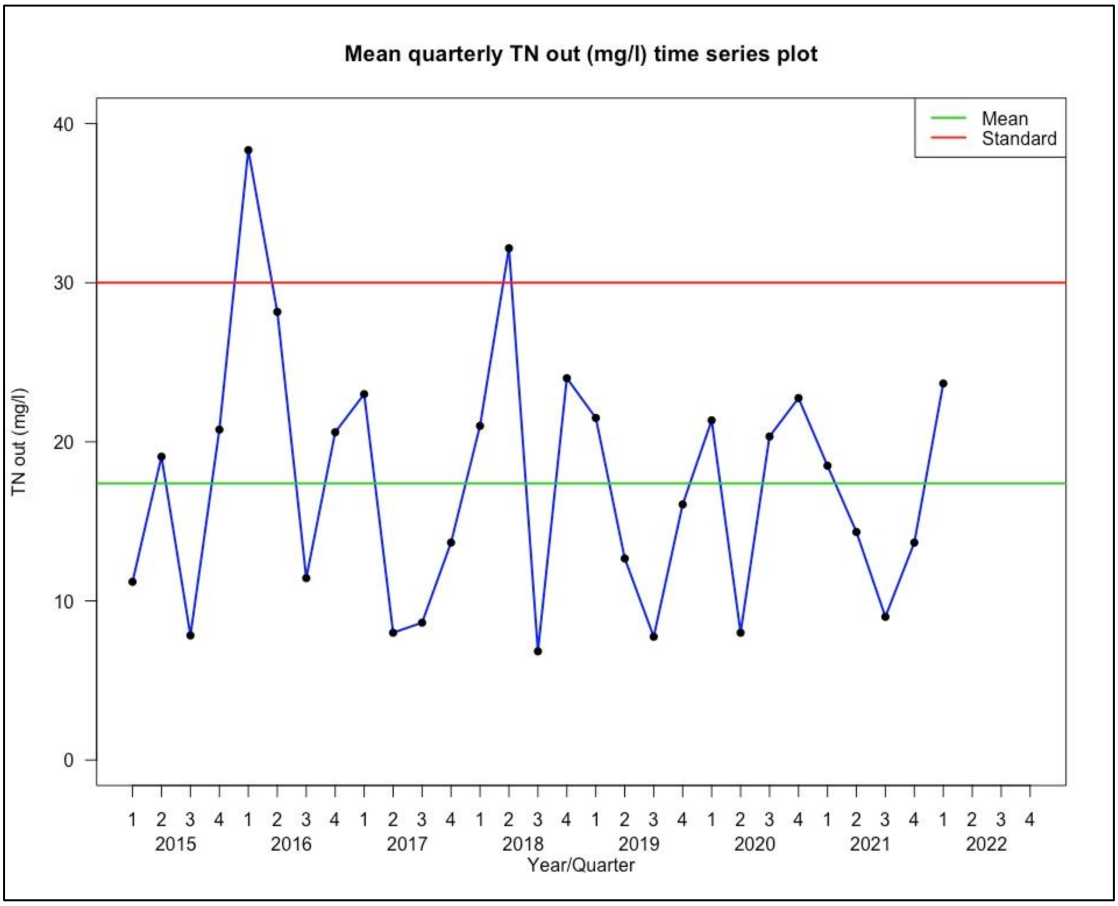

Figure 49: Outlet TN (mg/l), Nablus West case study.

4.11.6 PHOSPHORUS CONCENTRATIONS

From Figures (50) & (51), the values of influent concentrations of phosphate between (10-40) mg/l with average around 21 mg/l lower than the standers limit (30 mg/l). However, the removing efficiency is almost steady along the operational period producing an average phosphate concentration in effluent around 5mg/l.

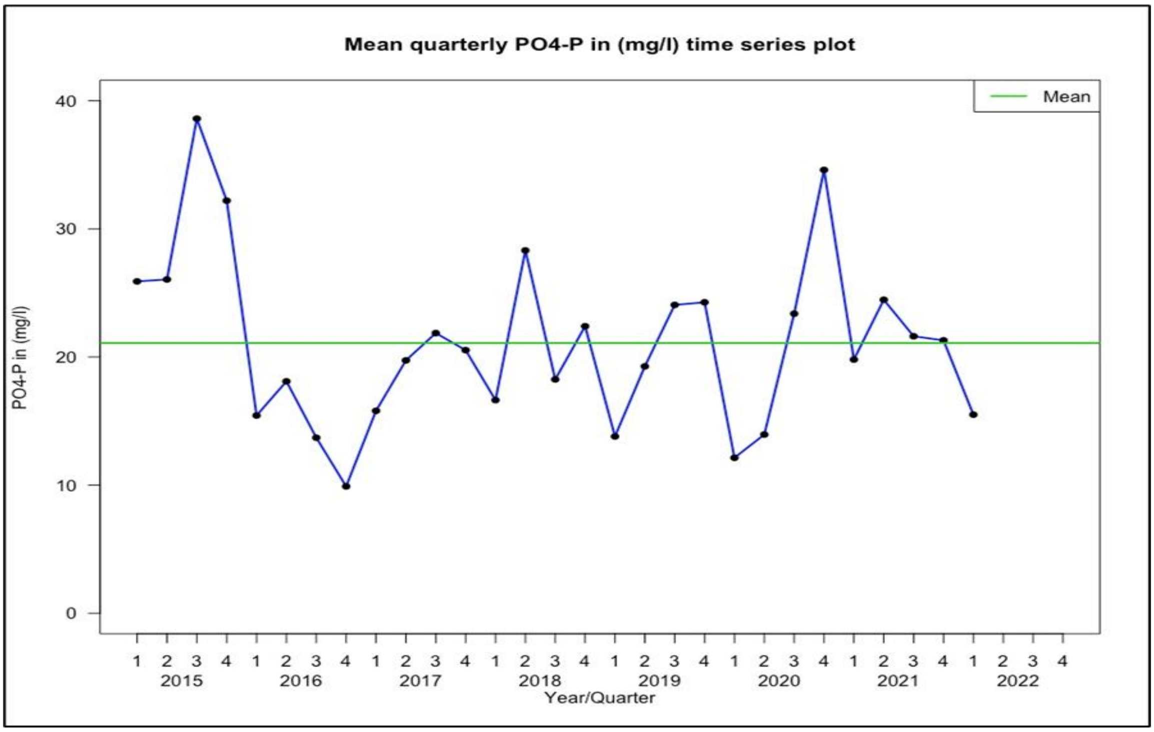

Figure 50: Inlet PO_4-P (mg/l), Nablus West case study.

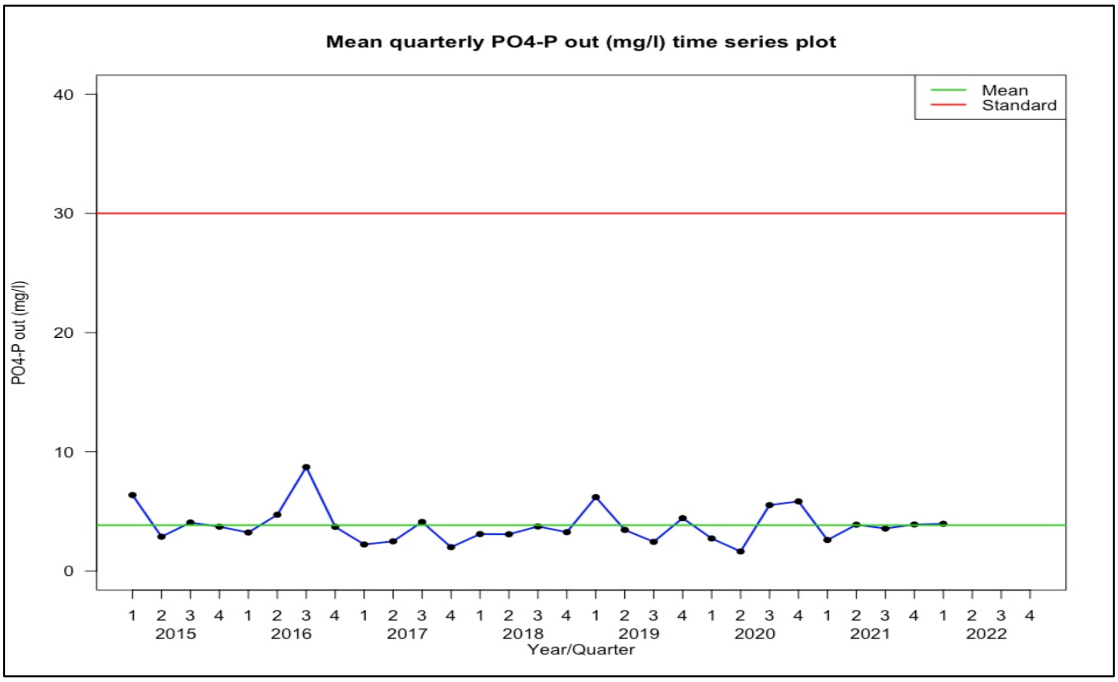

Figure 51: Outlet PO_4-P (mg/l), Nablus West case study.

4.11.7 POTENTIAL OF HYDROGEN (PH)

From Figure (52) its obvious that pH values through the whole operation period is located within the standards range (6-9). From first year till the end of year 2020 the values around 8, then it decreases continuously, which means it needs more control to keep it in the range.

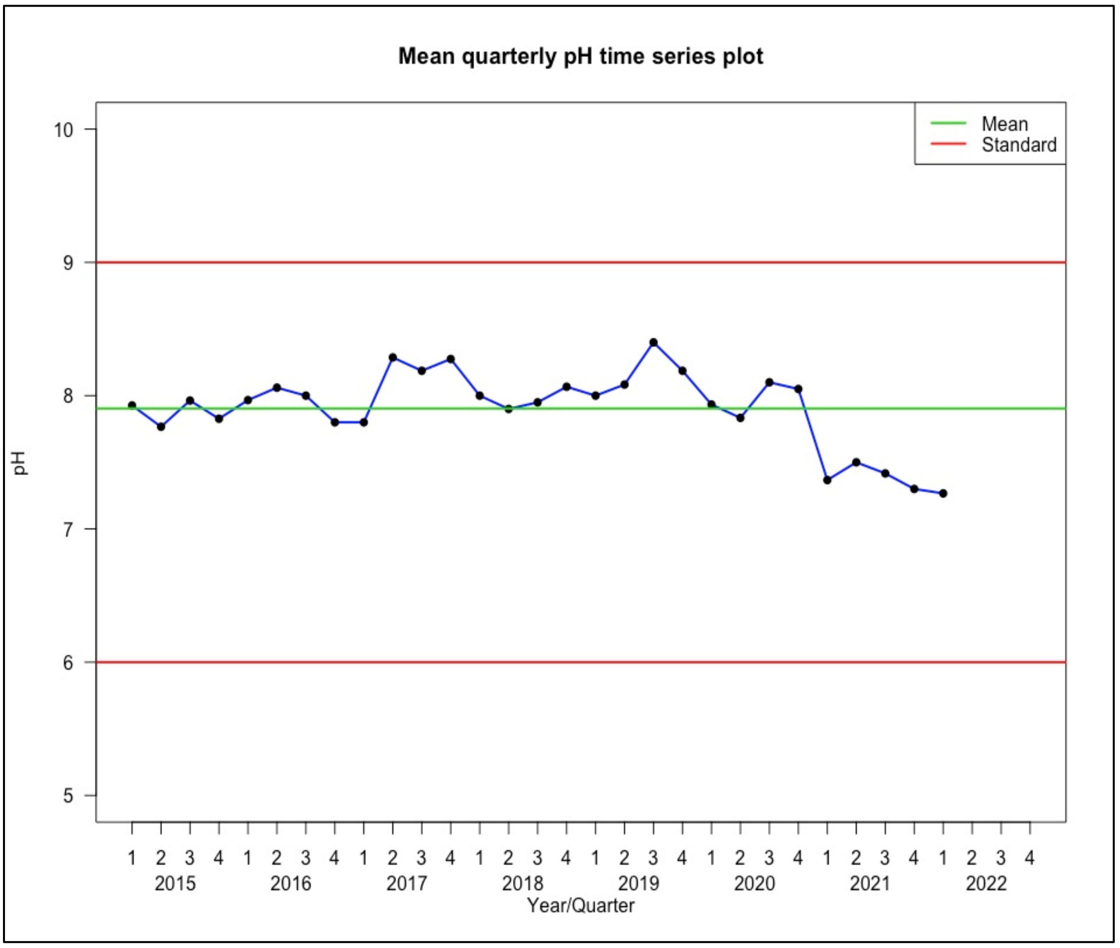

Figure 52: pH Values, Nablus West case study.

4.11.8 ELECTRICAL CONSUMPTION AND PRODUCTION

This part presents the electrical consumption of the WWTP along its operation period since 2015 till now, in addition to the production through solar panels system and biogas.

Figure (53) shows the values of consumed electricity, which increased gradually since its operation till the middle of year 2019, then decreases smoothly till now except the first half of year 2020. In general, the middle two quarters consumed largest quantities of electricity.

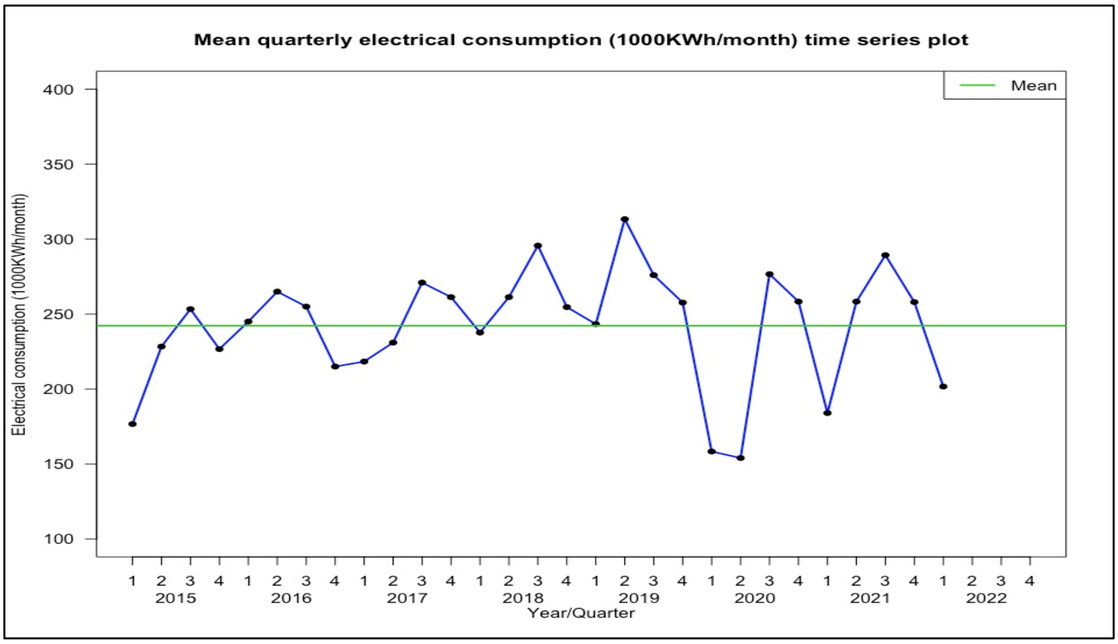

Figure 53: Electrical consumption (x1000 KWh/day), Nablus West case study.

Since the second quarter of year 2018, PV system was in operation produces in average 9000KWh/day. As shown in Figure (54), the largest production in the middle two quarters may reach to 22000 KWh/day.

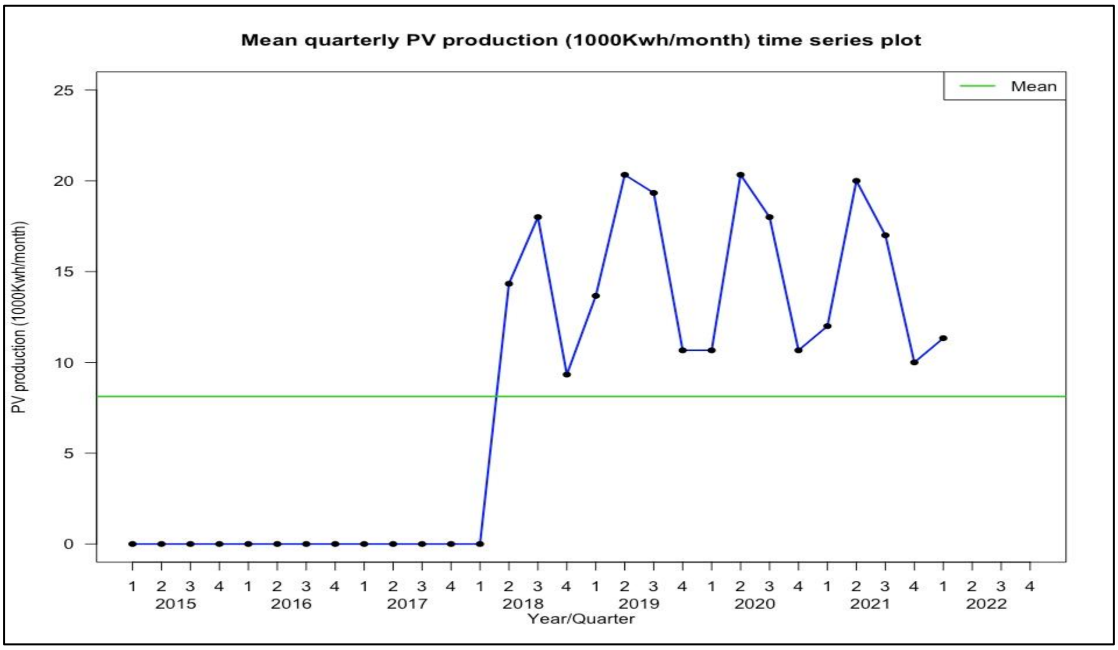

Figure 54: PV electrical production (x1000 KWh/day), Nablus West case study.

In the second quarter of year 2017, Nablus west WWTP was starting the production of electricity through CHP unit, producing average daily around 55,000 KWh.

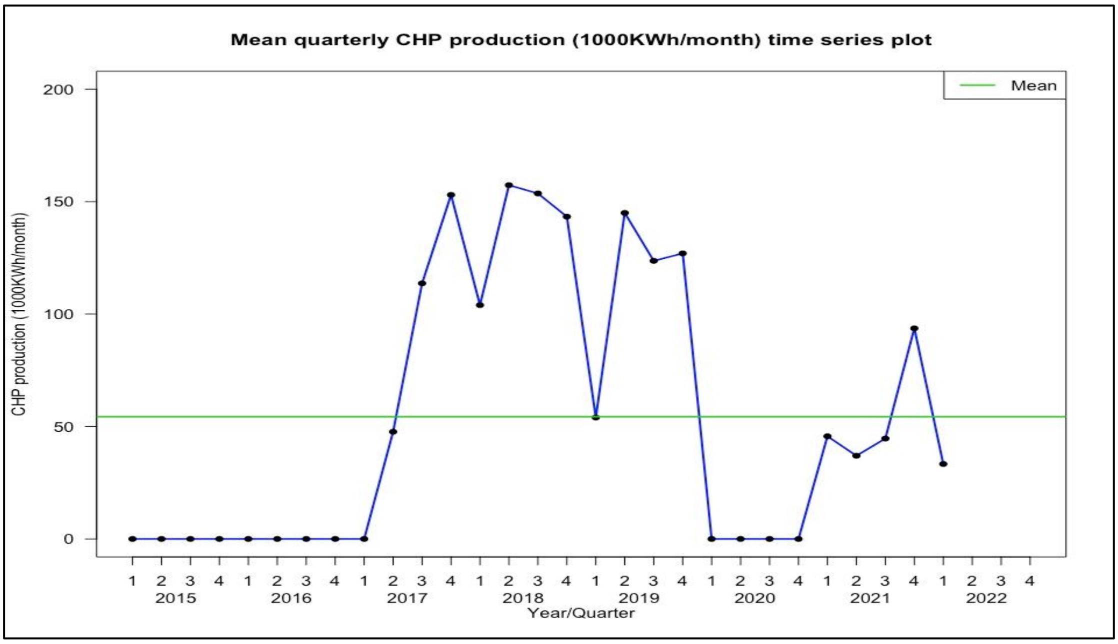

Figure 55: CHP unit electrical production (x1000 KWh/day), Nablus West case study.

Generally, the production of electricity was stared in high value along the first two years (around 150,000 KWh/day) then it decreases rapidly reaching now around 40,000 KWh/day. A year 2020 of no production for technical malfunction make a lost around 20 MKWh.

4.12 INTERVIEWS ANALYSIS

The analysis of this qualitative approach, of semi-structural interviews, a thematic analysis conducted as in Table (11).

Table 11: Thematic analysis of interviews.

Central them	Issue of discussion
Managerial	- Challenges and obstacles - Type of management - Idea of CMOU
Technical	- Challenges and obstacles - Effect of WWTP technology, volume and location
Financial	- Challenges and obstacles - Balance between expenditures and revenues
Social	- Challenges and obstacles - Effect of WWTP location on the community.

At the administrative level. Many of the WWTPs operated by local communities suffer from a challenge represented by the change of elected municipal council members, which exhausts the staff in re-clarifying the mechanism of work in the WWTPs for them. This is not a problem for Al-Aroub and Al-Tirah WWTPs, because the operator there is not a local authority. "The operator's willingness to operate and maintain the plant, to provide compliance with specifications is our biggest challenge as a Palestinian Water Authority" Eng. Adel said.

With regard to the CMOU, all the people interviewed were supportive of this idea, except Eng. Yosef and Eng. Rabee, explaining that, bureaucracy in government institutions may limit the speed of response to WWTP requirements. "Due to Palestine's difficult political circumstances, it is better for all infrastructure services to remain within the local community, as it is the last line of defense in the face of occupation," Eng. Rabee said.

Supporters, on the other hand, were of the view that the unit would ensure the performance of the WWTPs regardless of their financial burden, thereby removing a significant administrative burden from the local authorities. They also called for the consolidation of technology used in electrical and mechanical parts in all WWTPs, in order to facilitate their availability in the local market rather than imports, Eng. Ibrahim, Eng. Elias, Eng. Yosef, Eng. Asma and others said.

The PWA vision, CMOU is a proposal submitted to the Palestinian Cabinet of Ministers that "the only obstacle facing the implementation of CMOU, is the financial obstacle as a result of the Corona pandemic," said Eng. Adel. Explaining, it reduces operational expenses by minimizing the required teams, machinery, …etc. It also provides a participatory working environment among all teams working at WWTPs and contributes to the exchange their experiences. With regard to the collection of treatment fees, Eng. Adel says that "the network operator (the local authority) pays the fees to the management and operation unit," adding that "the local authority collects fees from citizens with water fees and the sewage system", which obliges local entities to collect the fees better.

"I am moving towards the private sector in the management and operation of the WWTPs, being more effective in performance. But it is more expensive as a profit sector. In addition to easy access to the plant's requirements for materials and spare parts," Eng. Malik said.

"Al-Aroub WWTP suffers from the lack of an administrative body to take over the management and operation of the Al-Aroub WWTP, as the municipality of Sa'ir refuses to manage it, as it serves Al-Aroub camp. It is known that the camps do not pay for the services they receive. The UN Relief and Works Agency for Palestinian Refugees (UNRWA) cannot take over the management of the plant, as it is outside the camp's borders and therefore outside its powers," Eng. Elias said. The idea of establishing this CMOU may be an opportunity by a government agency.

On the technical level. Many WWTPs suffer from a shortage of working teams, as they need an electrical technician, mechanics and laboratories, as Eng. Nour, Eng. Asma and Eng. Roa said.

The size of the plant and technology type affecting the crew operating the WWTP are also considered, as increasing its size means an increase in the required teams and a high degree of experience in dealing with the WWTP. While the impact of the type of technology used, all the people interviewed confirmed the ability of the current crew to deal with all the operation work, and most preventive maintenance work. "Sometimes, this technology is very sensitive to any change in the wastewater entering the plant. Which means it required external experiences" Eng. Malik said.

The lack of many spare parts for WWTPs in the local market is one of the biggest technical challenge facing operators, said Eng. Yosef and Eng. Asma. "We don't have spare parts, and worse still, the design of the plant does not have standby parts," said Eng. Elias.

The financial aspect is one of the most complex topics, as it is closely linked to the rest of the main themes mentioned. However, the lack of funding available to operators has caused them to be unable to hire the required teams, such as at Taybeh-Ramon WWTP, Al-Bireh WWTP and Jericho WWTP. Eng. Rabee said that "the collection rate at Missilya WWTP, the rate of collection of treatment fees ranges from 30% to 40%". However, Eng. Yousef believes "that the treatment fees should be gradually adjusted to cover the costs of depreciation. it is known that the economic conditions of the Palestinian citizen in general is very bad, but today we have obtained grants for the implementation of the plant. In the future there must be sufficient financial stock for the construction and expansion of the WWTPs, as we may not be able to get grants from the donors, so we must adjust the fees to have funding in a timely manner." Eng. Adel said the treatment fees "local authorities are lenient in their collection, for the purposes of Electoral advertising, reduce costs for citizens."

From a social perspective. In its infancy, all treatment plants suffered from community intolerance of these WWTPs. But for now, citizens' awareness is enough to make them demand that sanitation networks be expanded for everyone to benefit. As Eng. Yosef, Eng. Asma and Eng. Roa said. However, "Some citizens and industry owners consider the sewage system to be a dump," Eng. Elias said. This leads to damage to the biological treatment of the plant, affects the WWTP's commitments to farmers, as in the case of the Al-Aroub WWTP, and previously happened to Jericho WWTP, said Eng. Elias and Eng. Ibrahim, respectively. Operating the WWTP properly and in accordance with specifications "eliminates any objections of the citizens to it," Eng. Adel said.

CHAPTER FIVE: Conclusion and Recommendations

This conclusion and the upcoming recommendations are based solely on this study, i.e., they provide the summary of this research, which was conducted on eight wastewater treatment plants in the West Bank only.

5.1 CONCLUSION

- Common technology is (EAAS).
- 50% in areas (A), which are decentralized plant. More beneficiaries and coverage of served area the plant location towards to areas (C).
- Al-Aroub and Taybeh-Ramon have no expansion area.
- Decentralized plants do not carry out the minimum necessary laboratory tests, as well as central plants have weaknesses in this aspect.
- The Al-Bierh is overloaded and calls for urgent system upgrading, including anaerobic sludge stabilization for biogas utilization.
- Al-Aroub and Jenin plants do not perform the required maintenance.
- Only 50% carry out O&M recording, which affect the future benefit from these data.
- Only Nablus West WWTP has a website with useful resources [published annual reports]
- 50% of plant operators do not communicate with relevant government agencies
- 50% of treatment plants have PV solar panels systems.
- The only plant generates electricity from biogas is Nablus West.
- Low re-use projects. Jericho sells it, while Missilya for free.
- 62.5% of the plants produce tangible sludge quantities transported to landfills, while Jericho stores it.
- The more complex the technology and the more treatment stages, the more needs team. Nablus West the largest team, while Jenin plant smallest.
- 37.5% of treatment plants use chemicals within the treatment.
- 62.5% favor CMOU establishment, while 25% against.
- Missilya WWTP is the highest in area requirements, construction cost and electrical consumption regarding to the its treated quantity, which make it unfavorable technology for proposed WWTPs.
- Re-use projects at treatment plants are low, as Jericho plant sell most of their treated water for a return, while Missilya gives water to farmers free of charge. The Al-Tireh and West Nablus plants sell one part, use another and discharge of the rest (the majority) in the natural

valley stream, as do the other four plants with full treated water, which directly affect the sustainability of WWTPs.

- 62.5% of the plants produce sludge in tangible quantities transported to landfills, where sludge production ratios range from 0.5kg/m³ at Al-Aroub Plant to 0.2Kg/m³ at Jericho plant, indicating that the concentration of pollutants concentrations are high at Al-Aroub plant and lowest Jericho plant within these plants.
- The most expensive sludge disposal plants are Al-Tireh Plant at 40 $/ton and Nablus West Plant at 25 $/ton. The dumping costs are heavy burden on the financial system of WWTPs, while the treated sludge can be a finance source by use it as soil conditioners or through composting processes.
- The more complex the technology used at the plant and the more processing stages and sections the more the plant needs additional working teams, while the more plant employs its working teams is Nablus West plant because there are several sections and treatment stages that are not attended at other plants, and less workers are in Jenin plant, because of the simplicity of the technology used there.
- For Nablus West Plant:
    - It should start expansion, due to overcapacity flows.
    - It has the ability to control and treat (COD, BOD_5 and TSS) concentration more than the design considerations to very good effluent quality.
    - The pollutant concentrations increase over time, which may exhaust the plant.
    - When the plant start works, it had low removal efficiency, however it become better and better over time.
    - The Nitrogen amount is high, also nitrogen related tests should be enhanced.
    - The phosphate concentration entering the pant lower than the standards of effluent, also, its removal efficiency almost steady and very good.

5.2 RECOMMENDATIONS

- Upgrade the PWA lab, to be used as a central lab for testing mainly for decentralized WWTPs, and strengthen cooperation between centralized WWTPs and decentralized WWTPs
- Develop and conduct capacity building programs for WWTPs operators, tailor made on how to prepare and archive O&M reports.
- Encourage WWTPs operators to increase communication with relevant government agencies, regularly put them in the form and mechanism of operation of plants.
- Al-Bireh WWTP warrants urgent upgrading into a feasible treatment alternative using anaerobic sludge stabilization for biogas utilization. Sludge from Al-Tireh MBR system could be considered at Al-Bireh WWTP.
- Operators of Jenin and Al-Aroub WWTPs must perform periodic maintenance of the plants within reasonable periods of time (from one month to half a year) to ensure continuity of performance and quality of treatment.
- Though nature-based WWT alternatives, CW technology in Missilya is not recommended for future planning. Demand for large land areas with very high construction costs and evapotranspiration are among the reasons behind.
- Expansion and upgrading of PV power generation systems and the establishment of new systems for plants that lack such systems. Result: reduced operational costs and reduced burden on public electricity grids.
- Raising the effectiveness of reuse projects by educating farmers about the mechanism of using treated water and sludge, and encouraging them through projects that help them to have easy access to treated water (e.g., irrigation system projects), and transporting treated sludge to the land to be cultivated.
- With regard to sludge, cooperation can be conducted between plant operators so that a plot of land is purchased in relative partnership between plants close to each other that transport sludge relatively long distances (e.g., Al-Bireh and Al-Tireh), so that this land is turned into a sludge dump, which reduces the cost of disposing of it, and can be re-extracted in the future and exploited in agriculture work if farmers become accepted for use.
- Cooperation between the operators of plants that use chemicals within the processing stages, so that they buy them from one source and distribute them later among themselves, thus saving some expenses, especially since purchase prices vary from plant to plant.
- The performance of other WWTPs including sewerage networks warrants further performance evaluation.
- Establish a central management and operation unit [CMOU] for all Palestinian WWTPs to provide technical and administrative support aiming at facing urgent challenges and obstacles.

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ANNEXISs

ANNEX No.1: Questionnaire.

A Questionnaire to Measure the Performance of Service Providers in The Management and Operation of Selected Wastewater Treatment Plants in The West Bank.

Master's Thesis/ Water and Environmental Engineering

BirZeit University

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Introduction

This questionnaire aims to measure the efficiency of service providers in the management and operation of wastewater treatment plants in the West Bank, where this will do through the various sections of this questionnaire, which in turn measure the extent to which each section affects the overall performance of service providers. You have also been selected to respond to this questionnaire as your plant is one of the wastewater treatment plants in the West Bank.

The importance of answering these questions accurately and transparently may help detect and strengthen your strengths, as well as identify and treat vulnerabilities, thereby increasing the efficiency of the operation and development of plants.

1. General Information about the Plant

1.1. Plant name

- Jenin Industrial Plant / Jenin Governorate.
- Jenin Plant - Jenin / Jenin Governorate.
- Nablus West Plant/ Nablus Governorate.
- Al-Bireh Plant/ Ramallah governorate and al-Bireh.
- Al-Tira Plant/ Ramallah governorate and al-Bireh.
- Taiba Plant - Ramon / Ramallah governorate and Al-Bireh.
- Jericho Plant/ Jericho Governorate and The Valleys.
- Al-Aroub Plant - Sa'ir / Hebron Governorate.

1.2. Type of Technology used

- Extended Aeration Activated Sludge (EAAS).
- Conventional Activated Sludge (CAS).
- Rotating Biological Contactors (RBC).
- Aerated Lagoons (AL).
- Constructed Wetland (CW).
- Membrane Bioreactor (MBR).
- Another: Select (...))

1.3. Plant Operating Year

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2. Plant Size and Construction Costs

2.1.1. The daily capacity of the plant: ....
2.1.2. Daily capacity after the expected future expansion:
2.1.3. Number of citizens benefiting from the Plant:
(Number of citizens treated for wastewater coming out of their homes at the Plant)
2.1.4. The building cost the plant.........
2.1.5. The land on which the plant is located in the area of:

- A.
- B.
- C.

2.1.6. The area of land on which the plant is located:
2.1.7. The price per square meter of land on which the plant is located. ....
2.1.8. Planned expansion year:
2.1.9. The space required to expand the plant. ....
2.1.10. The area of land on which the plant is currently located is enough for future expansion

- Yes.
- No.

2.1.11. The expected cost of the plant's expansion..........

3. Electric Power Consumption

3.1.1. Daily consumption of electricity (KWh/day):
3.1.2. There is a solar power generation system (PV):
- ☐ Yes.
- ☐ No.

3.1.3. Average PV produced (KWh/day):
3.1.4. Methane assembly extraction system is available for electrical/thermal power generation:
- ☐ Yes
- ☐ No

3.1.5. The rate of energy produced by burning methane gas:

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4. Reuse of Treated Outputs

4.1.1. Reuse of Treated Water

4.1.1.1. The amount of treated water produced daily ....
4.1.1.2. The amount of treated water used for treatment plant purposes......................
4.1.1.3. The amount of treated water sold daily..
4.1.1.4. The revenues per cubic meter sold from treated water..........................
4.1.1.5. Treated water coming out of the plant is suitable for agricultural consumption, according to Palestinian specifications.
- ☐ Yes
- ☐ No. Explain...

4.1.1.6. The amount of water treated has not been able to be used, where it is disposed of ....
4.1.1.7. Chemical additives need to be used within the treatment process
- ☐ Yes, at the stage of .... And until...................................
- ☐ No

4.1.1.8. The rate of costs of chemicals added within the treatment process......................

4.2. Reuse Sludge

4.2.1. Average amount of sludge produced daily: ....
4.2.2. The resulting sludge is treated by:
- ☐ Turn it into fertilizer.
- ☐ Transport it to a dump.
- ☐ Warehousing.
- ☐ Other, select ....

4.2.3. The rate of return resulting from the reuse of sludge is monthly (if any) ....
4.2.4. The rate of costs resulting from the disposal of sludge per month (if any) ....

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5. Technical and Administrative Performance of Workers in Sewage Treatment Plants

5.1.1. Teams Working at Sewage Treatment Plants

5.1.1.1. Number of administrative staff (with scientific qualifications, not technical work). ....

5.1.1.2. Number of technical staff (engineers, laboratory technician, ...) ....

5.1.1.3. Number of skilled workers (driver, electrician, mechanic....) ....

5.1.1.4. Number of unskilled workers..

5.1.2. Training for Technical Staff

5.1.2.1. Trainings were conducted before the Plant started operating:

- ☐ Yes.
- ☐ No.

5.1.2.2. Trainings are conducted during the Plant's operation:

- ☐ Per month.
- ☐ Biannual.
- ☐ Annual.
- ☐ Other, explain......
- ☐ None.

5.1.3. Monthly Costs for the Wages and Salaries of the Workers at the Plant.......................

5.1.4. Laboratory Tests

5.1.4.1. There is a technical laboratory inside with the Plant.

- ☐ Yes.
- ☐ No.

5.1.4.2. The number of laboratory tests conducted inside the plant ....

5.1.4.3. Tests are carried out on influent of the plant ....

5.1.4.4. Number of laboratory tests conducted in laboratories outside the plant..................

5.1.4.5. Monthly costs of laboratory tests conducted outside the plant............................

5.1.5. Maintenance Work

5.1.5.1. There is periodic (preventive) maintenance performed:

- ☐ Per month
- ☐ Biannual.
- ☐ Annually.
- ☐ Other, explain....
- ☐ None.

5.1.5.2. There are records (Archives) the maintenance work done.

- ☐ Yes.
- ☐ No.

5.1.5.3. Costs of periodic maintenance work.. ....

5.1.5.4. Monthly costs of emergency maintenance work..

5.1.6. Administrative Follow-up of Wastewater Treatment Plants

5.1.6.1. Reports are prepared on the plant's performance.

- ☐ Per month
- ☐ Biannual.
- ☐ Annually.
- ☐ Other, explain....
- ☐ None.

5.1.6.2. Performance reports on the plant are published:

- ☐ Yes
- ☐ No.

5.1.6.3. Needs reports of the plant are prepared:

- ☐ Per month.
- ☐ Biannual.
- ☐ Annually.
- ☐ Other, explain....
- ☐ None.

5.1.6.4. There is a website for the Plant.

- ☐ Yes
- ☐ No.

5.1.6.5. Visits to other treatment plants in the region

- ☐ Per month
- ☐ Biannual.
- ☐ Annually.
- ☐ Other, explain......
- ☐ None.

5.1.6.6. Communication with government agencies following up the performance of the Plants.

- ☐ Per month
- ☐ Biannual.
- ☐ Annually.
- ☐ Other, select......
- ☐ None.

5.1.7. Do you support the establishment of a central government management unit, which will be responsible for the management and operation of treatment plants in the West Bank so that it belongs to the Palestinian Water Authority, without being affiliated with local councils or authorities?

- ☐ Yes. Explain: ....
- ☐ No, explain: ....
- ☐ I have another vision (Neutral), explain........

ANNEX No.2: Interviews.

Interview questions

1- What are the problems facing the operators of the WWTP?

a. Administrative

b. Technical

c. Finance:

d. Socia:

2- How do you evaluate the performance of the plant compared to others, and compared to the results of the treatment? What basis did you rely on in your evaluation?

3- What effect does the technology used in the plant have on its efficiency and on the performance of its staff?

4- What is the role of the plant size in influencing its performance in general, and do you think that the size has an important role in judging the effectiveness of the it?

5- The location of the plant for the serviced area and the impact on it?

6- What is your comment on the idea of establishing a central management and operation unit to operate treatment plants in the West Bank under PWA control?

7- Operation and maintenance cost?

List of interviewees

1- Adel Yasin. General director of strategic planning and sanitation, Palestinian water authority (PWA). Ramallah: Palestine.
2- Asmaa Salah. Executive Director, Joint Services Council of AL-Taybeh-Ramon. Ramallah: Palestine.
3- Elias Abu-Mohr. Applied Research Institute (ARIJ) - Bethlehem. Al Aroub WWTP manager. Hebron: Palestine.
4- Ibraheem Abu-Sebaa. Head of the water and sanitation department in Jericho municipality, director of Jericho WWTP. Jericho: Palestine.
5- Malik Ishtiah. Sanitation engineer, Ramallah municipality. WWTPs manager. Ramallah: Palestine.
6- Noor-Eden Abu-Gazala. Jenin WWTP manager, Jenin municipality. Jenin: Palestine.
7- Rabee Rabaiah. Executive Director, Joint Services Council of Maithaloon. Jenin: Palestine.
8- Roa Al-Taweel. Head of engineering department and WWTP manager, AL-Berih municipality. AL- Berih: Palestine.
9- Yousef Abu-Jafal. Operation manager of Nablus West WWTP, Nablus municipality. Nablus: Palestine.

ANNEX No. 3:

Nablus West WWTP layout.