BIRZEIT UNIVERSITY

Faculty of Graduate Studies
Water and Environmental Engineering Master Program
MSc. Thesis

Assessment of Public Private Partnership for Energy and Biosolids Management of Madaba Wastewater Treatment Plant- a Case Study

تقييم شراكة القطاعين العام والخاص لادارة الطاقة والحمأة في محطة مأدبا لمعالجة المياه العادمة – حالة دراسية

Master's Thesis Prepared By:

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Student number (1065187)

Supervised By:

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August, 2013

جامعة بيرزيت

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This thesis was prepared under the main supervision of Dr.-Eng. Rashed Al-Sa'ed and has been approved by all members of the examination committee.

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ABSTRACT

The erection and operation of wastewater treatment plants (WWTPs) in Jordan call for high capital and annual operational expenditures. The latter is reflected though a high energy consumption of about 14% of total electricity produced in Jordan. This forms a huge financial burden on the Water Authority of Jordan (WAJ), responsible for most of WWTPs in Jordan. Of equal importance, the issue of sludge management, particularly sludge treatment, dewatering and disposal, is a critical issue. Current management option entailing sludge transportation to specific WWTPs puts high financial burdens on the WAJ. Due to technical and managerial attributes, the current management practices of WWTPs in Jordan have resulted in un-sustainable wastewater treatment facilities associated with high operational costs and severe environmental impacts. All this urged WAJ in 2011 to apply the concept of Public private Partnership (PPP) aiming at improving the efficiency of the wastewater treatment facilities.

Local experience on the application of PPP in the Jordanian sanitation sector is limited and the role of PPP in reducing operational expenditures of WWTPs warrant investigation. This research study evaluates the first experience gained through PPP involvement pertinent to energy reduction and biosolids management at Madaba WWTP. Technical management tools including operational program of selective unit operations were developed to reduce energy consumption and associated costs. The data compiled, analyzed and presented in this thesis work are based on a pioneer PPP pilot case implemented by WAJ and a consortium of private companies (Engicon-Jordan and Huber SE-Germany).

Evaluation and analysis of the compiled results obtained on the PPP after the first year of operation showed improvement in the energy efficiency and sludge management effectiveness. Compared to conventional governmental management practices, application of the PPP concept achieved an average energy consumption reduction by 25%, where the

management costs of the sludge line were reduced by 68%. Without impacting the treatment efficacy of Madaba WWTP, the PPP initiative reduced the annual operational expenditures (OPEX) and improved the biosolids disposal path. Annual saved OPEX ensured sustainable operation and reduced the overall treatment costs rendering them affordable for the urban residents. Considering the specificity of each WWTP, the PPP concept can be applied on other WWTPs across Jordan, however, the institutional framework including the legal and administrative issues regards PPP involvement need further investigations.

الخلاصة

تشييد وتشغيل محطات معالجة مياه الصرف الصحي في الأردن تحتاج إلى استثمار عالي ومصاريف تشغيلية سنوية باهظة. يبدو هذا جليا في معدل استهلاك الطاقة المرتفعة والتي تعادل حوالي 14% من الإنتاج الكلي للطاقة في الأردن. هذا الاستهلاك العالي يمثل عبء مالي كبير على سلطة المياه الأردنية التي هي مسؤولة عن معظم محطات معالجة مياه الصرف الصحي في الأردن.

وبالأهمية ذاتها، فإن إدارة الحمأة وبالأخص معالجتها وتجفيفها والتخلص منها هو أمر حساس جدا. حيث أن الخيار الحالي لإدارة الحمأة القائم على نقل الحمأة إلى محطات معالجة خاصة بها يضع عبئأ ماليا كبيرا إضافيا على سلطة المياه الأردنية.

ونتيجة لإعتبارات فنية وإدارية، فإن ممارسات الإدارة الحالية لمحطات معالجة مياه الصرف الصحي في الأردن نتج عنها مرافق غير مستدامة لمعالجة المياه العادمة وتكاليف تشغيلية عالية وأضرار بيئية جسيمة. كل ذلك حث سلطة مياه الأردن في عام 2011 إلى تطبيق مفهوم الشراكة بين القطاعين العام والخاص لهدف رفع كفاءة مرافق معالجة المياه العادمة .

إن تجارب مشاركة القطاع العام والخاص في قطاع الصرف الصحي في الأردن قليلة ودور هذه المشاركة في تقليل التكاليف التشغيلية بحاجة إلى تقييم.

هذه الدراسة البحثية تقيم نتائج التجربة الأولى التي تححقت من خلال هذه الشراكة في محظة مادبا لمعالجة المياه العادمة لتقليل استهلاك الطاقة وإدارة الحمأة. تم تطوير أدوات إدارة الفنية للتقليل من استهلاك الطاقة والمصاريف المرافقة لها. كل المعلومات والنتائج التي تم جمعها وتحليلها وعرضها في هذه الدراسة البحثية مبنية على نتائج مشروع ريادي لمشاركة القطاعين العام والخاص والذي تم تنفيذه من قبل سلطة المياه الأردنية وتحلف من شركات القطاع الخاص من الأردن (انجيكون) ومن ألمانية (هوبر تكنولوجي) بدعم من الوكالة الألمانية للتعاون الدولي.

أظهر النتائج التي تم تحليلها وتقييمها للسنة الأولى للمشروع تحسن في كفاءة استهلاك الطاقة و إدارة الحمأة مقارنة مع ممارسات الإدارية الحكومية التقليدية. دون التأثير على فعالية المعالجة لمحطة مأدبا، خفضت مبادرة شراكة القطاعين العام والخاص استهلاك الطاقة بمقدار 25% وتقليل كلفة ادارة الحمأة بمقدار 68%. التوفير السنوي في كلفة التشغيل يؤمن استمرارية عمل المحطة ويقلل التكاليف الأجمالية لمعالجة المياه مما يجعل الكلفة محتملة من قبل المواطنين. يمكن تطبيق مبادرة شراكة القطاعين العام والخاص في محطات معالجة أردنية أخرى مع اعتبار خصوصية كل محطة على حدة. ولكن، مازال الإطار المؤسسي لشراكة القطاعين العام والخاص وما يشمل من أمور قانونية وإدارية بحاجة إلى دراسات أخرى.

DEDICATION

I dedicate this work to my Parents and to all my friends

ACKNOWLEGMENT

A part from my personal effort, the success of this work depends largely on the encouragement and guidelines of many others. I would take this opportunity to express my gratitude to everyone, who has a share in making this thesis work successful.

I would like to extend my greatest appreciation to Dr. Rashed Al-Sa’ed. No words can express the great help and support he provided all the way long as without his thorough advices and guidance this work would not have been materialized.

My deep appreciation is due to the GIZ Water Program in Jordan, Engicon Company and Huber SE for their remarkable support for making this work successful.

LIST OF ABBREVIATIONS

BOT: Build, Operate and Transfer

CAPEX: Capital Expenditures

DEAT: Department of Environmental Affairs and Tourism

GIZ: German Agency for International Cooperation

JISM: Jordan Institution for Standards and Metrology

KfW: German Bank for Reconstruction

LAB: Laboratory

NRW: Non-Revenue Water

OPEX: Operational Expenditures

PUDSS: Permissible Utilization and Disposal of Sewage Sludge

PCBs: Pesticides and Polychlorinated Biphenyls

PSP: Private Sector Participation

PPP: Public Private Partnership

WAJ: Water Authority of Jordan

WWTP: Wastewater Treatment Plant

USEPA: US Environmental Protection Agency

IEWS: Institute of Environmental and Water Studies

JOD: Jordanian Dinar

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CHAPTER ONE
INTRODUCTION

1.1 OVERVIEW

Madaba Governorate, located at around 25 km to the south-west of Amman City, and accessed through the Desert Highway that connects Amman with all the southern regions. It is an ancient city of mosaics, presenting an archaeological park and has the oldest preserved ancient mosaic map of the holy land. These proposed actions were selected based on their potentiality in terms of revitalizing the city through promoting the archaeological and historical sites. Figure (1) below shows the location map of Madaba Governorate in the Hashemite Kingdom of Jordan.

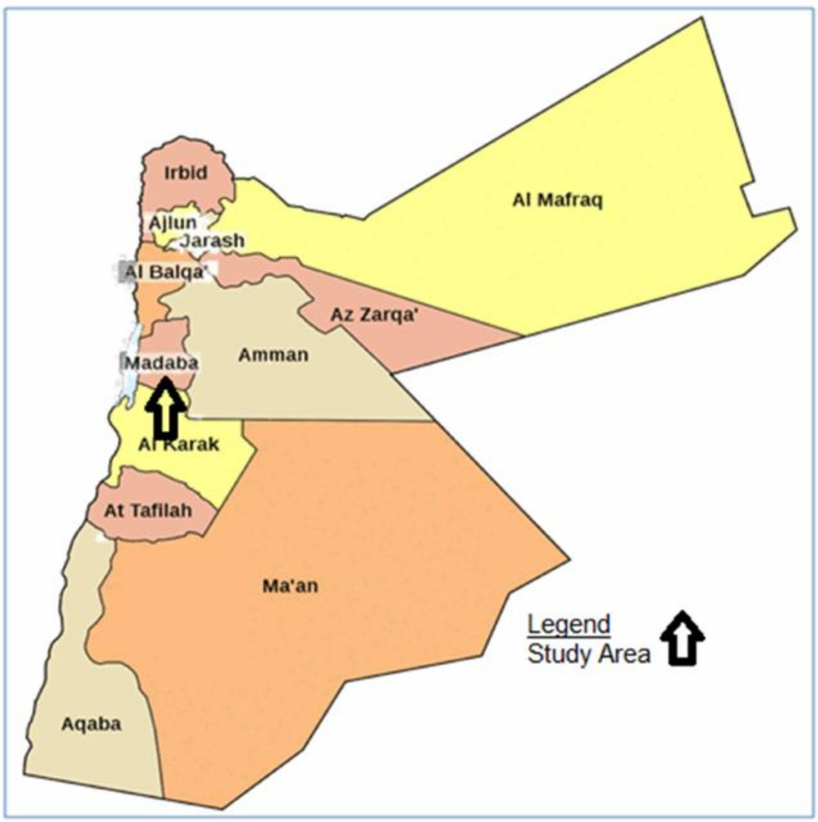

Figure 1: Location map of Madaba Governorate-Jordan (World of maps)

1.2 MADABA WASTEWATER TREATMENT PLANT

Madaba Wastewater treatment plant was built in 1988 and it was a stabilization pond treatment system. In 2002, the treatment plant was rehabilitated to raise the capacity to 7600 m^3/d and the treatment system was changed to extended aeration activated sludge system (KfW, 2012).

Figure 2: Madaba wastewater treatment plant (WWTP)

Currently, it serves around 100,000 habitants with average daily flow rate of 5200m^3/day. The treatment plant is treating about 1.6 % of the total wastewater quantity of Jordan. And now, Madaba WWTP is the seventh largest WWTPs in Jordan. Figure (2) shows a general view for Madaba WWTP and figure (3) shows one of the aeration tanks (KfW, 2012).

Based on site visits and Madaba Water Administration (personal communication), the main components of the Madaba WWTP are the followings:

1 Two mechanical screens
2 Two equalization tanks
3 Two grid and oil removal units
4 Two anaerobic zone units
5 Six anoxic zone units
6 Twelve aeration tanks
7 Two secondary sedimentation tank

8 Two sludge thickeners

9 One hundred sixty five sludge drying beds with capacity of 35 m^3 for each

The wastewater from WWTP Madaba is discharged to polishing ponds and is reused for irrigation in agriculture in the vicinity of the WWTP. The liquid sludge is dried during the summer times on the drying beds up to 50 - 60 % TSS and disposed onsite. According to Salah (2011), Table (1) shows the average effluent characteristics and the removal efficiency of Madaba WWTP.

Table 1: Characteristics of Madaba WWTP effluent and removal efficiency

<table>
<tr><th rowspan="2">Treatment Process</th><th colspan="6">Effluent Parameter</th></tr>
<tr><th>T N</th><th>TDS</th><th>TSS</th><th>COD</th><th>BOD_5</th><th>pH [-]</th></tr>
<tr><td>Activated Sludge</td><td>13.0</td><td>1169.3</td><td>39.5</td><td>72.5</td><td>16.0</td><td>7.7</td></tr>
<tr><td colspan="7">Effluent after the secondary settling tank (grab sample)</td></tr>
<tr><td colspan="2">Influent BOD_5</td><td colspan="2">Effluent BOD_5</td><td colspan="3">Removal Efficiency (%)</td></tr>
<tr><td colspan="2">745</td><td colspan="2">21</td><td colspan="3">97</td></tr>
</table>

[*] All parameters are in mg/l, otherwise stated

The quantity of the treated wastewater reused in agriculture from Madaba WWTP is 1,432,884m^3/year and it is reused to irrigate around 1308.57 Dunums.

Figure 3: Aeration tank in Madaba WWTP

The current operational procedures implemented in Madaba wastewater treatment plant are insufficient and make it unsustainable due to the high energy consumption and lack of adequate operation program.

Madaba wastewater treatment plant consumes around 7,000 kWh of electricity per day which equals to around 11,700 JOD per month (KfW, 2012). In addition to that, Madaba wastewater treatment plant faces major problems in the sludge management. The wastewater treatment plant produces 250 m^3 sludge daily and the Madaba Water Administration pays around 127,000 JOD per year to transport the sludge from the treatment plant to another treatment location (KfW, 2012). Moreover, odour problem in the area of the sludge thickener and the drying beds exists.

The financial resources of the Jordanian public sector particularly the Water Authority of Jordan are limited and not well allocated among the different sectors which place a major burden. In pursuing to develop its capacity to manage Jordan's scarce water and its financial resources, the Ministry of Water & Irrigation in Jordan has a successful cooperation with international donors and consultants under various management programs in different forms.

Therefore, in order to find solutions and overcome the problem of high electricity consumption and high cost of sludge management in Madaba WWTP, WAJ signed a PPP contract with the German Agency for International Cooperation (GIZ), and a private consortium in 2011 to reduce both electricity consumption and optimize the sludge management costs (GIZ, personal communication).

1.3 BRIEF ABOUT THE PPP CONTRACT(IMPLEMENTATION OF PPP FOR MADABA WASTEWATER TREATMENT PLANT)

The project was implemented by the German Agency for International Cooperation and the consortium of two private companies; Engicon from Jordan and Huber SE from Germany for the benefit of the Water Authority of Jordan (WAJ). The PPP project duration was two years started from June 2011 and ended by May 2013 (GIZ, 2011).

The cost of the project expenses has been shared between the project partners 50 %:50%. It is a non-profit project and the private consortium implemented to promote the PPP concept to improve energy efficiency and sludge management in the WWTPs in Jordan. The GIZ share covered 50% of the physical cost (Engicon, personal communication). Thus, it was difficult to compare this case with other cases in the literature because the financial side which is an important tool for the comparison here is not considered such as the tariff, the revenue percentage sharing, etc.).

From the project documents (Annex 1), the overall objectives of the project are summarized:

- Reduce the electricity consumption of Madaba WWTP to achieve energy savings.
- Improve the sludge drying process and run an onsite composting process at Madaba WWTP.
- Improve the process performance and operation of WWTP to secure efficiency and environmental wise operation of WWTP to minimize CO_2 emissions
- Cost optimization and efficient use of financial resources of WAJ.
- Provide the base for energy contracting in the operation of WWTPs, which helps to use private expertise, creates jobs and improves operational security.
- Efficient use of fresh water resources by treated wastewater as an additional irrigation water.

1.4 STUDY MAJOR GOAL AND SPECIFIC OBJECTIVE

1.4.1 RESEARCH QUESTION AND MAIN GOAL

How the public private partnership (PPP) with WAJ can better contribute to development outcomes pertinent to sustainable operation of Madaba WWTP. Hence, the research study aims at better understanding of private sector involvement through analysis and evaluation of the capital and operational expenditures (CAPEX and OPEX, respectively) considering energy consumption and optimized biosolids disposal. For this purpose, Madaba WWTP was taken as a case study in Jordan. Annex 5 illustrates the no objection provided by the WAJ and GIZ of using the data obtained from the PPP project for the sake of scientific purposes, i.e. to include as part of this research study.

1.4.2 SPECIFIC OBJECTIVES

The specific objectives of this research study are:

1. Analyze and assess the impacts of operational program of selective units operations [aerators] on the reduction of energy consumption and associated financial savings.
2. Evaluate composting of biosolids and assess the achieved costs reduction on current sludge management practices.
3. Investigate the possibility of PPP application on other WWTPs in Jordan.

1.5 EXPECTED RESULTS

Upon the successful implementation of this research study, the following results are expected to be achieved:

1. Synthesis of a technical and financial assessment depicting the performance of Madaba WWTP before and after PPP application through the private sector.
2. A safe disposal option for the sludge of Madaba WWTP is recommended.
3. Provide useful information for the regulatory and environmental authorities regards successful involvement of PPP in the planning or upgrading phases of sewage works.

1.6 RESEARCH APPROACH

It is worth mentioning that, within the framework of this research study, I was the project coordinator for the entire project, where I applied a systematic research methodology taking the costs and time frame into account. After a comprehensive literature review, the research study includes the following main activities:

1. Review of the Historical Plant Performance and Energy Usage Date
2. Monitoring of electricity consumption of the wastewater treatment plant after the Involvement of the Private Sector
3. Assessment of the influent and effluent characteristics of the WWTP
4. Impacts evaluation of a new sludge management applied and results analysis of the windrow compost piles implemented by the private consortium at Madaba WWTP
5. Evaluate the impact of the Private Operator on the CAPEX and OPEX of the WWTP.

1.7 THESIS BODY

1. Chapter 2 will discuss briefly the literature review; wastewater treatment in general and in Jordan in particular, energy consumption in wastewater treatment plant, sewage sludge, sludge treatment system, integrated waste management system and private sector participation in water sector in general and in Jordan in specific.
2. Chapter 3 will discuss in details the materials and methodology
3. Through chapter 4 results will be discussed and analyzed
4. Finally chapter 5 will show the conclusions, recommendations, and future work.

CHAPTER TWO
LITERATURE REVIEW

This chapter reviews the literature on Wastewater Treatment Plants including treatment, energy consumption, sludge treatment and disposal and private sector participation in water sector.

2.1WASTEWATER TREATMENT

Wastewater treatment is essential for both of human health and environment protection by removing pollutions and organic substances. Since the beginning of the 20th century public facilities have been installed globally which treat wastewater at a central location before discharge into the environment through direct discharge to the water bodies or reuse in agriculture (Robert et al. 2006).

Wastewater from households and industrial activities contains organic matters, nutrients, hazardous and pathogenic substances which put pressure on the environment and constitute risks to human health. In the developed countries, treatments have evolved throughout the years with the legislation playing an important role in establishing water quality objectives, preventing and improving current pollution in water bodies (Robert et al. 2006).

The other main objective of wastewater treatment is to perform the required wastewater treatment as cost effective as possible; for the sake of the taxpayers as well as for the nature in form of reduced energy usage deriving from fossil fuel (Robert et al. 2006).

It is not often recognized, but there is a considerable amount of the public energy involved in the continued operation of wastewater treatment plants all over the world.

The United States uses about 1-2 % of its national electric demand in treating of wastewater, while in the Netherlands this value is around 0.6 % (Salah, 2011).

In the Middle East, the operation of WWTPs is a very high energy consuming process, especially when it is not operated according to international best practices. For example, the Water Authority of Jordan (WAJ), which is in charge of most of the WWTPs in Jordan, is the biggest electricity consumer in Jordan. It consumes around 14% of the total electricity produced in Jordan (GIZ, personal communication).

It is well known that energy and water are closely linked together. Every step in the integrated water cycle starting from drinking water treatment and supply, wastewater collection up to the wastewater purification requires energy, and water is used in the generation of hydroelectric energy and in the operation of most thermal power plants (Molinos, et al. 2012). At the same time, there is a strong scientific consensus that climate change may negatively affect both the quantity and quality of available water and energy resources in light of predictions of more frequent extreme weather phenomena such as heat waves and intense rainfall in the coming years.

Operators and managers of water and wastewater facilities have a wide range of priorities, of which energy consumption is just one. Some of their primary priorities include (Daw et al. 2012):

1. Complying with regulatory requirements to meet public health, and ecological demands
2. Providing reliable service at reasonable and predictable rates
3. Balancing repair and replacement needs with long-term debt, equipment condition, ongoing operations and maintenance costs, and revenue
4. Optimizing operations and maintenance to reduce costs and ensure longevity of assets.

2.2ENERGY CONSUMPTION IN WASTEWATER TREATMENT

Energy consumption in wastewater treatment has grown considerably due to the increase in treated volume or due to the poor operation of the system.

The largest electricity consumer for every wastewater treatment plants is the biological treatment process. It uses normally 50-80 % of the total electrical energy consumption. This is due to the fact that the reduction of organic matter is high oxygen demanding and aeration systems require high amounts of energy (Malin, 2007). Table (2) shows the energy usage at typical municipal WWTPs (Chitikela et al. 2012).

Table 2: Energy Usage at Municipal WWTPs

Process or Unit Operation	Energy Use
Buildings and Lighting	10% or less
Wastewater and Sludge Pumping[1]	15 – 50%
Screens and Grit Removal	2% or less
Aeration based bioprocesses[2]	50% or greater
Solids Clarification[3]	10% or less
Disinfection[4]	2% or less
Anaerobic Digestion[5]	10 - 20%

[1] Influent raw wastewater pumping and sludge pumping operations; the 50% energy use is projected at WWTPs without the secondary aeration type process.
[2]Activated sludge process configuration.
[3] Primary and secondary settling of solids, and sludge thickening and dewatering.
[4] Chlorine disinfection.
[5] Based on sludge mixing configuration.

However, it should not be forgotten that reducing the WWTP carbon footprint is not only an environmental issue; there are also important economic repercussions for it (Molinos et al. 2012).

The energy demand in the water sector will pragmatically grow with time due to a number of factors, such as population growth and the corresponding growth in the contaminant load to be treated, as well as increasingly stringent regulatory and environmental protection standards for effluent quality and residual water reuse. These changes are expected to result in more energy intensive processes.

Thus, optimization of energy consumption, efficiency of design and of equipment and technology operations, energy recovery processes, and good management of energy pricing are being increasingly considered in the field of water treatment. Obviously, higher energy efficiency means lower energy consumption, lower greenhouse gas emissions, and lower operating costs for WWTPs.

However, substantial energy and financial savings can be uncovered through operational changes and capital improvements at water and wastewater utilities.

In Austria, the target ‘energy self-sufficient sewage plants’, has been reported in two municipal WWTPs (the Strass TP and the Wolfgangsee TP). This is the result of a longstanding and on-going optimization process at both plants including optimal aeration control and control of the aerobic section of the aeration tank to optimize denitrification and prevent degradation of particulate organic matter that should be degraded in the digester (Nowak et al. 2011).

Both of these treatment plants are activated sludge plants with nutrient removal with phosphorus effluent concentrations well below 1 mg P/L and about 80% nitrogen removal, for which no external carbon source is needed (Nowak et al., 2011).

According to Lingbo et al. (2010) the average energy consumptions in China for secondary WWTPs of different treatment technologies are (ranging from the highest to the lowest): 0.340 kWh/m^3 for extended aeration treatment systems, 0.336 kWh/m^3 for sequence batch reactors, 0.330 kWh/m^3 for Biomembrane systems, 0.302 kWh/m^3 for Oxidation ditches systems, 0.283 kWh/m^3 for anoxic-oxic systems, 0.269 kWh/m^3 for traditional activated sludge systems, 0.267 kWh/m^3 for Anaerobic-Anoxic-Oxic systems, 0.253 kWh/m^3 for constructed wetlands and 0.219 kWh/m^3 for adsorption-biology systems. Based on these numbers, average energy consumption of 559 secondary WWTPs is 0.290 kWh/m^3 or equivalent to 2.06 kWh/kg BOD, measured at 450 secondary sewage works.

In America the former energy consumption for secondary treatment was 0.20 kWh/m^3 while in Japan it is 0.304 kWh/m^3 including effluent disinfection and sludge digestions (Gao, 2002) and it is 0.42 kWh/m^3 in Sweden (Lingsten and Lundkvist, 2008).

Energy efficiency management and application of energy saving technology are the keys to energy conservation in wastewater treatment plants. The energy performance assessment allows WWTPs to evaluate their energy consumption level and track their energy use, thus it is the prerequisite step for taking efficient energy conservation measures.

In America, the Energy Star Program provided a platform for the comparison of different plants' energy consumption. Benedetti proposed a performance assessment for the integrated urban wastewater system with several original indicators (Benedetti et al., 2007). Lindtner et al. (2004) pointed out a statement that standard design load of pollutants had significant impact on cost, based on the investigation of most Austrian sewage plants.

Many countries in the Organization for Economic Cooperation and Development (OECD) performed statistic and assessment on total energy consumption of wastewater service (Merkel 2002; OECD 2006). International Water Association (IWA) summarized the indicators evaluating the process of waste water treatment and put forward different energy performance indicators to specifically evaluate certain energy consumption processes, such as energy consumption of influent flow pump unit per sewage volume pumped per pump head (Matos et al., 2003).

2.3FRAMEWORK OF OPERATIONAL ENERGY

2.3.1Performance Assessment

Energy consumption of WWTP was influenced by uncontrollable and inoperative factors, such as historic development of design (Lindtner et al. 2006), treatment technology, influent quality and discharge standard.

Lingbo and others (2010) developed in their study an energy assessment system, in this system the following points were taken into consideration:

1. Energy consumption which means electrical consumption (kWh), which is the most common energy source used in WWTPs.
2. Only the plants with the ratio of effluent standard compliance above 85% are qualified.
3. Industrial load does not account beyond 30 % and does not contain toxic matter.
4. It is assumed that the diversity of energy consumption is caused by influent quality, and water temperature difference of biochemical treatment process.

2.3.2Energy performance indicators

The energy performance assessment system contained 7 indictors that can be divided into three levels.

Level 1: comprehensive energy consumption level

Energy consumption per volume of wastewater treated and Energy consumption per total pollutant mass removed are chosen to represent the comprehensive energy consumption.

Indicator 1: energy consumption per volume of wastewater treated. It is the most common indicator for evaluating energy consumption.

Indicator 2: energy consumption per total pollutant mass removed.

Indicator 3: energy consumption of influent pumping unit per volume of wastewater pumped per pump head.

Indicator 4: energy consumption of aeration per volume of wastewater treated.

Level 2: unit energy consumption level

Evaluating energy performance of each main operational unit (energy consumed due to aeration, to wastewater pumping, and to sludge treatment) allows a WWTP to track its energy use and recognize the space for improvement in each unit and therefore to prioritize areas of intervention in a decision-making context. Three unit energy consumption indicators are adopted in our energy performance assessment framework, namely energy consumption of influent pumping unit per sewage volume pumped per pump head, energy consumption of aeration per volume of wastewater treated, and energy consumption of sludge processing unit per sludge mass treated.

Indicator 3: energy consumption of influent pumping unit per volume of wastewater pumped per pump head.

Indicator 4: energy consumption of aeration per volume of wastewater treated.

Indicator 5: energy consumption of sludge processing unit per sludge mass treated.

Level 3: energy recovery level

Energy recovery from residual sludge is a key to energy conservation and thus is a promising energy recovering unit for WWTPs. So energy recovery indicators are introduced into the energy performance assessment framework to stimulate WWTPs to invest in the residual sludge processing and energy recovery facilities and to try their best to improve the efficiencies of sludge digestion and energy recovery. Since the main energy recovered is in the form of natural gas from the sludge digestion process and electricity or heat generated by the natural gas, volume of biogas retrieved (produced by sludge digestion) per sludge mass treated and electronic energy retrieved per energy consumption are adopted as indicators for energy recovery from residual sludge.

Indicator 6: volume of biogas retrieved (produced by sludge digestion) per sludge mass treated.

Indicator 7: electrical energy retrieved per energy consumption.

2.4 SEWAGE SLUDGE

2.4.1 Definition of sewage sludge

Sewage sludge is the solid, semisolid and the liquid material produced at the several stages of wastewater treatment process (Jimenez et al., 2002). It is considered as a hazardous waste because it contains components such as organic matter, bacteria, viruses, heavy metals and nutrients which may have significant adverse effects on human health and the environment (Horan, 1990).

Sewage sludge has a wide range of physical, chemical and biological properties and according to its origin and type, sewage sludge is made of a complex mixture of compounds.

Primary and secondary sludge are voluminous mainly because they contain large quantities of water in addition to the solids removed during the treatment process (Burgess and Stuetz, 2002).

The typical concentration of solids in primary sludge is 4-8%, in secondary sludge 0.5-1.5%, and in secondary and primary sludge combined 3-6% (Jimenez et al., 2002). However, when primary sedimentation is excluded from the activated sludge process (such as in extended aeration systems), the concentration of secondary sludge is faintly higher and is between 0.8 and 2.0% (Horan, 1990).

2.4.2 Production of sewage sludge

When raw sewage is delivered via sewer system to a treatment plant it contains an appreciable amount of floating materials (such as wood, paper, rugs, plastics) as well as heavier solids such as grit and large suspended solids (Horan, 1990).

And in order to prevent damage to the mechanical parts of the treatment plant such as the pumps and aerators as well as blockage of pipes and valves, these solids have to be removed at an early stage in the treatment process. To achieve this, sewage is passed through a preliminary treatment process (Zavadska and Knight, 2002). This preliminary treatment generates small quantities of residuals.

However, sewage that has been subjected to preliminary treatment will still contain a high concentration of settleable solids and primary sedimentation tanks are used to remove these solids. Three types of sedimentation tanks are routinely used at treatment plants and these are designed according to their flow regime and the common tanks are the horizontal flow tanks, the radial flow tanks and the upward flow tanks (Horan, 1990).

Primary treatment generates a large amount of primary sludge that is removed periodically from the bottom of the sedimentation tanks together with minor quantities of oil, grease, and scum skimmed from the top of the tanks. This step also results in the separation of wastewater into two different streams, each of which goes to a different secondary treatment step

Untreated sewage sludge has relatively high levels of disease-causing microorganisms and pathogens and is decomposable or unstable.

The unstable nature of untreated sewage sludge can generate odors and makes it attractive to insects, rodents, and birds which are disease carrying vectors. Therefore, further treatment of sludge is needed to reduce pathogen levels and vector attraction. These sludge treatment processes are typically based on one or more of the following approaches: application of high temperature, application of chemical disinfectants, reduction of the microbial food source in sewage sludge which is measured as the volatile organic content, or removal of nearly all moisture from the sludge.

For example, aerobic and anaerobic digestions are common methods of sewage sludge treatment that reduce its volatile organic content and simultaneously apply heat (Arther et al., 1981; Alaerts et al., 1990; Horan, 1990; Hall, 1992; Jimenez et al., 2002; Marx et al., 2004).

According to Zavadska and Knight (2002), “the most neglected aspect of wastewater treatment is the treatment and disposal of its main by-product- sludge and technologies for low-cost and sustainable treatment of sludge are still mostly lacking".

Sewage sludge, which accounts for less than 1.0% of the wastewater volume, represents 50% of the treatment cost and 90% of the day-to-day problems for plant operators (Alaerts et al., 1990).

There are several ways to treat sludge including conventional and advanced treatment systems.

1. Conventional treatment includes the following methods:

- Stabilization: aims at reducing biodegradability matters and potential to cause nuisance.
- Dewatering: the dewatering helps to reduce the transport cost.

2. Advanced treatment includes: sludge disinfection which reduce or prevent health hazards (Jimenez et al., 2002).

Approximately 79% of the sludge produced in the Europe which equal around 4.38 million tons per year is treated before disposal (Odegaard et al., 2002).

However, contrasting the European countries, most developing countries do not monitor or keep records of the amount of sludge they treat before disposal.

2.5 SLUDGE TREATMENT PROCESSES

2.5.1 Thickening

The purpose of thickening process is to increase the solids concentration in the sludge by reducing its water content. Thickening process will increase the solids content to 2.0– 5.0% (Marx et al., 2004) and will decrease the capital and operating costs of subsequent sludge processing steps by substantially reducing the volume.

Thickening is usually accomplished by gravity, dissolved air flotation or centrifugation. Gravity thickening is by far the most commonly practiced internationally (Jimenez et al., 2002). Thickening activated sludge, for example, can increase the concentration of solids from 0.5-1.5% to 2.0-3.0% (Horan, 1990).

2.5.2 Stabilization

Sludge treatment also includes stabilization, which destroys volatile organic matter to minimize bad odors and reduce the number of pathogens.

Studies on the capacity of living of the pathogens and parasites found in sludge like helminth eggs confirmed the resistance of the eggs to most biological treatments such as aerobic stabilization, mesophilic anaerobic digestion and lagooning (Dominguez et al., 1997).

After applying other biological treatment (composting) and chemical treatment (liming) the viability of the parasite eggs clearly showed the necessity of precisely defining the process parameters (temperature, pH, homogenization, treatment time, end process heat value etc.) in order to efficiently destroy the helminth eggs (Dominguez et al., 1997).

It is generally demonstrated that heat is a powerful virus killer. Thermophillic aerobic digestion and pasteurization remain attractive processes to inactivate viruses and other pathogens (60°C for a treatment contact time superior or equal to an hour) (Keirungi, 2006).

Thermal conditioning processes have been used in South Africa but are not popular due to negative aspects such as high operation and maintenance costs and the treatment requirements for the dewatering liquors (Marx et al., 2004). Stabilization also reduces the volume of sludge because some of the organic solids are destroyed in the process (Hall, 1992). Stabilization is usually followed by a dewatering step.

2.5.3 Dewatering

Dewatering is a physical operation that separates the liquid and solid portions of the dilute sludge generated during the precipitation/clarification process. By increasing the solids content of the sludge, the volume is reduced, which in turn reduces transportation and often disposal/recovery costs. Dewatering is usually performed in a series of steps utilizing two or more pieces of equipment (Odegaard et al., 2002). Dewatering can be accomplished by natural methods or by mechanical means. Natural methods include sludge drying beds and lagoons although this requires long periods of time.

Faster and smaller, but more cost intensive, are machine processes such as vacuum filters, pressure filters, belt filter presses and centrifuges (Marx et al., 2004).

According to Odegaard et al. (2002), “for the choice of the correct dewatering process it is important to consider a multiplicity of further boundary conditions such as quantity, structural situation, disposal, regulations, availability and personnel”.

2.5.4 Conditioning

Mechanical dewatering can be aided by chemical conditioning of the sludge prior to dewatering which may raise the concentration of solids up to 35-40%. Chemical conditioning entails dosing sludge with chemicals such as ferric chloride, aluminum sulphate, lime or poly-electrolytes. Conditioning with polyelectrolyte can be found at most dewatering installations that employ centrifuges or filter belt presses (Marx et al., 2004).

The main advantage of chemical conditioning is that it improves sludge settling and dewatering characteristics and the main disadvantage is that the chemicals are relatively expensive (Horan, 1990).

Sludge treatment technologies employed at WWTPs vary according to the proposed method of final disposal and use. However, the costs of these operations also play a very important role in the type of treatment technologies selected and in so doing affect the quality of sludge generated.

A sludge management decision matrix has been developed In South Africa by the Water Research Commission (Marx et al., 2004) and it relates established end-use options such as incineration, agricultural, use etc. to required sludge treatment steps and the established technologies available under each treatment step.

For example, to use the sludge for land application to natural veld and tree plantations, it must has limited metal and inorganic contents as outlined in the Permissible Utilization and Disposal of Sewage Sludge (PUDSS) document (Water Research Commission, 1997) and must have undergone treatment such as alkaline stabilization, composting, pasteurization or thermal conversion in order to reduce the numbers of pathogenic organisms.

After the treatment stage, there are many disposal options for the treated sludge and these are discussed in the coming section.

2.6 SEWAGE SLUDGE DISPOSAL TECHNIQUES

During the wastewater treatment process, large volumes of sludge generated and the potentially hazardous nature of the materials contained in it, therefore the production and disposal of sewage sludge is a worldwide concern.

However, differences in geography and politics have meant that different approaches to sludge management have been emphasized in different parts of the world (Zavadska and

Knight, 2002). Nevertheless, in contrast to sewage treatment, the disposal of sludge in cities of developing countries has received very little attention (Strauss et al., 1999).

The cost of sludge disposal is expense incurred by operators of wastewater treatment plants and depends on the quality and quantity of organic substances, heavy metals and other pollutants. Stringent environmental regulations in most countries have led to the application of improved high-standard technologies for wastewater treatment often with a consequent rise in the cost of municipal wastewater treatment.

For example, some environmental regulations stipulate that wastewater should be biologically purified which inevitably leads to increased costs and subsequently increased sewage sludge production (Leschber, 1997).

Due to the increased production of sludge, it is often discharged in an uncontrolled manner into receiving waters, dumping sites or onto vacant plots and when sludge is disposed of on vacant plots serious problems arise due to the shortage of disposal capacity and leaching of heavy metals to underground water, surface water and soil (Marchioretto et al., 2002).

2.6.1 Disposal into large water bodies

Water utilities and municipalities have always found it convenient to dispose of untreated wastes to rivers and oceans, although the former quickly became untenable as the limited water flow resulted in catastrophic effects such as anoxia and death of fish (Marshall, 1988). Sludge dumping is a major component of waste disposal to the water bodies and is coming under increasingly close scrutiny because of possible adverse environmental effects. This development is perhaps best illustrated by the moves of the US Environmental Protection Agency (EPA) which has placed a ban on ocean dumping of sludge (Marshall, 1988) since 31 December 1998.

Disposal of sludge to surface water is no longer permitted in the European Union under the Urban Waste Water Treatment Directive and other countries are slowly phasing it out. The banning of ocean disposal of sludge certainly has ramifications for coastal cities such as Sydney and Brisbane in Australia.

Land disposal remains simple, safe and available option, however, this situation could change with increasing development and the main factors affecting ocean disposal need to be fully understood (Balkas at al., 1993; Carter and Howsam, 1998). Disposal of sewage sludge to the marine environment is still permissible in South Africa and the majority of developing countries.

The main advantage of ocean disposal of sludge is its simplicity and consequent low cost, although the latter may be disregarded if deep sea dumping is required (Kudo and Miyahara, 1991).

Furthermore, marine disposal can potentially fix carbon dioxide as carbonate in sediment (Odegaard et al., 2002). However, there are a number of components of sewage sludge which have the potential to cause problems particularly in the ocean environment. These components include organic matter, oil and grease, bacteria and viruses, heavy metals, organochlorines and nutrients.

Negative impacts include the depletion of available oxygen, environmental hazards, pathogen transmission to infants (0-4 years) who bathe in lightly polluted waters, bioaccumulation, whereby heavy metals present in sludge are concentrated through the marine food web (Kudo and Miyahara, 1991).According to Bascom (1982) and Calabrese et al. (1982) extensive studies conducted on both the east and west coasts of the United States indicated that many previously accepted beliefs concerning the toxicity of metals to marine life were wrong.

Another negative impact of sludge disposal into large water bodies is the excessive build-up of nitrogen and phosphorus compounds which can lead to eutrophication, characterized by increased production of a few species of algae and phytoplankton and subsequent decline in other types of species much of which cannot be consumed by predators, and therefore decomposed by bacteria reducing the available oxygen in the water column and, as the oxygen supply decreases, predatory species disappear (Bell, 1990; EMECS, 1990; Badger and Price, 1992; Odegaard et al., 2002).

2.6.2 Landfilling

Sewage sludge can be also disposed to landfills, in alternate layers, with municipal solid waste. In South Africa 4.0% of the sewage sludge produced annually is landfilled. Treatment prior to landfilling usually involves dewatering and possible anaerobic digestion (Marx et al., 2004) and the minimum solids concentration required is often determined by local sanitary landfill regulations. The degradation within the landfill of organic matter in sludge produces landfill gas, mostly methane. For safety reasons, this must be collected and either flared or used as an energy source. The disposal of sludge to landfills, especially sewage sludge with high water content, increases the volume of leachate that forms at the bottom of the landfill. Uncontrolled release of liquid leachate can cause severe damage to both ground water and surface water.

However the addition of sludge to landfills can improve some of the chemical properties of leachate such as reducing chemical oxygen demand (COD) and raising pH from about 6.0 to 7.5 (AWWA, 1990).

Landfills may be on public land, such as a municipality owned landfill, or on private land. Although they are often located on the outskirts of cities, local residents may be subjected to unpleasant odors from sludge dumping and spreading operations (AWWA, 1990). Transport of large volumes of sludge by sealed truck or tanker from WWTPs to the landfill is costly and energy intensive and it also poses the risk of accidental spillage. In addition, landfilling of sludge has become expensive because of the high costs associated with burial in properly constructed landfills. Landfilling also concentrates organic wastes and may result in point-source contamination for future generations to deal with.

Today, the legislation of countries such as Sweden forbids landfilling of sewage sludge. However the biggest challenge facing landfilling of sewage sludge is the fact that there is increasing international pressure to discontinue the disposal of sludge on landfills mainly due to the space it takes up. Even in a big country such as South Africa, available landfill sites are limited and it is important that all available space be utilized as efficiently as possible (Marx et al., 2004).

In some developing countries such as Jordan, the disposal of sewage sludge to dumping sites is still strongly practice due to the lack of treatment and disposal options.

2.6.3 Incineration

According to Horen (1990), incineration is a high cost/high technology option and is currently only likely to be cost-effective for large cities in developed countries.

Today, incineration technologies are highly developed (U.S.EPA, 1985) with the main types of equipment being multiple hearths and fluidized bed furnaces. Nevertheless, it does not have a high level of public acceptability due to the concerns over gas emissions, and gaining consent to construct new incinerators is often difficult. The main pollution problems arise from gaseous emissions and ash disposal, the former of which can be greatly reduced by scrubbers.

In recent years attention has been focused on pesticides and polychlorinated biphenyls (PCBs) contained in sewage sludge, which have been found to be the most thermally resistant of the chlorinated hydrocarbons.

According to Gorrie and Stone Ltd. (1977), "Test results concluded that 94% reduction of PCBs is achieved at 430°C and 99.9% at 600°C with detention times in the order of 0.1sec". With efficient gas cleaning systems and proper furnace operation, PCBs in sludge do not appear to represent a major hazard.

A study carried out by Dewling et al. (1980), on the fate of heavy metals in sludge incineration found that even after a water scrubbing system to remove particulates, 97.6% of the mercury in the sludge was found in the exhaust gases. For all other metals, 99% ended up in either the ash or the wash water.

Thus, incineration is in effect only a means of sludge minimization. It is not a means of complete disposal since 30% of the dry solids remain as ash (Marx et al., 2004). The ash is classified as hazardous waste due to its content of heavy metals, and so incurs further expense for its disposal in landfill sites where the main concern now centers on leachate characteristics.

Results from a Department of the Environment UK report (1995) indicated that leachate from sludge ash is generally comparable with that from municipal refuse landfills and, because of its generally small volume, represents only a small potential source of pollution. In spite of this, there are opportunities for utilizing this ash, such as for construction materials, and using sludge as a fuel in cement production, whereby the ash becomes an integral part of the product.

2.6.4 Disposal on agricultural land

Application of treated sludge directly to agricultural land promotes sludge decomposition with subsequent benefits to soil and crop production. Sludge application in agriculture as fertilizer or irrigation water has been recognized as worthwhile, both environmentally and economically.

According to the Commission of the European Communities report published in 2000, “the use of sewage sludge on agricultural soils as fertilizer is held as the best environmental option provided it does not pose any threat to the environment or to animal and human health”.

Land application provides a feasible means of managing sewage sludge, while also providing farmers with organic matter to improve soil physical conditions and supplement conventional fertilizers usually at little or no cost (Muse et al., 1991).

Organic matter in the sludge improves the structure and the workability of most soils. Additional to that, organic matter also improves water retention, permits easier root penetration, and reduces water runoff and soil erosion (Horan, 1990; Pescod, 1992).

Sewage sludge contains many nutrients needed for plant growth such as nitrogen, phosphorus, potassium, zinc, and copper. However, the amount of nutrients in sludge vary from source to source, based on treatment process, origin, types, and quantity and quality of wastewaters treated (Muse et al., 1991).

Nitrogen (N), phosphorus (P), and potassium (K) levels in sludge are about one-fifth of those found in typical chemical fertilizers; therefore larger amounts of sludge must be added in order to achieve the same effects as that of a commercial fertilizer.

Therefore, sewage sludge can be considered a high volume, low analysis fertilizer (Jimenez et al., 2002).

Much of the nitrogen and phosphorous in sludge is in an organic form and not all readily available to plants. When applied to land, part of the organic nitrogen will be mineralized or biologically converted into ammonium (NH_{4}), nitrate ($N0_3$), or both to become available to plants over time. Some nitrogen in the sludge may be lost to the air during this process because of ammonia volatilization (Cornway and Pretty, 1991).

To reduce the amount of nitrogen lost, sludge is often injected or ploughed into the soil directly after application. Incorporation also reduces any potential for odor problems sometimes associated with land application of sludge.

Most sludge is low in potassium, and this nutrient may need to be added as a supplement to the sludge (Muse et al., 1991). However, excess nitrogen and potassium applied as plant nutrients have a tendency to seep into groundwater, and excess phosphorous may flow into surface water supplies with eroded sediment (Fatoki et al., 2003).

In order to prevent surface and groundwater pollution, sludge nitrogen should be applied in amounts that will be utilized actively by growing plants (Muse et al., 1991; Richards et al., 2004).

There is always concern about the presence of high levels of heavy metals when large amounts of sludge applied to land. This group of elements includes cadmium, zinc, nickel, copper, chromium, lead and mercury (Muse et al., 1991). These components usually occur in small amounts not harmful to plants. Some heavy metals including, zinc and copper, are micronutrients that are necessary for plant growth but excessive amounts of these heavy metals, as well as nickel can however be damaging to plants, resulting in reduced yields or even plant death (Santos and Tsutiya, 1997).

Usually, heavy metals are not very mobile and tend to accumulate in surface soils. Plant uptake of heavy metals is very low and generally the only method of removal of these metals from the soil. The most effective method to reduce heavy metal uptake by plants is to maintain a pH at or above 6.5. A near-neutral pH renders heavy metals insoluble and therefore not available to be taken up by plants (Muse et al., 1991).

Due to the high amount of pathogenic parasitic microorganisms of a faecal origin that they contain, the reuse of sludge in agriculture has been limited and not widely applied (Frakenberger, 1985; Marx et al., 2004).

The public is keen to accept that reuse can be beneficial, especially when associated with problems of bad odors, potential risk of bacterial, viral and parasitic diseases that can be transmitted from man-sludge-soil-crop-man and the attraction of vectors (Jimenez et al., 2002). This is especially true in developing countries where data on microbiological quality of sludge are almost non-existent in spite of the fact that this represents the main problem for disposal.

Thus, the disposal of sludge to agricultural land requires that the sludge must undergo biological, chemical or heat treatment, long term storage or any other appropriate process to kill off disease causing organisms which may be in the sludge.

2.6.5 Composting

Composting is an accelerated bio oxidation of organic matter passing through a thermophilic stage where microorganisms mainly bacteria, fungi and actinomycetes liberate heat, carbon dioxide and water (Dominguez et al., 1997). During the composting process, the heterogeneous organic material is transformed into a homogeneous and stabilized humus-like product.

As reported by Epstein (1997), advantages of composting, based on experience in North Carolina, USA are:

1. Reduced cost of sludge composting by using the solid waste as a bulking agent;
2. Incorporation of diverse waste streams (sludge, septage, solid waste, yard waste, organic industrial waste;
3. Lower capital costs than most alternative technologies;
4. Combining the cost of sludge and solid waste disposal;
5. Process flexibility through modular construction;
6. Reduced volume of mass of solid waste to landfills;
7. Good environmental control;
8. A usable, marketable product or products can be produced;
9. Compatibility with recycling.

However, the composting process has certain disadvantages including:

1. A composting facility takes up more space than combustion systems;
2. Labor requirements are generally high;
3. Landfill space for solid waste residuals is needed;
4. A product or products are produced which need to be marketed or utilized.

The discussion of sludge treatment and disposal technologies indicates that there is no single treatment and disposal option which does not pose some threat to the environment and/or human health.

Therefore, it may be desirable to investigate an integrated waste management system approach in order to determine whether a combination of treatment processes may be able to provide a safe, sustainable disposal of sewage whilst at the same time addressing some of the constraints to waste management initiatives in developing countries.

2.7 INTEGRATED WASTE MANAGEMENT SYSTEMS

Decisions on waste management strategies and the structure of waste management systems in the past relied either explicitly, or implicitly, on the 'waste management hierarchy' (DEAT, 2000).

Despite the variety in the exact form of waste management, it is usually given the following order of preference; waste reduction, re-use, materials recycling, composting, incineration with energy recovery, incineration without energy recovery and finally landfilling (White, 1997).

The 'waste hierarchy' ranks individual waste management options in a priority order, but cannot deal with two or more options integrated together.

The use of priority list for various waste management options has serious limitations, which include (McDougall, 2000):

1. The hierarchy has little scientific or technical basis. There is no scientific reason why materials recycling should always be preferred to energy recovery;
2. The hierarchy is of little use when a combination of options is used, as in an integrated waste management system. In an integrated waste management system, the hierarchy cannot predict for example, whether composting combined with incineration of the residues would be preferable to materials recycling plus

landfilling of residues. What is needed is an overall assessment of the whole system, which the hierarchy cannot provide;

3. The hierarchy does not address costs. Therefore it cannot help assess the economic affordability of waste systems.

Even though useful as a mental checklist, the waste hierarchy will not always indicate the most sustainable waste management option for particular waste streams (Department of Environment United Kingdom, 1995).

In line with the three pillars of sustainable development, waste management usually needs to be environmentally effective, economically affordable and socially acceptable.

Environmental effectiveness requires that the overall environmental burdens of managing waste are reduced, both in terms of consumption of resources including energy and the production of emissions to air, water and land.

Economic affordability requires that the costs of waste management systems are acceptable to all sectors of the community served, including householders, commerce, industry, institutions and government.

Finally, social acceptability requires that the waste management system meets the needs of the local community, and reflects the value and priorities of that society (White et al., 1995).

Along with the overall need for sustainable waste management, it is also becoming increasingly clear that no single treatment method can manage all material in municipal solid waste in an environmentally effective way (White & McDougall, 1998).

In integrated waste management, decisions on waste management take account of different waste streams, collection, treatment and disposal methods to achieve a balance between collection and treatment methods that strive for environmental sustainability, cost effectiveness and social acceptability (Thurgood, 1998; Wilson, 1998).

Following a suitable collection system, a range of treatment options will be required, including materials recovery, biological treatment, thermal treatment, packaging derived fuel and/or mass-burn incineration and landfilling (White, 1997). Such approach is advocated in the current United Kingdom waste strategy, ‘Making Waste Work’ which states that “…it is likely that an integrated approach, where each option contributes to the overall recovery of the waste, will usually be the preferred practice."

Although limited by technical and financial resources, developing countries have the potential to significantly improve management of sewage sludge and it is clear from the discussion above that the best path to take in order to make sludge management efficient and effective in these countries is one that follows and implements certain elements of integrated waste management. Instead of focusing primarily on attempting to make single treatment and disposal options work better, the focus should be shifted to using a combination of these methods so as to gain a management system that is environmentally, economically and socially acceptable.

Integrated waste management system employs a variety of inter-linked waste conversion steps to derive value from agricultural waste. Such approach should be investigated for disposal of sewage sludge, especially at smaller WWTPs in developing countries (Todd et al., 2003).

2.8 WASTEWATER IN JORDAN

2.8.1 History of Wastewater Treatment in Jordan

Wastewater collection has been practiced in a limited way in Jordan in1930 in Al Salt city. Some wastewater treatment was achieved mostly by utilizing primitive physical processes.

However, septic tanks and cesspits were used with gray water were often discharged to gardens. This practice resulted in major environmental problems, especially groundwater pollution. The pollution problems were also became complicated by the rapid urban growth.

Modern technology for the collection and treatment wastewater was introduced in the late 1960s when the first collection system and treatment plant was built at Ain Ghazal utilizing the conventional activated sludge process.

The system consisted of a sewage network that runs by gravity to the lowest point in Amman, where the treatment plant was located and built. The treatment plant was designed to handle an average flow of (60,000 m^3/day) with a BOD_5 loading of (18,000 kg/d), for a population of (300,000). The design effluent standard was BOD_5 (20 mg/l). The treated effluent was discharged to Sell Zarqa.

Nevertheless, due to the high strength of the raw sewage, the effectiveness of the activated sludge process was drastically reduced.

However, Ain Ghazal Treatment Plant continued to operate under high organic overloading conditions, which resulted in major operational and environmental problems. As a result, the treatment plant produced odors that were a source of public nuisance to the surrounding areas. The quality of the effluent deteriorated the quality of surface, ground and irrigation water in the region.

Since the year 1980 and during the International Drinking Water and Sanitation Decade (1980-1990), the Government of Hashemite Kingdom of Jordan carried out significant and comprehensive plans with regard to the different issues of wastewater management primarily related to the improvement of sanitation. About 75% of the urban population and 52% of the total population (at that time) gained access to wastewater collection and treatment systems. This has raised the sanitation level, improved public health, and strengthened pollution control of surface and groundwater in the areas served by wastewater facilities.

The characteristics of wastewater in Jordan are somewhat different from other countries. The average salinity of municipal water supply is (580 ppm) of TDS, and the average domestic water consumption is low. These results are in very high organic loads and higher than normal salinity in wastewater.

This is particularly applicable to wastewater treated in waste stabilization ponds (85% of the total generated wastewater), where part of the water is lost through evaporation, thus increasing salinity levels in the effluents. In addition, high organic loads impose operational problems where the plants become biologically overloaded with only a portion of their hydraulic loads.

Given the low level of industrial discharges to sewage treatment plants, wastewater in Jordan is comparatively low in toxic pollutants such as heavy metals and toxic organic compounds. It is estimated that 10% of the biological load comes from industrial discharges.

The major receiving streams for wastewater have very low flow with wastewater comprising a significant portion of stream flow. These streams are not used for bathing or fishing. Much of Amman's wastewater treated effluent is discharged in the Zarqa River and is impounded by the King Talal Dam where it gets blended with fresh flood water and is subsequently released for irrigation use in the Jordan Valley.

The flow of freshwater in Zarqa River, WadiShuieb, Wadi Al-Karak, Wadi Kufranja and Wadi Al-Arab dried up as a result of increased pumping from the aquifers, and the flow was replaced with the effluent of treatment plants, a process that transformed the ecological balance over time.

Varieties of crops are grown using irrigated wastewater including citrus, vegetables, field crops and bananas. Soil characteristics vary widely from sand to clay. Principal concerns in the use of wastewater for irrigation include its salinity, chloride concentrations, and the presence of fecal coliforms and nematode eggs. Concern about heavy metal, has not been substantiated but is an area of public concern warranting monitoring.

The Jordanian standards and regulations which specify the quality of the treated effluents allowed to be discharged into wadis or destined for reuse in agriculture, require a secondary level of treatment. Quality specifications follow the World Health Organization (WHO) guidelines for the safe use of treated effluent in irrigation.

2.8.2 Wastewater Management in Jordan

Since its establishment, the Government of Jordan is constantly thriving to better develop and further improve the environment and health services throughout the kingdom. In the first few years, Ministry of Water and Irrigation is considering reclaimed wastewater as one of its top priorities for its use as an additional water resource for restricted irrigation. Ministry of Water and Irrigation has given the wastewater sector topmost importance. Many projects have been implemented since its institution.

In Jordan, 27 WWTPs are currently operated serving more than 67 % of the population. Table (3) presents these WWTPs and some important technical information about each plant (KfW, 2010).

Table 3: Overview about the WWTPs in Jordan

No	Treatment plant name	Year of Operation	Treatment technology	Design flow [m³/d]	Actual avg. flow [m³/day]	2010 Liquid Sludge [m³/d]	Technical Notes
1	Aqaba Natural	1987	WSPs	9,000	6,731	150	ok
2	Aqaba Mechanical	2005	EA	12,000	9,846	232	ok
3	Al Baqa	1987	TF	14,900	10,209	250	ok
4	Fuheis	1997	ASS	2,400	2,221	16	ok
5	Irbid Central	1987	TF-ASS	11,023	8,132	210	*
6	Jarash (East))	1983	EA	3,250	3,681	100	ok
7	Al Karak	1988	TF	785	1,753	10	*)
8	Kufranja	1989	TF	1,900	2,763	60	*)
9	Madaba	1989	ASS	7,600	5,172	250	Ok
10	Mafraq	1988	WSPs	1,800	2,009	47	*)
11	Ma’an	1989	EA	5,772	3,171	100	Ok
12	Abu Nuseier	1986	ASS-RBC	4,000	2,571	60	Ok
13	Ramtha	1987	ASS	7,400	3,488	100	Ok
14	As Salt	1981	EA	7,700	5.291	130	Ok
15	Tafila	1988	TF	1,600	1,380	8	Ok
16	Wadi Al Arab	1999	EA	21,000	10,264	240	Ok
17	Wadi Hassan	2001	OD	1,600	1,132	40	Ok
18	Wadi Mousa	2000	EA	3,400	3.029	100	Ok
19	Wadi as Seeier	1997	AL	4,000	3,624	86	Ok
20	Alekeder	2005	WSPs	4,000	3,908	92	Ok
21	Allijoon	2005	WSPs	1,000	853	20	*)
22	Tall Almantah	2005	TF-ASS	400	300	7	ok
23	Al- Jiza	2008	ASS	4,000	704	17	New
24	As Samra	1984	ASS	267,000	230,606	3,000	ok
25	Al- Merad	2010	ASS	10,000	1,000	24	ok
26	Shoobak	2010	WSPs	350	100	2	ok
27	Al- Mansorah	2010	WSPs	50	15	0.4	ok
	Total				323,951	5,352	

WSPs: Waste stabilization ponds; TF: Trickling filters; AS: Activated sludge; RBC: Rotating biological contactors; OD: Oxidation ditch; AL: Aerated lagoons; *) upgrading is planned

Salah (2011) reported on major reused wastewater quantities and irrigated areas through contracts (Table 4) issued by the Water Authority of Jordan and farmers.

Table 4: Quantities of reclaimed water and irrigated areas by contracts with farmers

WWTP's	Quantities used m^3/Year	Irrigated Areas [dunum]
AL Samra	2,303,756	2103.88
Mafraq	420,501	384.020
Baq'a	638,118	436.589
Salt	87,096	79.54
Ma'an	224,628	205
Karak	316,920	289.27
Kufranja	186,980	170.75
Madaba	1,432,884	1308.57
Ramtha	1,309,620	1196
Akeder	1,128,675	1030.75
Tafeleh	125,125	114.269
Wadi Seer	67,693	61.28
Shria	209,145	190.79
Total	8,435,732.25	7,746.253

2.8.3 Reuse Standards in Jordan

The standards in Jordan are issued by the Jordanian Institution for Standards and Metrology (JISM). Standards are set by technical committees formulated by The Institution for Standards and Metrology from members representing main stakeholders concerned with the subject. All concerned parties have the right to express their opinion and comments on the final draft of the subject standard during the notification period in order to make the Jordanian standards in harmony with international standards, to alleviate any technical boundaries facing trade and to facilitate flow of commodities between countries.

Based on this, the permanent technical committee for water and wastewater No.17 has set the Jordanian Standard 893/1995 dealing with "Water-Reclaimed Domestic Wastewater" and recommended its approval as a Jordanian Technical base No. 893/2002 in accordance with article (11) paragraph (b) of the Standards and Metrology Law No. 22 for the year 2000.

The Reclaimed Domestic Wastewater standard has two primary components:

1. Reclaimed water discharged to streams, wadis or water bodies.
2. Reclaimed water for reuse.

Reclaimed water must comply with the below conditions stated in this standard for each of its planned end uses.

1. It is not permitted to dilute or mix reclaimed water discharged from wastewater treatment plants with pure water intentionally to comply with the requirement set in this standard.
2. Should reclaimed water be used for purposes other than those mentioned in this standard (such as for cooling or for fire distinguishing), special standards or guidelines are to be applied in each case after conducting the necessary studies taking into consideration the health and environmental dimension.
3. Official and specialized concerned parties overseeing the operation and development of wastewater treatment plants must always work towards improving the effluent quality to levels, maybe, exceeding those presented in this standard to ideally use the reclaimed water and protect the environment.

2.8.4 Reclaimed Water for Reuse

This part of the standard consists of reusing reclaimed water for artificial recharge of groundwater aquifers and for irrigation purposes.

Reclaimed water reuse for Irrigation: the item concerned with reclaimed water reuse for irrigation purposes consists of two main groups; standards group and guidelines group:

1. Standards group: is the group of properties and standards that are presented in Table (5) and where operating parties must produce water complying to it and according to the usages mentioned in this standard.
2. Guidelines group: The guidelines group shown in Table (6) is considered for guidance only and in case of exceeding it values the end user must carry out scientific studies to verify the effect of that water on public health and the environment and suggest ways and means to prevent damage to either.

Table 5: Allowable Limit for properties and criteria for reuse in irrigation (JISM, 2006)

Parameter	**Unit**	**Cooked Vegetables, Parks, Playgrounds and Sides Roads**	**Fruit Trees, Sides of Roads outside city limits, and landscape**	**Field Crops, Industrial Crops and Forest Trees**
		A	B	C
Biological Oxygen Demand	mg/l	30	200	300
Chemical Oxygen Demand	mg/l	100	500	500
Dissolved Oxygen	mg/l	>2	-	-
Total suspended solids	mg/l	50	150	150
pH	Unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70
Escherishia Coli	MBN/100 ml	100	1000	-
Helminthes Eggs	Egg/l	< or = 1	< or = 1	< or = 1

Table 6: Guideline for reuse in agricultural irrigation (JISM, 2006)

Group B			
Fat And grease	FOG	mg/l	8
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	100
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	T-PO4	mg/l	30
Chloride	Cl	mg/l	400
Sulfate	SO4	mg/l	500
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	230
Magnesium	Mg	mg/l	100
Calcium	Ca	mg/l	230
Sodium Adsrptn Ratio	SAR	-	9
Aluminium	Al	mg/l	5
Arsenic	As	mg/l	0.1
Berelium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2
Floride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5(0.075 for citrus crops)
Manganese	Mn	mg/l	0.2
Molibdinum	Mo	mg/l	0.01
Nikel	Ni	mg/l	0.2
Lead	Pb	mg/l	5.0
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.1
Mercury	Hg	mg/l	0.002
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

2.8.6 Laws and standards with regard to reuse of sewerage sludge

The treatment and reuse of sludge is directly regulated with a standard, but also other laws control the reuse with clear monitoring responsibilities. In general, one needs to question, if composted sludge can still be considered as sludge, because ideally it contains at least 50% of additional input material such as plant residues, which is not regulated under this standard.

2.8.7 Jordanian Standard JS 1145-2006

The treatment and use of sewage sludge is regulated under the Jordanian Standard **JS 1145-2006.** This standard considers sludge as a resource and outlines the treatment options for sludge, and the maximum allowable concentrations of various chemical and biological parameters in treated sludge. It also outlines the allowed uses and proper methods for disposal of treated sludge. Three classes of sludge quality are described, depending on the content of heavy metals and level of treatment to reduce the pathogen content, as follows:

1. Type I–sludge may be used as fertilizer for agricultural purposes or for improving soil characteristics (as soil amendment).
2. Type II – sludge may be used as a soil amendment in areas which are not accessible to the public. In other words, it is not allowed to be used in public parks, household gardens, or landscaping adjacent to residential areas. However, it could be used as a soil amendment cultivated with fodder crops (no vegetables and root crops).
3. Type III – sludge is permitted to be landfilled. (Valid for Type I and Type II.

The standard stipulates that both Type I and Type II sludge can be used for agriculture; however, Type II can be used only as a soil amendment during land preparation. Table (7) summarizes the required quality parameters for Type I and Type II sludge.

Table 7: Excerpt of the Standard 1145/2006 quality requirements of sludge reuse

Minimum Monitoring Requirements for Regulatory Compliance – Sludge/Sludge Compost				
Test/ Parameter		**JS 1145/2006 Limit for Type I**	**JS 1145/2006 Limit for Type II**	**Units**
Arsenic	As	41	75	mg/Kg (dry)
Cadmium	Cd	40	40	mg/Kg (dry)
Chromium	Cr	900	900	mg/Kg (dry)
Copper	Cu	1500	3000	mg/Kg (dry)
Mercury	Hg	17	57	mg/Kg (dry)
Molybdenum	Mo	75	75	mg/Kg (dry)
Nickel	Ni	300	400	mg/Kg (dry)

Table 7 continued

Selenium	Se	100	100	mg/Kg (dry)
Lead	Pb	100	840	mg/Kg (dry)
Zinc	Zn	2800	4000	mg/Kg (dry)
Moisture Content (max.)		10	50	%
Fecal Coliform (total)		1000	2.000.000	MPN/g
Nematode Eggs		4	-	egg/g
Calcium	Ca	-	-	mg/Kg (dry)
Magnesium	Mg	-	-	mg/Kg (dry)
Total Nitrogen	TN	-	-	
Total Organic Matter	TVS	-	-	%
Potassium	K	-	-	mg/Kg (dry)

Notes:
JS 1145/2006, Part 8-6, Table 3 - Quantities of Produced Sludge and Sequence for Testing: requires analysis once each 2 months for facilities producing between 1,500 - 15,000 tones/year.
JS 1145/2006, Part 9 - Quality Control of Treated Sludge: requires collection of 3 samples.

The standard also stipulates application rates according to the nutrient or heavy metal concentration. However, there is a general limit of "not more than 6 tons/ ha" that massively limits the application of sludge on soils. The rule is not clear on whether the application rate refers to dried sludge or dry sludge solids. It also provides guidance on the suitable application time for various crops.

2.8.8 Agricultural Law of 2002

The Agricultural Law states: "The Ministry of Agriculture is responsible for agricultural consultation and research." As noted in Article 7c of the law, the Ministry is assigned the role of protecting human life from any risks related to agricultural products or the spread of any related disease. Instructions detailing the conditions for using treated wastewater are issued by the Minister of Agriculture. Entities using wastewater that are not compliant with the JS 893/2006 for irrigation will be subjected to fines and potentially destruction of their crops.

2.8.9 Soil Protection Bylaw (No. 25 of 2005)

Article 3e of the Soil Protection Bylaw states: "The Ministry of Environment in coordination with the Ministry of Agriculture is responsible for studying the sites of development projects and their impact on land and natural resources." Environmental considerations should be taken into account when developing these projects.

2.9 SLUDGE PROBLEMS IN JORDAN

According to KfW report (2012), the sludge problems in the WWTPs in Jordan can be summarized in the following points:

1. Sludge is not stabilized in most of the WWTPs in Jordan and accordingly causes odor and environmental problems.
2. Dewatering characteristics of not stabilized sludge are less favorable
3. Existing drying beds are not in operation mainly due to mentioned problems
4. The majority of the WWTPs do not operate digesters for anaerobic sludge stabilization
5. Liquid sludge transport causes high operation cost
6. Mechanical sludge dewatering is presently not under practice in Jordan
7. The presently practice of sludge landfilling is ecologically critical and not sustainable
8. None of the generally applied disposal methods, nor land-use, nor landfill, neither incineration are presently under practice in Jordan

2.10 PRIVATE SECTOR PARTICIPATION AND PRIVATE PUBLIC PARTNERSHIP IN THE WATER SECTOR

2.10.1 Needs for the involvement of the private sector

According to the Development Bank for Reconstruction and Development (2006), the provision of water services is unsatisfactory in many developing countries.

Many people do not receive water from the main water utilities, even though they would be prepared to pay for the services. Others are connected, but get water for only a few hours a day. Even fewer are connected to a sanitation network. Often the water is not safe to drink and wastewater is not properly treated.

The Dublin Water Conference 1992 described water as a social and an economic good. Never the less, the World Water Vision called for full cost pricing to encourage water conservation, to ensure water availability and to pay for the proper operation and maintenance of infrastructure, including wastewater treatment to prevent water pollution (Cosgrove and Rijsberman, 2000).

As known, the lack of money is a major part of the problem. If customers have more to spend on services and the government has more tax revenue, solutions would be easier. Yet the problems run deeper than money: water services have characteristics that create special problems for public policy (Angel, 1996).

Water services can create benefits for people not receiving the services, for example sanitation services can reduce the spread of diseases, thereby bringing to a community major benefits for which individual customers may not be willing to pay (Angel, 1996).

Other problems are created by the fact that the assets of water utilities are largely underground and their condition cannot easily be appraised by newcomers. This makes it harder for companies to make sensible bids when governments auction the right to provide services, and harder for the government to set appropriate prices for water services. Still more problems are created by the fact that local, provincial, and central governments may have overlapping responsibilities.

Never the less, three other factors may also create serious obstacles under both public and private operation to achieving a government’s goals in the water industries (International Bank for Reconstruction and Development, 2006):

1. Water services are critical and essential to all consumers.
2. They are often provided under conditions of natural monopoly; one well running firm can supply the services at a lower cost than two or more other running firms.

3. The investments required to provide the services are often long-lived and irreversible; once made, they cannot be reversed unless the returns to the investment prove less than expected.

The combination of these factors leads to trouble. The first two factors mean customers tend to doubt that they are getting a good deal and thus they will typically resist any increasing in the prices even when prices are lower than costs. As a result, governments face strong pressure to keep prices below costs.

Whilst the third factor means that governments can accede to that pressure without causing suppliers to cease providing services, so long as prices remain above operating costs. So prices are often too low to cover full costs, including investment and repairs to infrastructure.

Yet, unless governments make up the difference between prices and costs with subsidies, providers, whether public or private it will not invest. Private providers will not invest because they do not believe investment will be profitable and non for- profit public providers will generate too little cash to finance investment internally and will be insufficiently creditworthy to finance it externally.

The biggest challenge for governments with either public or private operations to address these problems and thus encourage investment to improve quality, lower costs, and extend access (Lars et al., 2002).

Public private partnerships (PPPs) are a tool, where utilities can use to ensure efficiency in running water and wastewater facilities. Under PPPs, the public partner owns the assets, controls the management of the assets, and establishes user rates. The private partner operates and maintains the facility under a contract with the public partner (Tang et al., 2010).

Two common approaches have been used by governments for the implementation of public-private partnerships PPPs: a finance-based approach that aims to use private financing to satisfy infrastructure needs, and a service-based approach that aims to optimize the time and cost efficiencies in service delivery. However, the implementation of PPPs may suffer from legal, political, and cultural impediments (Abdel Aziz, 2007).

As depicted in Figure 4 (Tang et al., 2010), it should be clearly defined that a partnership is not privatization. Although the terms "public-private partnership" and "privatization" often are used interchangeably, they are not the same. Figure 1 shows 6 PPPs forms (Table 8).

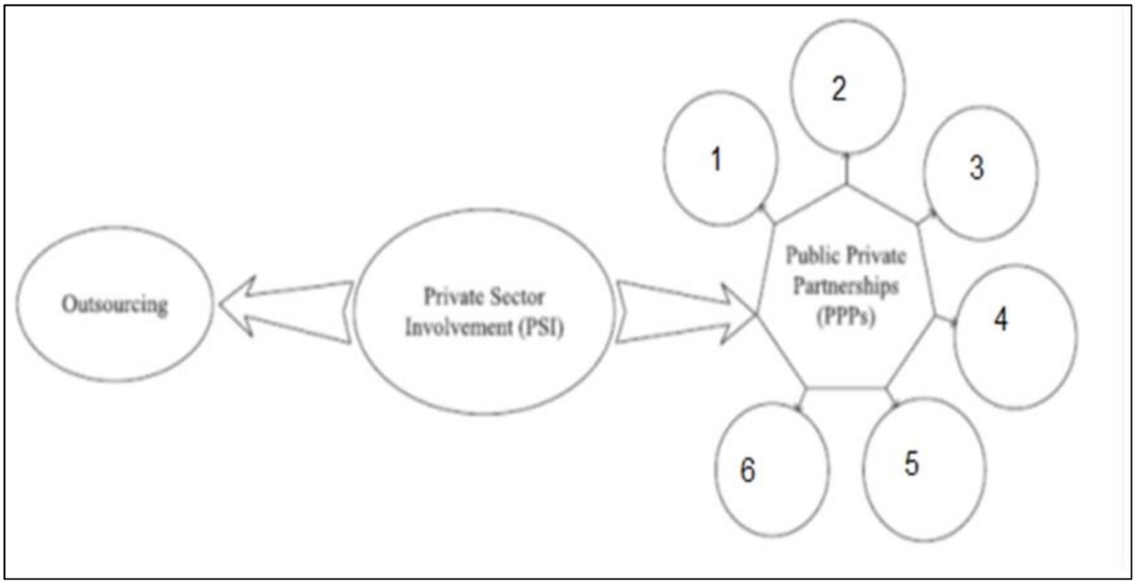

Figure 4: The PSI and the PPPs forms (1-6, see Table 8)

Privatization involves the sale or transfer of ownership of public assets to the private sector. While, under all public private partnerships, the public partner owns the assets, controls the management of the assets and establishes user rates (Patrick and Christopher, 2001).

On the other hand, the private partner operates and maintains the facility under a contract with the public partner (Patrick and Christopher, 2001).

Sagalyn (2007) contended that existing Public Private Partnership (PPP) projects have three generations. In the first generation, mistakes easily emerged due to lack of experience by public and private partners and their consultants. In the second generation, large development companies developed specialized.

As a result of social development, the third generation has emerged, which are urban PPP projects initiated by developers seeking private-sector involvement.

The number of PPP projects is expanding in the third generation and it is anticipated that they will be used more widely in public service, city reconstruction, and so forth. The idea of allowing private firms to finance projects of public sector infrastructure results in the emergence of PPPs (Li and Akintoye, 2003; The World Bank, 1992).

Table 8: The Efficiency Unit description for the different forms of the PPPs

No.	PPP Form	Description
1	Creating wider markets	Mean to utilize the assets in terms of skills and finance from both the public and private sectors.
2	Private Finance Initiatives	Involve the public sector purchasing quality services while the private sector maintains or constructs the necessary infrastructure. The private sector supplies designs, builds, finances and covers the costs through charges on the users of the asset.
3	Joint ventures	Mean that the public and private sectors pool their assets, finance and expertise under joint management. Under this type, the private sector participates more in management.
4	Partnerships companies	Introduce private sector ownership into state-owned businesses through legislation, regulation, partnership agreements, or retention of a special government share.
5	Partnership investments	Ensure that the public sector shares in the return generated by investments made by private sector parties.
6	Franchises	Mean the private sector pays a fee during the concession period awarded by the government for the revenue (or a share of the revenue) that the service generates.

However, PPP has various definitions due to the many forms of PPP projects and situations in different countries. In the UK, the United Nations Development Programme (2007), when planning PPPs for the Urban Environment, stated that the definition of the PPP should be broad such that even the informal dialogues between government officials and local community-based organizations, which are perceived to be essential to successful PPPs, should be included.

In the US, the National Council for Public Private Partnership defines a PPP as a “contractual arrangement between a public sector agency and a for-profit private sector developer, whereby resources and risks are shared for the purpose of delivery of a public service or development of public infrastructure” (Li and Akintoye, 2003).

In Canada, the Council for Public Private Partnerships (2004) defines a PPP as a “cooperative venture between the public and private sectors, built on the expertise of each partner, which best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards".

In Hong Kong, the Efficiency Unit (EU) has developed another definition. The EU (2005) created a new focus on private sector involvement (PSI) to "assist the government in meeting its priorities, building on the clear recognition that public funds are limited".

As defined by the EU, the PSI has two forms: Outsourcing and Public Private Partnerships (PPPs). It introduced the concept of PPP for the maintenance of infrastructure facilities in Hong Kong, and defines a PPP as "arrangements where the public and private sectors both bring their complementary skills to a project, with varying levels of involvement and responsibility, for the purpose of providing public services or projects".

The Efficiency Unit describes six forms of PPPs; the PSI forms and the PPPs forms are shown in Figure 4. Tang (2010) listed in Table 8 the different PPPs forms as defined by the efficiency units. However, another form that is not mentioned above is the Build–Operate–Transfer (BOT) which can be regarded as another form of PPP. In a BOT project, the private sector 'builds' the project, 'operates' it for a concession period, and, at the end of the period, 'transfers' it to the client without consideration.

Yaron (2000) also described four different privatization models. These models range from the most to the least degree of public control (Table 9).

Table 9: Privatization models and corresponding responsibilities

Model	**Responsibilities**
Operations and lease contracts	Governments will outsource specific tasks to private firms. Investment funds are often provided by development bank loans to the government.
BOT contracts	The private partner must build and operate the system and transfer all assets to the government immediately or following the contract term.
Concessions	Full operational responsibility and commercial and investment risk are placed on the private sector.
Divestitures	Ownership is completely transferred to private interests.

The involvement of the private sector changes the water sector by introducing an operator that is independent of the government and has a strong incentive to be profitable. This obviously creates problems for the government. A private provider cannot be directed in the same way as a public provider and its profit incentive can cause it to take actions that are not in the public interest. Yet, independence and the profit incentive may also support the government to achieve its goals (Lars at al., 2002).

Private participation may have effects in three areas:

1. The operating performance of the utility
2. The utility's investment decisions
3. Policy and its enforcement.

2.10.2 Operating Performance

The private provider's profit incentive, its expertise and professionalism may cause it to operate more efficiently than its public counterpart. For example, the private operator may provide services with less staff and be more diligent in billing customers and collecting payments from the public operator.

The private provider is likely to retain as profits at least some of the benefits of improved operating performance. Nevertheless the improvements can also allow lower tariffs for customers, reduced subsidies from the government, or higher quality services for the same level of tariffs and subsidies. However, if the private provider can keep at least part of the increase in profits as a result of the improvement in the billing and collection and can disconnect long term nonpaying customers, billing and collection should be improved.

However, if the rules governing price setting are completely cost-plus, and if the operators cannot disconnect nonpaying subscribers, private provider participation is unlikely to improve billing and collection of water utilities.

2.10.3 Investment decisions

The profit incentives may lead the private provider to make better and more investment decisions to increase the revenue. It may miss fewer profitable opportunities to expand the business, such as extending access to unconnected households that want service and can pay for it.

Also, the private provider may build fewer “white elephants,” or projects with more costs than benefits.

For example, if the private provider has some responsibility for determining and financing investment, if prices cover costs and can be expected to do so in the future, and if the operator keeps some of the profits that result from increasing access, the private provider can be expected to invest in increasing access. On the other hand, if extending access to poor households will cost the private provider more than it gains in revenues and subsidies, or avoids in contractual penalties, it cannot be expected to increase access.

2.10.4 Water Policy and its enforcement

The presence of independent private providers will strongly influences government policies toward water services and the way it is enforced.

However, the private provider will seek always to shape policies in its favor. For example, a private provider may offer bribes to achieve favorable arrangements, and some politicians and officials may be willing to trade policy for money.

These problems are not specific only to private provider participation, lobbying and corruption occur under public provision as well. However, they definitely increase the challenge of designing and enforcing good arrangements. In general, private provider participation may still improve policy and its enforcement in water sector.

For example, if the government enforces the private operator to compliance with environmental standards more rigorously than it enforces compliance by public agencies, private participation may lead to environmental benefits and protection, even if the private provider has no fundamental interest in the environment.

Private participation also offers the prospect of changing policy in a way that alleviates the fundamental problem set out earlier—namely, that the politics of water pricing lead to prices being set below costs, frustrating the extension of access. A private firm that finances investment cares deeply about the rules for setting prices and subsidies, because those rules determine whether it gets its money back. The private provider will therefore insist, before investing, that the government establish clear and prospectively stable rules for setting prices and subsidies. And thereafter it will try its best to hold the government to its promises. If stable rules about pricing and subsidies are achieved, that should encourage investment and thus help the government achieve its objective.

In these cases, the potential advantage of private participation is indirect: the benefits come from good rules and enforcement, not private participation, but good rules and enforcement may be encouraged by private participation.

There are private water utilities in almost every part of in France, some of which were already established more than a hundred years ago, whereas in Great Britain, the privatization process was initiated just at the end of the 1980s.

On the other hand, the Netherlands, decided by vote of parliament not to allow any form of privatization on the water supply and disposal sector whatsoever; all related tasks are being concentrated on a few enterprises over which the municipalities retain ownership and with that control. In Germany the first approaches towards privatization of the water sector was in the 1980s; but the share of privately organized wastewater disposal operations still is in the range of 5% only (Beckereit and Stemplewski, 2002).

The situation worldwide can be summed up as follows. Around 80% of the world's population has no connection to sewers at all. While 16% of the population is connected to publicly owned sewerage systems, only 4% are to privately owned disposal systems. And private engagement within this 4% share is often limited either to participations in the enterprises concerned or to wastewater treatment services (Grünebaum and Bode, 2004).

In principle, it can be said that neither the legal and organizational form (public/private), nor the scale of operation can be regarded as guarantor per se for economic efficiency and successful performance (Braadbaart, 2002).

The most benefits of transferring tasks from public authorities to private organizations are the following:

1. Enhanced efficiency by introduction of competitive elements and the principles of private-enterprise to unlock saving potentials,
2. Use of synergy forces – helping to comply with the tasks in hand within an extended scope of action thanks to the availability of private-sector expertise – whether the area of responsibilities is expanded horizontally (which means by taking over tasks of

exactly the same type, e.g. an additional catchment) or vertically (taking over additional, yet similar tasks, e.g. wastewater treatment and potable water treatment),

3. Raising of additional (private) capital otherwise not available on the public sector,
4. Earmarking of gains on disposal to ease the stress on public budgets,
5. Modifying and streamlining of organizational and operational structures of public bodies, otherwise hardly or even never enforceable,
6. Limiting cross subsidization to finance other public tasks through wastewater rates, otherwise frequently practiced, thanks to additional control by private shareholders.

Experiences from some countries show that outsourcing involves an immense control effort on the part of the state. That means, public authorities would not only have to monitor the proper performance of all operations, but also the pricing policy as private sector companies might be tempted to raise water rates in order to maximize profits (Grünebaum and Bode).

If this control is not successful privatization might end in fees which are much higher than they would have been if the task would have remained in public hands.

Table 10 (Braadbaart, 2004) lists the private water and sewerage projects in middle and low income countries recorded in World Bank database in the first generation of PPP from 1990 to 1998. According to Braadbaart (2004), Table 11 shows the duration of 155 contracts. As may be seen, about two-thirds of all contracts franchised all or part of the water business to private providers for periods ranging from 20 to 40 years.

Table 10: Private water and sewerage projects in middle and low-income countries

Contract mode	No. of projects	Value (in US$ x 10^9)
Private concession contracts	48	19.91
Private BOT contracts and BOT variants	30	4.03
Private contracts, other	13	Not available
Permanent divestitures	6	0.99
Total	97	Not available

Table 11: Contract lengths of water and wastewater PPPs in low and middle income countries

Duration of contract (years)	Number of contracts	Share (%)
Up to 2.5	11	7
3–9	24	15
10–19	21	14
20–29	62	40
30 and more	37	24
Total	155	100

According to the U.S. Environmental Protection Agency's (EPA) guidance on the privatization of federally funded wastewater treatment works "the private sector has the potential to be a significant partner in the development of the wastewater infrastructure in this country" (EPA, 2000).

2.10.5 Why municipalities contract a private sector to provided wastewater services?

From its experience operating plants and facilities, a private company brings knowledge about the most efficient and effective way to manage and operate a wastewater treatment facility. With this knowledge, a private company can recommend improvements in the treatment process and suggest more efficient operations, such as new methods for treating wastewater or more effective techniques for laboratory analysis (Mays et al., 1999).

In addition, a private company brings knowledge of the most up to date technologies to the system's staff. This often results in cost savings to cities with privately operated plants.

For example, when the city of Somersworth, New Hampshire, decided to bring a private company for operating its wastewater treatment plant, it identified several significant issues that needed to be addressed. The status of the safety program, along with a much needed headwork upgrade, were growing concerns of both plant staff and city management. During contract negotiations, the private company's creative solutions, experience running municipal facilities and its resources resulted in the city's saving hundreds of thousands of dollars (Mays et al., 1999).

The municipalities that are responsible for water services will enter into a partnership to:

1. Ensure Technical Expertise. Water and wastewater operations are just a small part of a municipality's daily business. In contrast, private partners focus their businesses on operation and maintenance of these facilities.
2. Ensure Water Quality and Achieve Regulatory Compliance. A private partner's ability to secure new contracts rests to a significant degree on how well it manages its existing contracts. Therefore, private partners have powerful incentives to comply with all applicable federal and state regulations and standards.
3. Increase Operating Efficiencies. A public-private partnership often results in increased operating efficiencies and annual operating cost savings to the municipality.

The implementation of public private partnerships for operation and maintenance of water and wastewater facilities in the United States has been both praised and challenged (Patrick and Christopher, 2001).

Patrick and Christopher (2001) interviewed 31 representatives of public entities that outsource the management, operation and maintenance of their water and/or wastewater facilities to a private partner in whole or in part.

The interviewed facilities serve populations ranging from 4,000 to 1.2 million. The total population covered by the surveyed partnerships is 4.7 million.

The municipalities surveyed by Patrick and Christopher (2001) entered into public private partnerships to save money, gain operating expertise, and improve compliance with environmental regulations.

Table (12) below listed the impacts of the private operators based on the responses of the surveyed municipalities on the environment, on the customers, on the municipalities, and on the employees.

Table 12: Summary of the impact of the private sector on the surveyed utilities in the US

Sector	**Impacts**
Impact on Environment	Many respondents cited improving environmental management as the main reason that they enter into a partnership. This survey used regulatory compliance to measure environmental management. Municipalities work with their private partners to bring the municipality back into regulatory compliance efficiently and cost-effectively. In addition, the private partner has a large incentive to be in compliance. If a plant is out of compliance, the private partner, not the municipality, is often responsible for the fines. Respondents believe that this focus on environmental compliance is coming straight down from the highest levels of their private partner companies.
Impact on Customers	Usually, partnerships often benefit the customer or at least have no negative impact on the customer. Patrick and Christopher (2001) used three criteria to evaluate the impact on customers. The first criterion was the frequency of customer complaints in comparison to before the partnership. The second criterion was how customer rates have changed during the partnership while the third was whether or not the private partner makes a positive contribution to the community and the customer above and beyond what is mandated in the contract. In 37 percent of the partnerships surveyed, customer complaints decreased. In 56 percent of the partnerships surveyed, the number of customer complaints remained the same. In two cases (7 percent), the frequency of customer complaints increased after the partnership began.
Impact on Municipalities	The municipal officials saw real and tangible benefits from the Public private partnership. One of the most important benefits they cite was having access to greater expertise than they would otherwise. Other benefits respondents cited included: 1. Handling employee relations and benefits; 2. Providing the same level of service at a lower cost; 3. Assuming liability and risk for environmental compliance; 4. Recruiting and retaining operators; and 5. Purchasing materials in an expedited manner. Specific reasons mentioned by respondents for their high ratings include: 1. The private partner found and fixed the wastewater treatment odor problems; 2. The private partner is able to bring in outside expertise; 3. The private partner is able to leverage the expertise of employees throughout the company; 4. The private partner focuses on training for the employees; 5. The private partner keeps the municipality in compliance. Only 46 % of the surveyed municipalities projected cost savings before entering into the partnership. 92 % of those respondents noted that projected cost savings were achieved, and the other 8 % noted that it was too early in the contract term to know. Savings ranged from 5 % to 25%. Respondents mention that their private partners were able to keep costs

	down through: 1. Making high volume purchases for such things as chemicals; 2. operating the plants with fewer personnel; 3. Investing in technologies; 4. Reducing overhead costs; and 5. Performing preventive maintenance programs. The other 54 % of municipalities may have entered into the partnership because they were out of compliance with environmental regulations, or because the municipality did not have the appropriate personnel. All of those municipalities reported that regulatory compliance were equal or even better and that their partners make a positive contribution to the community above what is required in the contract.
Impact on Employees	For both the private operator and the public authority, enhanced training translates to more efficient and environmentally sound facilities. For the employees, enhanced training means more professional growth and advancement opportunities. Respondents mentioned that employees are generally satisfied with their partnerships. Initially, employees were apprehensive about working for a private firm as opposed to a municipality. They fear job loss, reduced salaries and benefits, and loss of union representation. In 29 % of the partnerships surveyed, the municipality required contractually that the partner at least maintain salary and benefit levels. Employees have the option of staying with the city taking a buyout, or being hired by the private partner, some of respondents indicated in open responses that if they would give this opportunity they will prefer going with private sector, stressing on the fact of increasing morale and satisfying if the employee when they feel comfortable and settled.

2.10.6 Advantages and Disadvantages of PPP

One of the main advantages of the PPP approach is it can save resources of the government in several ways. The government can concentrate on its core competencies, and does not need to rely on its resources for unfamiliar projects (Cumming, 2007). However, because of the private sector participation, government assets, data and intellectual property can also be utilized more productively, which leads to substantial improvement in the quality of public facilities and services (Edkins and Smyth, 2006). On the other hand, by proper use of the private sector’s skills, experience, technology and innovation, public services can be delivered more satisfactorily. Another advantage of the PPP approach is that the public and private sectors can share risks at different stages (Shen et al., 2006). As the private sector brings commercial disciplines into public projects, the risk of cost overruns and project delays can be drastically reduced (Li and Akintoye, 2003; Holmes, 2006). To finish the design, build, and operation stages with PPP, the private sector can help to make a leaner civil service structure with a more efficient hierarchy of responsibility for services delivery (EU, 2005).

Other than the advantages for saving resources and more efficient use of them, the economic aspect can be improved by using the PPP approach. For example, it has been showed that PPP leads to the reduction of lifecycle costs (Li and Akintoye, 2003), since these projects spread government capital investment over the life of a project. This guarantees the expected rate of return for governmental investment.

Although PPP is perceived as a way of creating public infrastructure at little or no cost to the public purse, it is still the notion that "there is no free lunch" is true (Kumaraswamy and Zhang, 2001). Kumaraswamy and Zhang (2001) presented several cases of BOT ventures that had run into problems due to cost overruns, unrealistic price and income projections, and legal disputes between private operators and the government. In virtually all of these cases, the government and the general public, but not the private operators, have ultimately shouldered the cost of failure. Their research led us to focus on the point of view from the public sector about the failure of PPP performance.

Practitioners have indicated that political obstacles stand in the way of using PPPs (Algarni et al., 2007). This view is not surprising since PPPs projects always need special legislation. In most circumstances, the municipal or state legislature has to discuss this issue at length before legislation is enacted to regulate the use of PPP. Also, some government agencies may exhibit resistance to change in the context of adopting a new delivery/financing approach. The PPP method of project development may not be well understood and sometimes may not be well received by the government agencies that handle it (Tang, 2010).

2.11CHALLENGE OF GETTING PRIVATE SECTOR TO WATER SECTOR

Two major things should be done properly to achieve the possible benefits from the participation of the private providers (Asian Development Bank, 2000).

1. Giving the private provider the ability and incentives to make good operating and investment decisions. This means giving the provider enough freedom to make decisions and exposing it to the related business risks, so that it gains when getting decisions right and loses when getting them wrong. The provider should be allowed to

do well when it improves the business, but likewise it should bear the risks it has agreed to bear; it should not automatically be able to renegotiate the agreement when its profits decline.

2. Protecting the operator from the risk of losing from the government changing the rules of the game rather than from bad operating and investment decisions. This means protecting the operator from the risk that the government will opportunistically cut prices after the operator has invested, or take similar actions that undermine the investor's profitability.

The past experience has shown that it can be difficult to get these things done right. Many arrangements for private participation in water services have been cancelled, or at least run into trouble, as either customers or the operator or both of them have felt that the arrangements have not been fairly implemented.

Making progress is partly a matter of writing pricing rules into contracts or other legal texts that cannot easily be changed without both the government's and the operator's agreement and allowing disputes to be settled by independent experts or arbitration when local courts are not trusted. But for the arrangement to work well, the government must create an arrangement that most people perceive as fair.

2.12 PRIVATE SECTOR PARTICIPATION IN WATER SECTOR IN JORDAN

In 1997 the Jordanian government embarked upon a privatization program, the goal being to orient Jordan's economy more towards the private sector and best present Jordan to the international financial community.

The specific objectives of the program were to increase the efficiency of enterprises, consolidating public finance and attracting private investment into the economy. In response to a parliamentary request, the government developed a strategy for the privatization program for appropriate situations, including management contracts and other privatization systems.

It has been noted that the major underlying and significant contributing factor to the privatization success to date has been the emerging and unequivocal support at the highest level for privatization transactions.

As part of the privatization process promoted by the government of Jordan, the Ministry of Water and Irrigation (MWI) has produced a number of key policy documents, including Jordan's water policy, groundwater policy and water utility policy.

However, Jordan engaged in active privatization in 1996 and adopted a privatization law in July 2000, law 25(2000). The privatization law defines privatization broadly as enhancing the private sector role in the economy to include those state enterprises that should be managed on a commercial basis. Under this 2000 law, the Privatization Council is to decide on policies, enterprises, methods, consultants and contracts regarding privatization processes, subject to clearance by the Cabinet of Ministers. It also recommends the establishment of independent regulatory commissions for sectors subject to privatization.

This council is supported by a permanent agency, the Executive Privatization Commission (EPC). EPC is in charge of proposing and supervising the privatization processes in co-ordination with relevant agencies. Below is the statement of one of the articles in the law:

Article (3):

Privatization is defined as the adoption of an economic policy that enhances the role of the private sector in the national economy to include those particular public sector enterprises whose nature dictates that management should be based on a commercial basis. In this contest, privatization aims at:

1.1 Contributing to the attraction and flow of local, Arab and foreign investments by providing favorable investment and inductive environment.
2.1 Direct private savings towards long-term investment to strengthen and consolidate the internal capital market and the national economy.
3.1 Alleviate the debt burden of the Treasury through ceasing its financial commitments in terms of loans and grants for those projects deemed unsuccessful and unproductive.
4.1 Manage economic projects through modern techniques including the usage of developed technology to open up stable markets and to penetrate new markets by emphasizing its international competitiveness.

According to Kachel (2011), the private sector only plays a marginal role in management and operation & maintenance of water systems in Jordan.

The Ministry of Water & Irrigation embarked on a road to commercialize operation and management of water systems by involving the private sector.

The few successful Private Sector Participation (PSP) and Public Private Partnership (PPP) projects in reduction of NRW and energy saving are clearly illustrating the importance of involving the private sector through performance based contracting.

What is still missing is a clear focus on the most important fields of inefficiency such as the NRW and energy consumption and a more dynamic and flexible implementation outside the present bureaucratic system.

A major limiting factor is the subsidies in water and electricity tariffs, which does not reflect the real costs of producing water and energy and thus the obvious benefits of private sector engagement are not visible.

The Ministry of Finance on the other hand is facing high deficit in the Water Authority of Jordan budget and subsequently a high burden on the other ministries and government budgets.

If the real cost of energy production/ distribution and water production/ distribution would be reflected in the respective tariff structures, the private sector would be very interested to at least partially cover the needed investments and engage in performance based contracting models (Kachel, 2011).

However, the inflexible institutional framework and highly bureaucratic procedures in most government institutions, have to be either by-passed or a coherent system of performance based management be introduced.

This could start within the Ministry of Finance and the Ministry of Water and Irrigation themselves by introducing performance budgeting principles and a proper assessment of opportunity costs in combination with timely implementation of the needed projects.

In Jordan, the private sector can interfere and engaged in the following areas:

1. Water loss reduction through performance based contracting, accordingly indirectly reducing energy usage and improving the financial performance of a water utility, which in turn generates the needed revenues to cover the required investments.
2. Improving the energy efficiency in water pumping through investment in pumping

equipment, operation of pumping stations and capacity building.

3. Generating energy in water supply and wastewater systems like installing power generating devices in high pressure pipelines to or producing gas in wastewater treatment plants.
4. Investment in renewable power generation like solar and wind farms in suitable areas.

CHAPTER THREE
MATERIALS AND METHODS

As mentioned earlier, the researcher was the project coordinator within this study. The following main activities were performed under his supervision. The research study builds on several activities, which were carried out through the researcher as a project coordinator. Part of the lab analysis was made at the Royal scientific Society, also a part of the activities to evaluate the process performance.

It is also important to mention that the main required service from the private consortium was to optimize the operation of the WWTP and to provide the data to the Water Authority without further analysis. Thus all the results obtained from this research study is not part of the project activities.

3.1 LITERATURE REVIEW

As the first step, most of the available literature was reviewed and the main points were summarized. The topic energy efficiency in the wastewater treatment plant is still considered relatively new therefore few articles and papers have found tacking this subject. Most of the studies on improvement of energy efficiency in the WWTPs were implemented in Europe.

3.2 REVIEW OF THE HISTORICAL PLANT PERFORMANCE AND ENERGY USAGE DATA

The operational data of 2011 was obtained from Madaba Water Administration (MWA) to establish a baseline for plant performance and energy usage at the WWTP. Annex 2 depicts an example on the operational data collected from MWA. These data was used to compare the performance of the WWTP before and after the involvement of the private sector.

Data obtained was included:

1. Average, minimum, and maximum daily flow.
2. Influent, primary effluent, final effluent total suspended solids (TSS) and biochemical oxygen demand (BOD_5) concentrations.
3. Daily produced sludge quantities.
4. Historical electric energy usage including available time-of-use monitoring data, last year of utility bills, and any process changes recently undertaken or contemplated.

3.3 MONITORING OF THE ELECTRICITY CONSUMPTION AFTER THE INVOLVEMENT OF THE PRIVATE SECTOR

The daily electricity consumption of Madaba WWTP was documented and monitored, a sample of these data is annexed (Annex 3). The higher electricity consumers in the WWTP are the aerators and the irrigation pumps. The consumption of the 12 aerators and the irrigation pumps were monitored for one month. A comparison between year 2011 (base year), 2012 and the first 4 months of year 2013 has been done for the energy consumption, cost of the electricity and the quality of the effluent

3.4 EVALUATION OF THE IMPACT OF THE NEW SLUDGE MANAGEMENT SYSTEM APPLIED IN MADABA WWTP

The private enterprise supplied, installed and put in operation a mechanical sludge dewatering machine at the WWTP site to help the Water Authority to minimize the transportation cost of the liquid sludge from the WWTP site to the Ein Ghazal site. The installed type of the installed dewatering machine is screw press type.

The results showed high saving in the cost of the sludge management system in Madaba WWTP.

A comparison between the situation before and after the installation and operation of the sludge dewatering machine was conducted in as part of this research study.

3.5 ASSESSMENT OF THE CHARACTERISTICS OF THE INFLUENT AND THE EFFLUENT OF THE WWTP

The main objective of the wastewater treatment plant is to protect and save the environment and the receiving water bodies. A monthly laboratory analysis program was conducted to guarantee that the improvement in the energy efficiency has no negative effects on the overall treatment process.

Influent and effluent samples were collected and analyzed at the Royal Scientific Society laboratory once per month by the project. Main quality parameters measured were: BOD, COD, TSS, TS and NH_4. All parameter were analyzed according to APHA (1999). For quality control and legal compliance with effluent quality rules, the central laboratory of the Water Authority of Jordan has performed one sample analysis per month. Annex 4 illustrates examples for results of lab analysis.

The research study evaluated the results obtained and compared them with the Jordanian standards.

3.6 EVALUATING OF THE CONVENTIONAL WINDROW COMPOST PILES AT MADABA WWTP

As a part of the project objectives to assist WAJ to develop solution for sludge disposal, conventional windrow compost piles were constructed at the WWTP site by the private consortium wherein the researcher was one of the project implementation team. The objectives of these piles are to test the possibility to produce safe and healthy compost to be used as fertilizer in agriculture.

For each pile, about 4-5 m^3 of sludge and bulking material were mixed in order to have the "critical" volume of organic matter which allows the development of temperature and sufficient air supply. The size was limited due to the turning and handling capacity of the "bobcat" that was used for piling and turning.

In the beginning, the sludge was mixed with bulking material that was readily available at the WWTP site. It consisted of twigs and leaves from nearby trees.

As this material was limited, additional piles were set up with alternative materials like straw and shredded garden waste. In March, another pile was set up with pure dewatered sludge in order to assess the performance of such an approach.

All piles followed a similar treatment pattern that can be described as follows:

Month 1: Turning of pile every other day. Daily temperature control

Month 2: Turning of pile every other day. Daily temperature control and weekly moisture control

Month 3: Turning of pile once a week, temperature control before turning and 2 days after turning, weekly moisture control

Month 4: Turning of pile once a week, weekly temperature and moisture control

Month 5: Turning of pile every 2nd week

Month 6: Turning of pile every 2nd week–after that, spreading to dry and sieving

Month 7: Sieved material is piled up and stored unturned until final use

Based on the PPP project (Engicon, 2012), Table (13) gives an overview of the different mixing ratio and starting times of the batches.

Table 13: Overview of compost batches at the WWTP in Madaba

Old Pile Twigs/leaves	Pile 1 70:30	Pile 2 50:50	Pile 3 Straw	Pile 4 Straw/ Shreds	Pile 5 Straw	Pile 6 pure sludge
June 2012	December 2012	December 2012	March 2013	March 2013	April 2013	March 2013
Unknown	70 % sludge 30 % twigs and leaves	50 % sludge 50 % twigs and leaves	50 % sludge 50 % twigs	50% sludge 30% shredds 20 % straw	40 % sludge 60 % straw	Pure sludge
At start of the project, this pile was 3 months old but still developed temperature when watered and turned.	Still very wet and sticky after mixing	Much drier and coarse twigs visible	Mixing of straw is difficult. Material too soft to have large airgaps – sticky	Mixing of straw difficult. Better mixture due to coarser material from shredds	More straw in the mix, pile seemed to be stable and quite dry	Very sticky and wet. "flows" on the ground.

Figure (5) shows how the piles were set up with the bobcat. First, the materials were piled up in layers; then the whole pile was spread and piled up again several times with the shovel of the bobcat. This mixing procedures were sufficient for the pilot trial but would not be efficient for a full scale composting site, as it is too time intensive and does not effectively mix/ turn the material. Figure (6) shows the mixing process of the material.

Figure 5: Pilling up dewatered sludge with straw 50:50

Figure 6: Mixing of the material

The material was piled up to a height of one meter, however, in the beginning, the mixtures often were so wet that they “flow” apart (particularly Piles 1, 2, and 6). Only after 2 weeks of intensive turning they became more stable and picked up temperature). In the beginning, the piles were turned every other day in order to enhance air provision and evaporation of excessive water.

Figure (7) shows the final piles as under operation in April 2013. The pile in the front was the latest one and is a mixture of straw and sludge.

Figure 7: Overview of most compost piles in operation in May 2013

As the composting trials were only done from December 2012 until June 2013, the results were influenced by cold and rainy weather conditions. Heavy rains caused the flooding of the composting areas several times and slowed down the composting process and monitoring. However, the following results shall give a first indication about the technical feasibility of composting for sludge. In summer time, the process might be much faster and might require much more watering due to higher evaporation.

Through this research study, the performance and development of the composting piles were evaluated and compared with the Jordanian standards for sludge reuse in agriculture. Also, the investment and the operational cost of the composting plant form Madaba WWTPs were estimated.

3.7 IMPACT EVALUATION OF PRIVATE OPERATOR ON WWTP OPERATION

After all the relevant data has been collected, an assessment system between the operation of the WWTP under the public operation and the operation of the WWTP under the private operation has been developed.

The main assessment criteria were:

1. *Overall efficiency*: the overall efficiency of the treatment process has been assessed. The quality parameters of the influent and the effluent were tested for the whole duration of the project. The main parameter to evaluate the overall efficiency was the Biochemical Oxygen Demand (BOD).
2. *Capacity of the WWTP*: the daily flow rate of the wastewater treatment plant before and after the private operation was monitored in order to check if there is any change in the average daily flow of the WWTP.
3. *Process Monitoring*: the characteristics on the influent and the effluent of the WWTP were monitored. The main parameters were the BOD, COD and TS.
4. *Comply with the reuse regulation*: the quality of the effluent was checked to guarantee that the quality is in complain with the Jordanian standards for agriculture irrigation where the treated wastewater is reused in the farmers around the treatment plant.
5. *Energy consumption*: the average energy consumption per month and per m^3 influent treated was calculated and evaluated before and after the private operator involvement. The evaluation also included financial comparison and saving under the old operation program and under the modified one.
6. *Sludge production and disposal*: the sludge management system before and after the installation and the running of the mechanical sludge dewatering machine.
7. *Emergency response*: the response time to the emergency operation cases was assessed before and after the private operator involvement.
8. *Qualification of the staff*: the qualification level of the operators and technicians was evaluated before and after the private operator involvement.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter the data collected and results obtained will presented and discussed to show the impact of the private operator on the energy efficiency and sludge management of Madaba Wastewater treatment plant.

4.2 RESULTS

The wastewater treatment plant was officially operated by the private enterprise in December 2011. The first step of the project was the assessment of the daily operation program, flow rate, quality of the influent and effluent of the treatment plant for 3 months (October, November and December 2011).

The assessment showed that the quality of the effluent is below the required standards but the WWTP was not operated in sufficient and economic way, it was operated based on its full capacity and in improper way.

The available data was double checked especially the average daily flow rate to calculate correctly the organic loading rate and to identify the required oxygen percentage in the aeration tanks.

Table (14) below shows the flow measurement of the influent for one week in October, 2011 using another electronic flow meter (Engicon, 2011).

Table 14: Flow rate measurement of Madaba WWTP in October, 2011

Day	Date	Time	Existing Meter	Installed Meter	Difference		
			Readings (m3)	Flow (m3/day)	Readings (m3)	Flow (m3/d)	(m3/d)
Tuesday	4/2011	10:00 AM			3,715		
				5,038		4,855	183
Wednesday	5/2011	10:00 AM			8,570		
				5,050		4,777	273
Thursday	6/2011		10,088		13,347		
				4,606		4,362	244
Friday	7/2011	10:00 AM	14,694		17,709		
				5,086		4,800	286
Saturday	8/2011	10:00 AM	19,780		22,509		
				5,110		5,206*	-96*
Sunday	9/2011	7:00 AM			27,715		
				5,250		1,385*	
Monday	10/2011	7:00 AM			29,100		
				4,872		4,650	222
Tuesday	11/2011	7:00 AM			33,750		
Wednesday	12/2011	12:30 PM			35,073		
Total Flow (m^3/week)			35,012		30,035	4,977	
Min.				4,606		1,385	-96
Max.				5,250		5,206	286
Average				5,002		4,291	185

* Flow readings on Sunday and Monday (Oct. 09 &10) are not logical, it is strongly clear that the Breaker was switched off in these 2 days.

From the results showed in table 1, we can notice the below:

The average flow rate in 2011 was 5,000 m^3/day.

The quality of the effluent was very high and extremely below the Jordanian standards for agriculture irrigation purpose.

The average $BOD_5$of the effluent was around 20 mg/l while the Jordanian standard requires $BOD_5$of 300 mg/l for the irrigation of field crops.

According to the energy monitoring program and literature, the main two energy consumers in the WWTP are the aerators and the pumps.

The electricity consumption of the irrigation pumps in the WWTP which supply the surrounded farmers with treated wastewater was monitored. Table (15) shows the average electricity consumption of the irrigation pumps for 20 days during January 2012 (Engicon, 2012).

Table 15: Electricity consumption of the irrigation pumps

January 2012	Power kWh/day
01	570
02	600
03	630
04	666
05	573
06	717
07	657
08	494
09	438
10	481
11	528
12	518
13	621
14	583
15	533
16	630
17	648
18	838
19	698
20	639
Average Consumption kWh/day	**603**

Based on the above table, the average electricity consumption of the pumps is 603 kWh/day which presents only 10% of the daily electricity consumption of the WWTP. Therefore, the major electricity consumers are the surface aerators.

After evaluating the practiced operation program, the operation program has been adjusted and modified based on the actual organic load and the daily flow rate. However, before the adjustment, the 12 surface aerators were working 24 hours on the high speed which means they were working on the full capacity of the WWTP. The modified operation plan was adjusted to run the first 4 aerators on high speed and the remained 8 aerators on low speed in the summer time.

In the winter time it was adjusted to run only the first 2 aerators on high speed while the remained 10 aerators on low speed.

However, in order to overcome the problem of the seepage received from the tankers and to avoid any load chock on the treatment plant, the equalization tank was put in operation again. Figure (8) shows the equalization tank of Madaba WWTP.

Figure 8: Preparation of the equalization tank

The modification on the operation plan resulted in saving in the electricity consumption of the WWTP. Table (16) shows comparison between the electricity consumption in 2011 (before the private operator) and 2012 (after the operation of the WWTP by the private operator). Table (17) shows also the electricity consumption in the first three months of the second year of operation in 2013 and the base year 2011.

Table 16: Comparison between the electricity consumption in 2011 and 2012

Month	kWh consumed Year 2011	kWh consumed Year 2012	kWh Saved	Saving %	Saving JOD
Jan.	266540	187760	78780	29.5	4,727
Feb.	252761	181790	70971	28	4,258
March	248238	171210	77028	31	4,622
April	259071	211310	47761	18*	2,866
May	265833	212570	53263	20*	3,196
June.	265976	237570	28406	11**	1,704
July	361142	257610	103532	29	6,212
August	347571	258354	89217	26	5,353
September	334000	229140	104860	31	6,292
October	296738	238297	58441	20	3,506
November	323142	231060	92082	28	5,525
December	322857	220660	102197	32	6,132
Total Saving in 2012			**906,538**		**54,393**
Average Saving				**25**	

Remarks on table 16:

*Dewatering machine started operation and two extra aerators in the aeration tanks were put in operation at high speed due to high temperature

**Equalization tank containing 6 mixers and one pump started operation and third aerator was operated at high speed.

Table 17: Comparison of energy consumption during first 3 months of years 2011 and 2013

Month	kWh consumed per day Year 2011	kWh consumed per day Year 2013	kWh Saved per day	Saving %	Saving JOD
January	8598	5830	2768	32	1.71
February	9027	5517	3510	31	1.84
March	8008	6340	1668	22	1.71
AVG	**8544**	**5896**	**2649**	**31**	**1.75**

The cost of 1 kWh in 2012 was 0.06 JOD (Source: WAJ). The average consumed kWh/ m^3 in 2011 and 2012 was 1.93 and 1.38 respectively. Therefore, the average energy saved n 2012 was 0.55 kWh/m^3.

For the first three months of 2011 and 2013, the average saved kWh/m^3influent treatment was 0.62.

Figure (9) shows a comparison of the average electricity consumption between years 2011 (the base year), 2012 and the first four months of year 2013.

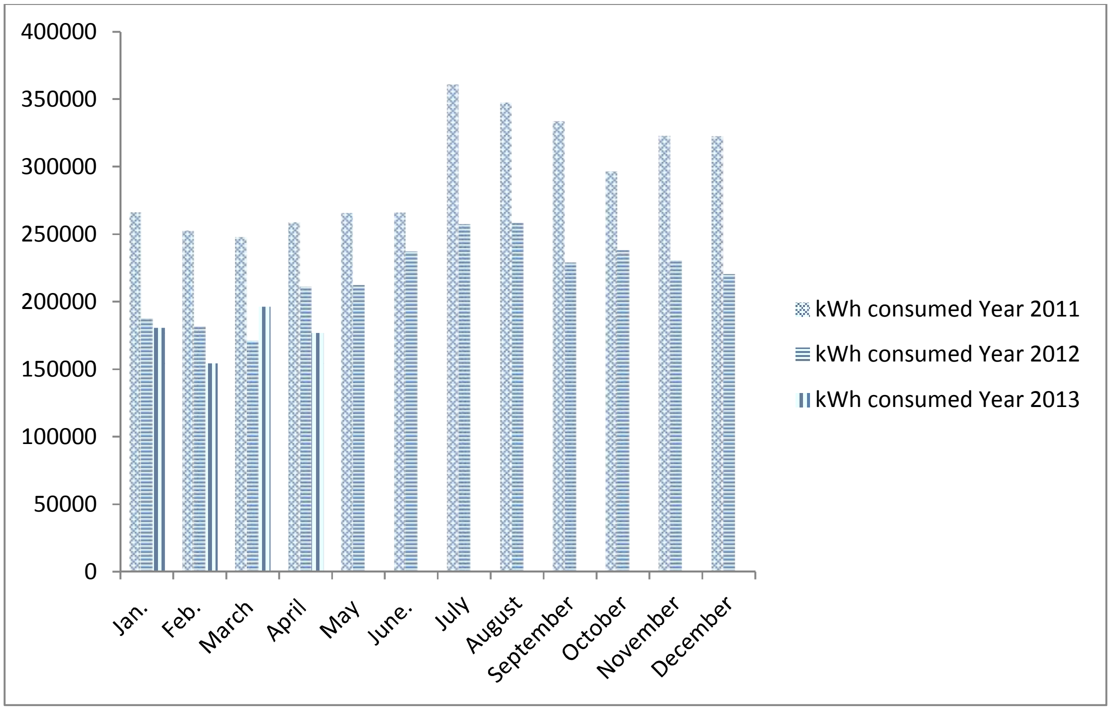

Figure 9: Average energy consumption for 2011 (base year), 2012 and four months of 2013

From the first month of the project activities in, a monitoring program for the quality of the effluent was started. The first test was conducted in December 2011. The laboratory tests for the effluent quality were conducted by the laboratory technician of the WWTP with double check from the Royal Scientific Society Laboratory, the University of Jordan laboratory and the central laboratory of WAJ.

Tables (18), (19) and (20) show respectively the laboratory tests' results for some quality parameters of the influent and the effluent of Madaba WWTP in December 2011, January-December 2012 and for January to April, 2013.

Table 18: characteristics of the influent and effluent in December 2011

Dec. 2011	BOD mg/l	COD mg/l	TSS mg/l	Ammonia NH_4 mg/l	Nitrate NO_3	TDS mg/l
Influent	820	1993	575	150	285	1190
Effluent	5	113.4	43	14	19	1062

Table 19: Characteristics of the influent and effluent of Madaba WWTP in 2012

Parameter	BOD mg/l		COD mg/l		NH_4 mg/l		TS mg/l		TSS mg/l	
Year 2012	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
January	1158	10	1993	85.5	155	20	/	1043	575	43
February	957	22	1464	39	/	/	/	1034.5	885	17
March	1263	28	2005	55	/	/	/	1256	1108	16
April	1510	23	2105	198	/	/	/	1103	874	86
May	1437	33	2803	108	123	26	/	1312	1098	60
June	976	26	2640	132	/	/	/	1217	1130	74
July	768	17	1111	193	92.8	97.4	/	1210.5	620	310
August	734	16	1056	160	79.2	78.1	/	1129	600	64
September	1395	9	2009	55	/	/	/	1102	1410	23
October	946	12	1691	65	/	/	/	1061	948	24
November	874	7	1264	39.2	104.5	15.0	1798	1063	431	5
December	1086	11	1603	70	/	/	/	1184	940	21
average	1092	17.8	1812	100.0	110.9	47.3	1798.0	1142.9	884.9	61.9

Table 20: Characteristics of the influent and effluent of Madaba WWTP in 2013

Parameter	BOD mg/l		COD mg/l		NH_4 mg/l		TS mg/l		TSS mg/l	
Year 2013	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
January	1292	25	1737	66					1000	25
February	1172	14.2	2000	134	127	76.8	2100	522	660	15
March	1143	30	1918	51					1095	23
April	1295	36.6	2026	147	120	68.3	2352	1284	710	12

The sources of the results are the WWTP laboratory, University of Jordan Laboratory, the Royal Scientist Society Laboratory and the Central laboratory of WAJ. From tables (19) and

(20) above, it is clearly shown that the adjustment in the operation program of the WWTP has no negative impact on the quality of the treated wastewater and the all the quality parameters are still below the required standards. The Jordanian standard indicates that the maximum allowed BOD_5 for reuse in Field Crops, Industrial Crops and Forest Trees is 300 mg/l.

On the sludge management side, the mechanical sludge dewatering machine was installed in January 2012 and put in operation in March, 2012. It is a screw press dewatering type produced by the German company Huber SE. The installation of the dewatering machine helped WAJ to cut off the transportation cost of the liquid sludge. Currently, all the liquid sludge is dewatered by the dewatering machine and in some cases the drying beds are used and disposed at the WWTP site. As mentioned in the introduction chapter, WAJ used to transport the liquid sludge to other place by tankers.

Figures (10) and (11) below show the installation of the sludge dewatering plant and dewatered sludge produced from the sludge dewatering plant respectively.

Figure 10: Installation of the sludge dewatering plant

Figure 11: Dewatered sludge produced from the sludge dewatering plant

The using of the dewatering machine saved around 94,500 JOD in the first year of operation of the sludge dewatering machine.

Table (21) shows the main figures and items used in the calculation of the saving.

Table 21: Calculation of cost savings in sludge management of Madaba WWTP

No.	Item	Unit	Figure
1	Produced Sludge	m^3/day	150
2	Transportation Cost	JOD/m^3	2.37
3	total transportation cost	JOD/year	127,920
4	Cost of treatment in As Samra WWTP	JOD/m^3	0.2
5	Cost of treatment in As Asmra WWTP	JOD/year	10,800
6	Sludge Dewatering cost*	JOD/m^3	0.82*
7	Transportation and minimum treatment cost of sludge as wastewater in As Samra WWTP	JOD/year	138,780
8	Cost of sludge dewatering and disposal onsite	JOD/year	44,280
Saving		**JOD/year**	**94,500**

Remarks:

The cost of sludge dewatering includes the cost of the electricity, the polymers, operator and labors input and the transportation of the sludge from the sludge dewatering plant to the disposal site inside the WWTP boundaries.

As part of the project activities, small conventional windrow composting piles have been constructed to test the possibility to consider the composting as an option for sludge disposal in Jordan.

At the beginning of the composting project, 2 samples of the dewatered sludge were tested at the Royal Scientific Society laboratory. Table (22) shows the results of the laboratory test. The date of sampling was December 2012 (Engicon Madaba WWTP PPP Project, 2013).

Table 22: Characteristics of dewatered sludge of Madaba WWTP

Test/ Parameter	**Results/ Sample**		**Unit**
	Sample 1 dewatered sludge (20% TSS)	Sample 2 dewatered sludge (20% TSS)	
Ca	13050	12850	mg/kg (dry weight)
Mg	8000	7800	mg/kg (dry weight)
Moisture Content	85.5	85.1	%
T.N	8.18	7.02	%
T.K.N	6.35	6.93	%
NO_3– N	<16	<16	
NH_4– N	0.648	0.865	%
Total Organic Matter (TVS)	4.61	4.90	%
Organic Carbon Content	1529	1026	mg/kg (dry weight)
K	2170	1970	mg/kg (dry weight)
Na	890	820	mg/kg (dry weight)
As	<7.5	<7.5	mg/kg (dry weight)
Cd	1.12	1.16	mg/kg (dry weight)
Cr	13.7	13.2	mg/kg (dry weight)
Cu	68.8	66.5	mg/kg (dry weight)
Mo	19.0	17.0	mg/kg (dry weight)
Ni	15.5	14.7	mg/kg (dry weight)
Pb	19.6	19.4	mg/kg (dry weight)
Se	<10.0	<10.0	mg/kg (dry weight)
Zn	715	703	mg/kg (dry weight)
Hg	<1.0	<1.0	mg/kg (dry weight)
E.coli	1.0x105	1.1x108	MPN/g
Nematode Eggs	Not Seen	Not Seen	Egg/150g

Composting of dewatered sludge with a TSS of (17 – 20) % was a challenge, because it was still “liquid” and sticky. It was either need to be further dried (e.g. in a drying bed) or mixed with a dry bulking material which should be rich with carbon. It was estimated that up to 70% of bulking material can added as the C:N ratio of dewatered sludge in Madaba is very low (<5:1). It could not be clarified to what extend the polymer added during the dewatering process influences the low C:N ratio.

However, it is not applicable in Jordan to add high amounts of bulking material due to the limited availability of bulking material. Therefore, the maximum mixing ratio applied was a 50:50 mixture. The sticky sludge “glued” the bulking material together and thus prevented the development of the required air gaps. This could be only avoided by daily turning of the material, thus delaying a fast increase of temperature.

It seems that straw was not suitable as bulking material, as it degrades only slowly and it is not stable when getting wet. The composting process developed best in Pile 4 that got mixed with straw and shredded green waste.

It seems that the limited mixing effectiveness of the bobcat also caused the development of anaerobic “pockets” that did not get in touch with sufficient air. When those pockets were opened, the emitted odor clearly indicated anaerobic conditions.

The moisture content of the dewatered sludge was quite high with a TSS value of 15-18 %. As further drying was not planned, more bulking material (up to 70 % was added) was added. The initial moisture content was still high with a TSS of 20-25 %. In combination with the heavy rainfalls in winter, the composting process was delayed. As ambient temperatures were rising and rainfall got less over the months, the compost piles also dried out. From April, some piles required some water in order to maintain the required TSS value of 45%.

The mature compost was spread out for drying before sieving. The final product had a TSS value of 92% while the analysis of dried sludge showed a TSS value of 75% only.

In general, the moisture content was not distributed evenly in the piles due to the limited mixing and turning capacity of the bob cat. The tests showed that composting of sludge requires strong and effective turning equipment in order to achieve a homogeneous end product.

The initial plan was to measure temperature daily and moisture content weekly. However, this was not manageable due to some management issues and due also to the unexpected weather conditions. Therefore, temperature was measured at least every third day. The temperatures measured varied but were highest about 2-3 days after turning.

The composting trials started in winter and therefore, the small piles got affected by cold temperatures and heavy rains. Hence, expected fast startup of biological processes was delayed. High temperatures were only reached after 4-5 weeks, when the material was dryer and a visible degradation of the material had started.

The old pile showed very high temperatures (up to 63 °C) after turning and watering though it was already 3 months old. As the pile was not moved for more than 2 months, it showed that the provision of air and the right moisture content were crucial for a fast degradation of the material.

As per data obtained from Madaba PPP project (Engicon, 2013), Table 2) gives a summary of the temperature results on a monthly basis. The results are average values and the piles showed quite inhomogeneous results due to the limited turning effectiveness. All piles reached the required high temperatures which are required for the significant reduction of pathogens in the compost.

Table 23: Temperature development over time in the compost piles

Month/ Temp (°C)	Description	December (7 °C)	January (12 °C)	February (10 °C)	March (20°C)	April (15°C)	May (25°C)
Old Pile		63	15	13	used for demo		
Pile 1	70:30	12	12	13	56	45	Sieved/ stored
Pile 2	50:50	13	12	18	31		
Pile 3	Straw				24	45	32
Pile 4	Straw/shreds				18	53	29
Pile 5	Straw					51	31
Pile 6	Pure sludge				23	40	30

The development of the organic matter commonly expressed as Total Volatile Substances (TVS) is an indicator about the maturity of the sludge. The Jordanian Standard stipulates a reduction of TVS through anaerobic digestion by 38 %. Composting also shows a reduction of TVS; however it cannot be compared with the standard, as more than 50 % of an additional organic carbon source is added. This material also contributes to an increase of TVS. However, the results in Table (21) indicates that even with composting the TVS can be reduced from about 50% to about 30% and the material gets stabilized and safe for reuse in agriculture.

The nutrient concentration is an important sealing factor for the planned reuse of sludge in agriculture. Table (24) summarizes and compares nutrient values in dewatered sludge, dried sludge and different composts. As the number of samples is limited, only a first indication can be given (Engicon, 2013).

As expected, the total nitrogen level in fresh sludge is higher than in compost, as nitrogen is a volatile element and a part of it is "digested" to gaseous substances during the microbiological transformation. The remaining nitrogen is rather fixed in organic structures and released slowly over 1-2 years to the plants. Therefore, compost is considered a long-term fertilizer and soil amendment.

The results for Phosphorus confirm the common understanding that sludge and composts containing sludge are considered as phosphorus fertilizers. The content is normally much higher than in conventional composts and therefore beneficial to plant growth.

Table 24: Summary of nutrient values and TVS in different sludge products

Parameter	Unit	Dewatered sludge1	Dewatered sludge2	Dried Sludge 12months	Compost			Plant Compost
					3 months	5 months	8 months	
T-N	%	8,2	7	6,2	3	2.8	2.5	1.3
NO_3	mg/kg*	16	16	10	3.5	10	48	124
NH_4	%	0,6	0,9					
TP	%			1,7	2.5	0.9	5.8	0.8
Ca	mg/kg*	13050*	12850*	390	6	154	38.2	187
Mg	mg/kg*	8000*	7800*	209	27.5	83	70.2	93
K	mg/kg*	2170*	1970*	556	337	698	703	6240
TVS	%	46	49	50.2	48.4	38.1	24.4	19.4

* DM: Dry matter

The concentration of heavy metals is a concern for reuse activities with regard to a long-term accumulation in the soils. Therefore, the application rates are often limited according to the heavy metal concentration. The analysis of dewatered sludge and dried sludge of Madaba WWTP shows that the concentration of heavy metals is low and fit for use in general. They are comparable with the results provided by similar WWTP like Ma'an and Wadi Mousa that receive mainly domestic wastewater. Table (25) illustrates the results for dewatered and dried sludge from Madaba WWTP in comparison with the standard.

Table 25: Heavy metal concentrations* in dewatered and dried sludge

Parameter	Dewatered sludge1	Dewatered sludge2	Dried Sludge (12m)	Standard 1145 Type II	Standard 1145 Type I
As	7,5	7,5	7,5	75	41
Cd	1,1	1,2	1,5	40	40
Cr	13,7	13,2	18,4	900	900
Cu	68,8	66,5	117	3000	1500
Mo	19	17	27	75	75
Ni	15,5	14,7	22	400	300
Pb	19,6	19,4	25,6	840	300
Se	10	10	10	100	100
Zn	715	703	988	4000	2800
Hg	1	1	1	57	17

* All units are in mg/kg DM; dry matter.

One of the biggest concerns with regard to sludge application on land is the spread of pathogens and thus diseases. Therefore, the JS 1145 sets quite strict levels of pathogen concentrations for land application with a Total Fecal Coliform value of 1000 MPN/g for Type I sludge and 2,000,000 MPN/g for Type II sludge. As results show above, composting generates the required temperature to ensure pathogen removal, therefore, significant lower pathogen values for the final compost product is expected. Table (26) shows the comparison of e-coli levels from:

- two samples of dewatered sludge as received from the dewatering machine,
- one sample of dried sludge that was left in drying beds for about 12 months,
- Three samples of compost in different maturation phases and an alternative compost product made from plant residues and animal manure only.

Table 26: Reduction of pathogens throug composting and drying of sludge

Parameter	Unit	Dewatered sludge1	Dewatered sludge2	Dried Sludge (12m)	Compost (3m)	Compost (5 m)	Compost (8m)	Plant Compost	JS1145* Type I Sludge
e-coli	MPN/g	1,0E+06	1,1E+08	4,7E+02	1,5E+02	2,0E+03	1,0E+00	1,0E+00	1,0E+03

*JS1145/2006 shows the values for Total Fecal Coliform Count (TFCC) – unfortunately, all samples were analyzed on c-coli only. Normally, the TFCC and e-coli values lie within the same log and can be compared to a certain extent.

As both parameters normally lay within the same log, the results give a first indication that the values are in the acceptable range. The reduction of pathogens in compost can be attributed to the high temperatures and other chemical-physical processes. The reduction of pathogens in dried sludge is mainly attributed to the long retention time (die-off) and excessive exposure to UV-radiation (sun).

The analysis of two samples dewatered sludge samples did not show any nematode eggs. This analysis was performed by the Royal Scientific Society and financed by Madaba WWTP PPP project. The first test for the characteristics of the three piles was done end of December 2012. Table 27 shows the results of this test (Engicon, Madaba PPP, 2012). Figure 12 shows a ready compost pile at Madaba WWWTP site.

Table 27: Results of the first lab test of the three compost piles

Test	**Result/ Sample**			**Unit**
	Sample (1) 50%:50 % Mixture	Sample (2) 70:30 Mixture	Sample (3) Mature Compost	
Moisture Content	74.4	81.1	69.6	%
Total – N	4.86	5.91	5.66	%
TKN	4.78	5.79	5.42	%
NO_3 – N	<16	<16	451	mg/Kg (dry weight)
NH_4 – N	0.403	0.550	1.40	%
Total Volatile Solids (TVS)	10.08	5.81	19.41	%
Organic Carbon Content	853	1078	836	mg/g (dry)

Figure 12: Ready compost pile at the site of Madaba WWTP

The subsequent calculations based on the following assumptions and facts:

- **Compost Production:**
- Current production of dewatered sludge: 17 m^3 dewatered sludge/ day = 6120 m^3/ year
- Composting area is available
- Water is available, treated effluent
- Bulking Material only available for about 30 % of sludge – 1,800 m^3 bulking material/ year
- Expected compost production: about 3,000 m^3/ year
- Rest of sludge needs to be dried in drying beds before other reuse is possible: number of drying beds is 156 and the area is 6x20m each = 18,720 m^2
- Disposal of untreated dewatered sludge on-site is ceased.

- **Potential Market around Madaba**
- Calculation based on final product (not dry matter):
- According to JS 1145 maximum application rate = 6 tons/ ha and year * 170 ha = 1,020 tons (approx. 1,700 m^3)

- According to heavy metal content maximum application (Zn is limiting factor) = 80 tons/ ha and year = 13,600 tons (approx. 22,600 m^3) – this potential demand would by far exceed the available compost production or even sludge production!

All material is handled with two haul trucks and the front shovel of the tractor. The composting facility receives approx. 1,800 m^3 of shredded bulking agent from different sources. The facility has a mobile shredder/chopper that is sent to the sources where the material is shredded on the spot and transported to the treatment plant.

About 30 % of the dewatered sludge (approx. 1800 m^3) is mixed with the equal amount of bulking material and composted in windrows. The size of one windrow is about 2 m wide, 1.5 m high and 20 m long. This would accommodate about 30 m^3 of fresh input material. About 60 windrows need to be set up per season. An area of about 1500 m^2 is required to compost 30 % of the dewatered sludge. This might be done from January until July when plenty of bulking material is available. The plant is equipped with a windrow compost turner that is attached to a tractor with a "creep speed gear" to allow the slow movement of the equipment through the compost.

After a loss of organic matter and moisture it is expected to produce about 3,000 m^3 of compost per year. The requirement of screening equipment depends on the market.
Compared to the potential market in the vicinity of the WWTP site, the produced amount could be easily applied without any technical restrictions. The cost/price for the compost rather might be a limiting factor for the marketing potential. First interviews revealed that the composted sludge might have a better market in tree farming and landscaping than forage production. These markets need to be further investigated.

The remaining dewatered sludge will be applied to drying beds. First trials showed that dewatered sludge is drying faster due to better infiltration. Furthermore, the reduced volume will allow much longer retention times in drying beds that ensure a better die off of pathogen and makes it more save for final dumping or reuse.

Composting is a work intensive process and causes considerable costs for machinery and workers. Therefore, the concept has to be designed in a way, that the final product can compete with currently used organic fertilizers like chicken manure or composted manure. In general mobile equipment should be used to reduce infrastructure costs and allow more flexibility.

Table (28) gives an overview of the required equipment and estimates the investment costs for a composting plant that can process about 1800 m^3 of sludge and the same amount of bulking material per day (over 6 months). The equipment could handle more material over the full year, but considering the limited availability of bulking material, the operation might be a seasonal business from January until early summer. The calculation omits any cost for office buildings or storage facilities, as it is assumed that the composting site is located at or close to the WWTP and managed partly by the WWTP staff.

The investment costs are estimated at about 276,000 JD for required trucks, shredders, compost turners and a sieve. Based on the defined depreciation time of the equipment, annual costs of about 40,000 JD have to be expected.

Table 28: Capital expenditures for the composting plant

Equipment	Description	Handling Capacity	Investment Cost (estimates) JD	Depreciation	Annual Cost (JD/year)
Haul Truck	Sludge Transport (Diana)	6 m^3	40,000	7	5,714
Haul Truck	Bulking Agent Management	10 m^3	60,000	7	8,571
Mobile Shredder	For Green waste Collection	5 m^3/hour	35,000	5	7,000
Compost Turner on Tractor	Core equipment for Composting		50,000	7	7,143
Tractor with front shovel (and super slow gear)	Multi-Tasking equipment to handle input material, also used to run the compost turner		40,000	7	5,714
Rotating drum sieve (mobile)	e.g. Terra Select or Doppstedt	60m^3/hour	20,000	7	2,857
On-site Compost Monitoring Equipment	Thermometer, CO_2 measurement		1.500	5	300
Required Area (paved/sealed)	to compost 17 tons dewatered sludge/day 20m2x60 days composting + storage: 1200 m^2	approx. 1500 m^2	30,000	15	2,000
Total Cost (JOD)			276,500		39,300

Table (29) summarizes operation costs for the composting plant including the annual depreciation costs for the equipment. The operation costs are based on an input of about 3,600 m^3 of sludge and bulking material. The calculation of specific operation costs are based on an expected output of final compost of about 3,000 m^3. The specific production costs of compost are 28 JD/m^3 and 47 JD/ ton.

Table 29: Operation and specific production cost

Item	Calculation Basis	Annual Costs in (JOD)
Sewerage Sludge Input (dewatered sludge (DM 18 %)	30% of total amount: 1800 m^3	0
Bulking Agent Input	1800 x 15 JD/m^3	27.000
Water	2 m^3/day x 265 (reclaimed water is free but pump cost)	500
Fuel	Estimates	1.500
Labor (1 technician/engineer, 2 workers)	12x600 JD + 24x350 JD	15.600
Depreciation of Investment	(described in Table 25)	39.300
Total Annual Operation Costs		**83.900**
Output Biosolids Compost (DM 70 %)	approx. 3000 m^3	3.000
Specific Production Costs (JD/m^3)		**28**
Specific Production Cost (JD/ton)	**density 0.6 t/m^3**	**47**

A cost assessment of alternative organic fertilizers showed that compost can compete with other fertilizers but will require intensive promotion and initial technical assistance. The above mentioned plant compost is sold for 60 JD/ m^3 as loose material and about 140 JD/ m^3 in bags (1.5 – 2.5 JD/ 20 liter bag). Raw chicken manure costs approx. 60-80 JD/m^3, but this material requires at least 2-3 months of further treatment before it can be applied to plants.

As mentioned and reported by the operators of the WWTP, the response time for the failure or trouble in the pumps or any other equipment has been decreased under the operation of the private operator.

Before the private operator involvement, the maintenance of any equipment or pumps was taking long time due to the governmental procedures. While under the private operator it is faster and easier to take actions and reduce the troubleshooting time.

On the personal qualification level, all of the operators and technicians have been trained on the modern operation of the wastewater treatment plant as well as on energy saving and sludge management.

Based on their feedback, their knowledge and technical level have been improved and they got the opportunity to be trained under the operation of the private operator.

4.3 DISCUSSION

This section entails solely the discussion of impacts of involving the private sector in the operation of Madaba WWTP and the implemented activities in reducing the energy consumption. The achieved improvement can only be measured by comparative analysis of past operational management style and the modified one. A comparison between the Jordanian experiences with regional or international knowledge is beyond the scope of this study. The energy efficiency in the water sector in Jordan is a very important issue and the Water Authority of Jordan is giving it a big attention. This is due to the following:

1. The poor performance of the technical staff with regard to energy efficiency as well as the lack of financial resources of WAJ.

2. The water sector in Jordan is subsidized by the government which means that WAJ should minimize the operation cost of the water systems.

Therefore, WAJ started to involve the private sector in the water sector since 2005 to support and help WAJ to improve the performance of the water utilities in Jordan through Private

Sector Participation (PSP), Built, Operate and Transfer (BOT) and Public Private Partnership (PPP) approaches.

Most of these projects are considered as successful stories and helped WAJ to improve the performance and generate more revenue.

We can see from the results of this project that it is a successful one as well, and it helps WAJ to minimize the electricity cost and almost cut off the cost of sludge management.

The private sector helped WAJ through this PPP project to save 53,821 JOD per year though it puts in operation an equalization tank to control the flow enters the WWTP.

This was done through only changing the operation program of the WWTP with small investment in the operation and maintenance equipment.

It was difficult to compare Madaba WWTP PPP experience with other experiences mentioned in the literature review because there was no similar experience to compare this Madaba experience with it.

However, as mentioned in table (3) in the literature review each WWTP in Jordan has special conditions, it is difficult to disseminate Madaba WWTP PPP project experience on the other WWTPs without further investigation of their operation plans.

Also, they managed to save around 94,500 JOD yearly for the sludge management of Madaba WWTP. This was achieved by installing a modern mechanical sludge dewatering machine (screw press model) with cost of 200,000 JOD (this amount was financed by the GIZ and the private enterprise).

Thus, the total saving in year 2012 was 148,321 JOD in the Operation of Madaba WWTP which is considered as small- medium WWTP in Jordan.

In addition to that, the saving in the electricity consumption helps to reduce the Co_2 emission to the environment,

The amount of saving can be increase yearly due to the increasing in the electricity, fuel and labor prices.

On the other hand, Madaba WWTP is lucky because it has enough space to dispose the dewatered sludge inside its boundaries without any additional transportation cost.

However, this option seems difficult for most of the WWTPs in Jordan and thus other options for the sludge disposal should be considered and evaluated.

Madaba WWTP is a location where compost generated from biosolids has a market, as the surrounding area is dominated by agriculture. In direct vicinity of the WWTP about 1,700 Dunums (170 ha) are under irrigation with effluent to produce forage crops. But the whole region around Madaba is known for its rich soil and intense irrigated agriculture for vegetables and rain fed agriculture for trees (olive, grapes) and grain and straw production.

Several farmers connected to the WWTP are frequently asking the staff to provide them with dried sludge for their fields that are irrigated with effluent from the plant. Until now, WAJ is rejecting that request, as it is not clear, who is responsible for the approval and control of sludge reuse. The treatment of biosolids by thermophilic composting might reduce the concerns of both farmers and authorities and actually reduce health and environmental risks.

Also, the moisture content needs to be controlled and adjusted in order to ensure an efficient process. The final product might be dried before sieving to achieve a more homogeneous end product. However, it should be not too dry, as it might cause dust problems and will require significant amount of irrigation water during field application. Therefore, a TSS content of 75 % is recommended, though the Jordanian Standard stipulates a TSS content of 90%.

It can be assumed that all piles reached the required high temperatures of 55-60°C over several days and thus meet the requirements of the standard. Efficient turning of piles will ensure that all material is exposed to high temperatures and thus sufficiently hygienic.

The nitrogen concentration in sludge was much higher than in compost which will have a direct effect on plant growth. Farmers might consider dried sludge more valuable due to the immediate positive effect on plants. The high phosphorus content in almost all samples will contribute to a better development of leaves and thus to an increased production of biomass.

In general, the application of dried sludge has more immediate effect on plant growth than the compost, while compost has more long term fertilizing effects and will contribute to a remediation of soil structures and water holding capacity due to the addition of stable organic matter.

The heavy metal values in sludge were comparable with the results of similar WWTPs in Jordan like Ma'an and Wadi Mousa WWTPs. The compost based on sludge contains similar amounts of heavy metals like the sludge itself. The addition of bulking material might lead to lower Zinc values what is preferable, as Zinc is currently the limiting factor for agricultural application. All results suggest that the sludge can be reused as Type I biosolids in agriculture.

The results of the composting trials clearly showed that untreated dewatered sludge does not meet the requirements for reuse. But both composting and long-term drying of sludge reduces the e-coli concentration by 4-6 logs or even to a level that no e-coli can be detected. All levels are reduced to an acceptable level for reuse in agriculture for either Type I or Type II applications. It can be expected that mature compost with an age of 6-8 months is save for reuse as Type I fertilizer.

However, the current JS 1145-2006 limits the reuse of sludge to such an extent that farmers might not be interested. If the reuse of sludge should be part of a national strategy for sludge management, a revision of the current standard is required.

In summary, promoters of PPP often argue that it provides an opportunity to provide the same sanitation assets (full or individual unit operations) and wastewater services at reduced costs. The outputs of Madaba WWTP case delivers the evidence for this argument as true, thus depicts a successful PPP story. For instance, while the energy costs for wastewater treatment were at a flat rate of 0.12 JD/m^3, the PPP involvement achieved OPEX rates as low as 0.09 JD/m^3. Therefore, compared with the base line year 2011, the PPP application in 2012 achieved a saving about 25% (54,393 JD/year) in the OPEX costs for the energy consumption. Again, the output of the PPP application in biosolids treatment and disposal OPEX cots of 0.81 JD/m^3 compost, three times lower than the WAJ current biosolids disposal practices (2.53 JD/m^3). Similar to energy costs savings, compared with the base line year 2011, the PPP application in 2012 achieved a saving about 68% (94,500 JD/year) in the OPEX costs for the biosolids treatment and disposal using the windrow composting facility.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1CONCLUSIONS

The impacts of PPP involvement on the energy reduction and biosolids management of Madaba WWTP, as a case study, were investigated and assessed in this study. The following conclusions can be reached from this study:

1. Annual operational expenditures can be optimized and associated wastewater treatment costs through optimal operational plan, where the aeration system has the major energy consumption rate. This can only be made by achieved through a committed operational and managerial staff.

2. Within the introduced PPP concept, the various applied process control measures toward energy and chemical reduction were successfully implemented without compromising the Jordanian national effluent quality requirements.

3. Results analysis revealed that the Private operators' involvement in sanitation sector enabled WAJ improve the operation of Madaba WWTP, where as they acquired expertise and financial resources to develop better management and improve operation systems.

4. The involvement of the private operator helped knowledge transfer and improved staff experience of Madaba WWTP through offered training opportunities at affordable costs.

5. Due to the different conditions and situation of each WWTP in Jordan including the technical specification and treatment process, it is difficult to apply Madaba WWTP PPP experience in other WWTPs without adaptation and modifications.

6. Also, the private sector played a major role in improving the sludge management through composting piles at Madaba WWTP wherein it has the ability to invest and transfer knowledge in this specific field. Also, marketing of the produced compost may be used as fertilizer or soil amendment.

7. From the composting trials, it was concluded that strong and effective turning are key factors for an effective composting process and for an efficient composting scheme. It is recommended to use a mix of shredded twigs, branches and leaves from green garden or agricultural waste.

8. The results of the laboratory analysis showed that the implemented compost piles were safe without negative impact on health or environment.

9. The composting can be considered as a disposal option of Madaba WWTP sludge due to the availability of the land as well as green material around and inside the WWTP. Also, the farmers around the WWTPs showed interest to use the composting as a fertilizer in their farms.

10. However, the composting as a strategy for the disposal of the sewage sludge in Jordan is not applicable in all cases due to the following major challenges;

- The first one is the availability of the green bulk agent wherein it is well known that Jordan is a semi-arid country.

- The second challenge is the public acceptance of using the compost produced from sewage sludge as agricultural fertilizer (although they are currently using the animal manure without any treatment as fertilizer).

- The third one is the marketing of the products produced by using the composting as a fertilizer, the farmers are afraid to face difficulties in marketing their products because they believe that the people are not willing to buy their products.

- The PPP application for sanitation services at Madaba WWTP is desirable since the WAJ cannot afford covering high OPEX, while saved public capital can be invested for covering the annual running costs and upgrading the WWTP and service to other municipal areas.

5.2RECOMMENDATIONS

The following recommendations can be made:

1. Knowing that the energy consumption at sewage works occupies a significant percentage with impacts on annual running costs, further research is needed on the wide application of the PPP at other WWTPs.

2. Renewable energy sources including solar energy and biogas utilization at urban sewage works warrant deep investigation during both planning and retrofitting of current WWTP in Jordan. As Samra WWTP can provide a potential case for effective biogas usage.

3. The current institutional framework of sewage treatment facilities in Jordan needs further reform pertinent to biosolids management including disposal strategies and regular training programs.

4. The private sector can support the water authorities to build the capacity of their staff and to introduce them to the modern management systems. However, in order not to give the whole responsibility of the management of water sector to the private sectors, it highly recommended to outsource specific tasks to the private sector and to keep all the assets owned by the water authorities.

5. Further investigation should be done to identify disposal options for each WWTP in Jordan based on its conditions.

6. Finally, research questions still continue about how to ensure that the general public, who is the target of PPP interventions, actually can benefit from the private sector operations. Therefore, critical analysis for the performance of the private sanitation service providers and deep consideration of urban residents` perceptions need further investigations.

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Annex A1: PPP-Contract Measure

Development partnership with Engicon O&M and HUBER SE

Title:	Management of Water Resources Programme		
Country:	Jordan	Term:	From: 01.06.2011 To: 31.05.2013

Measure no.:	2010.2242.5-001.00
Contract no. and type:	81136718 – PPP-Contract
Contact person at GIZ for development partnerships with the private sector:	Friederike Sorg
Contact person at GIZ for sector-specific issues:	Dieter Rothenberger
Contact person: Address of the partner company:	Tarek Zuriekat / Michael Sammiller ARGE Engicon / HUBER SE, P.O. box 926963, Amman 11190, Jordan

Date, signature: ____

1. **Current status of the project (01.02.2012) with reference to the plan of operations**

Goal and short description:

The aim of the measures is to establish know how in the optimization of the operation of WWTP´s with regard to energy consumption, sludge dewatering and composting.

Services / activities (01.06.2011 – 01.01.2012)

Result 1	Preconditions for the optimization of the WWTP Madaba are assessed, evaluated and documented and respective measures, including supervising the operation of the WWTP Madaba, are being implemented by Engicon/Huber.			
Indicator /Milestones	**Time schedule (by when?)**	**Person responsible**	**Please give a brief description of the activities involved in achieving the indicator and/or of any problems that arose if you were not able to achieve the indicator.**	**Assessment of outcomes**
1.1 Memorandum of Understanding between WAJ and Engicon/Huber	**June 2011**	**WAJ, Engicon/Huber**	**MoU was signed by the partners on June 26, 2011 in Amman**	**A**
1.2 Collecting of relevant operational data	**July 2011**	**Engicon/Huber**	**The operation data and results of the lab analysis were collected and investigated. In some cases, the uncertainly in the data was very clear therefore, the consultant conducted his own measurements for daily flow, electricity consumption of the irrigation pumps, quality analysis for the wastewater samples.**	**A**
1.3 Estimation of the optimisation potential	**August 2011**	**Engicon**	**The practiced operation program has been assessed and evaluated. The estimated potential reduction in the electricity is (25-30%) based on the findings. A plan for optimizing the operation process and energy efficiency has been developed and it is in the implementation phase.**	**A**

1.4 Monthly documentation of the optimisation processes and the respective results	**As of September 2011**	**Engicon**	**The monthly results and data of the optimization process are documented on a regular basis. In some cases, it was difficult to document the data due to faults in the measurement equipments, uncertainly in the lab measurements or due to interruption in the electricity.** **The laboratory tests results shown small changes in the quality of the treated wastewater but it is still within the allowed values in the Jordanian Standards.**	
1.5 Operation of the sludge dewatering and composting facilities until May 2013	**As of September 2011**	**Engicon/ Huber**	**The start-up of the plant is intended for week #11 in 2012. The delay resulting by a longer planning phase for implementation of the sludge dewatering plant.**	**B by 5 months**
1.6 Reduction of the energy consumption per m³ treated wastewater until May 2013	**As of September 2011**	**Engicon**	**The energy consumption of the treatment process has been reduced after 5 months to around 29%. The cost of treating 1 m^3 has been reduced from 0.082 to 00.053 JOD saving value is around 0.031 JOD). The comparison was made between January, 2011 and January, 2012.**	**B for 5 months**

Result 2	**The sludge treatment of the WWTP is upgraded to reduce the sludge disposal costs.**			
Indicator /Milestones	**Time schedule (by when?)**	**Person responsible**	**Please give a brief description of the activities involved in achieving the indicator and/or of any problems that arose if you were not able to achieve the indicator.**	**Assessment of outcomes**
2.1 Installation of the sludge dewatering equipment at the WWTP	**October 2011**	**Engicon/ Huber**	**The installation of the plant is intended for end of January 2012. The delay resulting by a longer planning phase for the implementation of the sludge dewatering plant.**	**B by 4 months**
2.2 Operation of the composting pilot plant	**As of September 2011**	**Engicon**	**The composting pilot plant is not operated yet because the operation of the sludge dewatering machine is still under testing to reach the optimum operation criteria. The composting pilot plant will be operated in cooperation with the faculty of Agriculture of the University of Jordan.**	**B by 9 months**

Result 3	The operational staff in charge for running the WWTP is doing so in accordance with best practice and proofs able to do so even after termination of the project.			
Indicator /Milestones	Time schedule (by when?)	Person responsible	Please give a brief description of the activities involved in achieving the indicator and/or of any problems that arose if you were not able to achieve the indicator.	Assessment of outcomes
3.1 Providing manuals for operation, maintenance, repair of WWTPs in English and Arabic	November 2011	Engicon/ Huber	Providing of the operational instructions for the sludge dewatering plant in English via download link (23.11.2011) and in written form (mid of January). Operation plan for the WWTP regarding to energy saving has been provided. Preventative maintenance manuals for the existing and new equipments have been prepared in English.	A
3.2 Providing relevant training materials for sludge treatment and composting	December 2011	Engicon/ Huber	Providing of training material for the sludge dewatering plant after the start-up and run-in-period.	B by 3 months
3.3 Training on the job of the seconded staff of the WWTP Madaba	October 2011	Engicon/ Huber	Training on the laboratory water quality tests was conducted for the lab technician. Also, Training on operation with regard to energy efficiency was carried out for the operators of Madaba WWTP. Training on the sludge dewatering plant will take place after the start-up in week #11 (by Yousef Al Abedi / Huber Middle East).	B by 4 months
3.4 Developing of general training programme and training modules / 5 trainings with WAJ	December 2011 / April 2012	Engicon/ Huber	Participation at the training programme (April 2012) with training of technicians and engineers of Madaba WWTP on the sludge dewatering plant.	A
3.5 Operating of the WWTP and sludge dewatering facilities	Until May 2013	Engicon/ Huber	Ongoing	A
3.6 Ensuring the technical and managerial supervision of the project	Until May 2013	Engicon/ Huber	Ongoing	A

Annex 2: Examples on the operational data collected from MWA

A 2.1 Influent and Effluent flow rate of year 2011

Date	Influent Flow Rate (m^3/day)	Effluent Flow Rate (m^3/day)
January	5015	4846
February	4901	4700
March	4692	4260
April	4860	4678
May	4958	4842
June	5048	4788
July	5413	5195
August	5396	5079
September	5152	4733
October	5128	5051
November	4965	4679
December	4633	4502
AVG	5013	4774

A 2.2 كشف بقيمة الكهرباء لمحطة مادبا لمعالجة مياه الصرف الصحي (2007-2010)

السنة	اسم المشترك	كانون ثاني	شباط	اذار	نيسان	ايار	حزيران	تموز	اب	ايلول	تشرين اول	تشرين ثاني	كانون اول	الاجمالي
2010	سلطة المياه- محطة التنقية	10,647	9,556	11,295	11,295	11,341								54,134
2009	سلطة المياه- محطة التنقية	10,743	10,572	9,810	11,302	12,343	11,275	11,149	12,640	11,885	12,106	10,959	10,730	135,514
2008	سلطة المياه- محطة التنقية	10,200	10,008	9,947	11,034	10,954	11,579	11,949	13,645	12,905	13,457	13,232	13,432	142,340
2007	سلطة المياه- محطة التنقية	8,103	9,001	9,850	11,781	11,101	10,061	11,425	12,501	10,260	11,471	12,677	11,839	130,069

A 2.3 Transported liquid sludge quantities, 2011

No.	Month	Q (m^3)	Cost (JD)
1	Jan + Feb	8362	14466
2	March	4104	7100
3	April	3305	5718
4	May	2759	4773
5	June	1712	2962
6	July	1651	2856
7	Aug	971	1680
8	Sep	1440	2960
9	Oct	3634	6226
10	15. Nov	801	1385
	TOTAL	28739	50126

Transportation cost from 2.2.2011 -22.12.2011 was 1.73 JD/m^3

Cost from 22.12.2011 is 2.38 JD/m^3

A 2.4 Influent and Effluent quality of Madaba WWTP

Month	BOD		COD		TSS	
	INF.	EFF.	INF.	EFF.	INF.	EFF.
January	1275	17	1970	46	932	17
February	1152	21	1674	45	1000	15
March	1105	20	2118	40	969	15
April	1476	19	1822	41	917	17
May	1713	21	2014	45	1030	16
June	1225	21	1393	43	931	16
July	1256	22	1391	39	986	14
August	1162	22	1375	40	997	15
September	1254	24	1450	39	1013	15
October	1158	29	1440	41	943	16
November	1176	26	1547	39	1016	17
December	1210	32	1788	49	1170	17
AVG	1264	29	1665	43	992	16
Efficiency		98%		97%		98%

Annex 3

A3.1 Electricity consumption of year 2011

Month	Cost (JD)	kWh consumed 2011
Jan. 2011	11195	266540
Feb	10616	252761
March	10426	248238
April	10881	259071
May	11165	265833
June	11171	265976
July	15168	361142
Aug	--------	
Sep	14028	334000
Oct	12463	296738
Nov	13572	323142
Average	10971	8707 kWh/day

A3.2 Electricity Consumption of year 2012

Date	Readings	Power consumption (kWh/d)
2/1/2012	766172	7410
3/1	766878	7060
4/1	767627	7490
5/1	768386	7590
6/1	769151	7650
7/1	769818	6670
8/1	770622	8040 (more aerators at High)
9/1	771414	7920
10/1	772079	6650 2 aerators rpm is lowered
11	772769	6900
12	773444	6750
13	774024	5800
14	774580	5560
15/1	775240	6600
16	775816	5760
17	776420	6040
18	777070	6500
19	777672	6020
20	778309	6370
21	778947	6380
22	779585	6380
23	780214	6290
24	780796	5820
25	781350	5540
26	781913	5630
27	782470	5570
28/1	783066	5960
29/1	783643	5770
30/1	784293	6500
31/1 TUESDAY	784948	6550

Continue A 3.2

Date	Readings	Power consumption (kWh/d)
1/2/2012	785638	6900
2/2/2012	786220	5820
3/2/2012	786806	5860
4 Saturday	787417	6110
5	788010	5930
6	788648	6380
7	789263	6150
8	789867	6040
9	790518	6510
10	791103	5850
11Saturday	791687	5840
12	792321	6340
13	792970	6490
14	793603	6330
15	794313	7100
16	794982	6690
17	795622	6400
18	796174	5520
19	796770	5960
20	797365	5950
21	797965	6000
22/2	798565	6000
23	799224	6590
24	799886	6620
25	800517	6310
26	801147	6300
27	801797	6500
28	802505	7080
29/2/2012	803127	6220

Continue A 3.2

date	reading	Power consumption (kWh/d)
1/3/2012	803713	5860
2/3/2012	804265	5520
3/3	804817	5520
4/3	805363	5460
5/3	805916	5530
6/3	806473	5570
7/3	807125	6520
8/3	807721	5960
9/3	808322	6010
10/3	808902	5800
11/3	809525	6230
12/3	810175	6500
13/3	810790	6150
14/3	811446	6560
15/3	812073	6270
16	812668	5950
17	813280	6120
18	813857	5770
19	814505	6480
20	815090	5850
21	815771	6810 **(IRRIGATION STARTED)**
22	816464	6930
23	817149	6850
24	817833	6840
25	818500	6670
26	819168	6680
27	819846	6770
28	820525	6790
29	821206	6810
30	821815	6090
31/3/2012	822484	6690
Average		**6055**

Continue A 3.2

Date	reading	Power consumption (kWh/d)
1/4/2012	823277	7930
2/4/2012	823962	6850
3/4/2012	824673	7110
4	825362	6890
5	826060	6980
6	826664	6040
7	827336	6720
8	827998	6620
9	828780	7820
10		6890
11	830158	6890
12	830839	6810
13	831560	7210
14	832287	7270
15	832920	6330
16	833646	7260
17	834349	7030
18		6710
19	835690	6700
20	836436	7460
21	837215	7790
22	837969	7540
23	838645	6760
24		7203
25		7203
26		7203
27		7203
28		7203
29		7203
30/4/2012		7203
	844408	

Continue A 3.2

DATE	Reading	Power consumption (kwh/d)
1/5/2012	844408	6890
2/5/2012	845159	7510
3/5/2012	845869	7100
4/5/2012	846516	6470
5/5/2012	847235	7190
6/5/2012	847980	7450
7/5/2012	848693	6780
8/5/2012	849371	6810
9/5/2012	850052	6910
10/5/2012	850743	6620
11/5/2012	851405	7080
12/5/2012	852111	7550
13/5/2012	852866	7190
14/5/2012	853585	7250
15/5/2012	854310	6520
16/5/2012	854962	6600
17/5/2012	855622	6930
18/5/2012	856315	6410
19/5/2012	856956	7120
20/5/2012	857668	7020
21/5/2012	858370	-
22/5/2012	858945	6750
23/5/2012	859620	
24/5/2012	-	-
25/5/2012	860884	6450
26/5/2012	861529	6660
27/5/2012	862195	
28/5/2012	-	-
29/5/2012	863503	6910
30/5/2012	864195	7170
31/5/2012	864912	7530
1/6/2012	(865665)	
TOTAL		**212570**
AVG	**6857**	**6857**

Continue A 3.2

DATE	Reading	Power consumption (kWh/d)
1/6/2012	865665	7530
2/6/2012	866418	7150
3/6/2012	867133	7830
4/6/2012	867916	
5/6/2012		
6/6/2012	869554	9060
7/6/2012	870460	8860
8/6/2012	871346	
9/6/2012		
10/6/2012	873048	8990
11/6/2012	873947	8580
12/6/2012	874805	
13/6/2012		
14/6/2012	876400	7890
15/6/2012	877189	8040
16/6/2012	877993	
17/6/2012		Power off
18/6/2012	879425	8000
19/6/2012	880225	
20/6/2012		
21/6/2012		
22/6/2012	882523	
23/6/2012	883304	
24/6/2012	884134	
25/6/2012		
26/6/2012	885828	
27/6/2012	886750	
28/6/2012		
29/6/2012		
30/6/2012	889422	
TOTAL	**237570**	**237570**
AVG	**7919**	**7919**

Note: the power price will be raised to 0.066 JD/kWh from June 2012

Power Consumption in 2011

Continue A 3.2

Month	kWh consumed 2011	kWh consumed 2012	kWh Saving (%)
Jan	266540	193967	27.2
Feb	252761	174870	30.8
March	248238	187705	24.4
April	259071	211320	18.4
May	265833	212567	20.0
June	265976	237570	10.7
Average	**259737**	**203000**	**21.80**

Annex 4

Annex A4.1: Examples for the Lab analysis results

Environmental Laboratories

الجمعية العلمية الملكية
Royal Scientific Society

Reference: (0302)/ 330/55/1//12439

Date: 8/5/2013

Custom Ref. No: Date: / 5 / 2013
Sample Designation No. : 03/2013/8712
Report No.: 03/13/ 417
Total No. of Report Pages including this page: (2)

Messrs O & M Engicon

Address: Amman/ Tel: 0797031673

Reference to your email, dated (2/5/2013). Please find enclosed results of your calibration(s)/test(s)/service(s) is; (214) Two Hundred and Fourteen JD only.

Please note that the following items marked as ☒ is applicable:-

☐ No need for further action, reason:
☐ Fees paid cash ☐ Agreement No. (/) ☐ Others ....
☐ Pay the invoice which you will receive separately from RSS Financial Department.

Yours sincerely,

/ RSS Testing Executive Director

Dr.Rafat Ahmad
Rafat.ahmad@rss. jo
Phone no:5344701

Notes:

- Payment in checks shall be issued to the name of the Royal Scientific Society.
- Enquires or complaints regarding the attached report should be addressed to Executive Director within ***one month*** of issue.
- Results of tests by the Royal Scientific Society shall not be used for advertising or publicity purposes without prior written approval by the Royal Scientific Society.
- Test reports without signature and seal are not valid.
- You have to send your representative to receive the equipment immediately ***or the test*** sample within ***one month.***
- ***If customers did not claim their test samples, the test samples will be disposed of 1 month after the date of the final report.***

RSSPMP1304, Rev2

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صندوق بريد ١٤٣٨ عمان ١١٩٤١ الأردن
Tel +962 6 5344701 Fax +962 6 5344806

Annex A4.2: Examples for the Lab analysis results

الجمعية العلمية الملكية
Royal Scientific Society

UKAS TESTING
1797

Test Report

Sector: Testing

Division: Enviromental labs

Laboratory: Chemical Analysis Lab.

Sample Designation No.:03/13/8712

Lab Report No.:03/13/917

Client	O & M Engicon
Address	Amman / Tel. 0797031673

Our Reference No.: (0302) 330/55/1/12439

Date: 8/5/2013

Your Reference No.: ---------------

Date: --/--/----

Type of sample: Wastewater

Method of sampling: collected and delivered by your representative

Date of Receipt: 1/5/2013

Date of end Test: 7/5/2013

Test	Results		Unit	Testing method *
	Inlet	Outlet		
NH_4	120	68.3	mg/L	4500 – NH_3 B, C
TS**	2352	1284	mg/L	2540 – B
TSS	710	12.0	mg/L	2540 – D
COD**	2026	147	mg/L	5220 – B
BOD_5**	1295	36.6	mg/L	5210 – B

*: Standard Methods for the Examination of Water & Wastewater. Online.

**: Test is not accredited by UKAS.

Notes:

- Samples were received in a good condition.
- Samples were labeled by your representative.

Royal Scientific Society
RSS Testing

Lab Supervisor: Rula Abu El Hassan

Division Head: Dr. Nisreen Al- Hmoud

Eman

Page (1) of (1)

FORM NO. RSSPMP1302 REV. (1)

تقرير الفحص غير رسمي مالم يحمل التوقيع المعتمد وختم القسم

لا ينسخ التقرير بشكل مجزأ إلا بأخذ موافقة خطية من الجهة المصدّرة للشهادة

نتائج الفحص تمثل العينة المفحوصة فقط

أي كشط او تعديل يلغي هذا التقرير

Test report is only valid with devision-stamp and signature

Test report shall not be reproduced other than in full, except with the written approval of the issuing party

The test results relate only to the items tested

Any erasure or attrition in the report will invalid it

Annex A4.3: Examples for the Lab analysis results

Environmental Laboratories

الجمعية العلمية الملكية

Royal Scientific Society

Reference: (0302)/ 481/55/1/7816

Date: 24/3/2013

Custom Ref. No: Date: / 3 / 2013

Sample Designation No. : 03/2013/4852

Report No.: 03/13/ 201

Total No. of Report Pages including this page: (2)

Messrs Engicon

Address: Amman/ Tel: 0797031673

Reference to your letter No. (--------------), dated (--/--/----). Please find enclosed results of your calibration(s)/test(s)/service(s) is; (560) Five Hundred and Sixty JD only.

Please note that the following items marked as ☒ is applicable:-

☐ No need for further action, reason:

☐ Fees paid cash ☐ Agreement No. (/) ☐ Others ....

☐ Pay the invoice which you will receive separately from RSS Financial Department.

Yours sincerely,

RSS Testing Executive Director

Dr.Rafat Ahmad
Rafat.ahmad@rss.jo
Phone no:5344701

Notes:

- Payment in checks shall be issued to the name of the Royal Scientific Society.
- Enquires or complaints regarding the attached report should be addressed to Executive Director within ***one month*** of issue.
- Results of tests by the Royal Scientific Society shall not be used for advertising or publicity purposes without prior written approval by the Royal Scientific Society.
- Test reports without signature and seal are not valid.
- You have to send your representative to receive the equipment immediately ***or the test*** sample within ***one month***.
- ***If customers did not claim their test samples, the test samples will be disposed of 1 month after the date of the final report.***

RSSPMP1304, Rev2

Annex A4.4: Examples for the Lab analysis results

الجمعية العلمية الملكية
Royal Scientific Society

Test Report

Sector: Testing

Division: Environmental labs

Laboratory: Chemical Analysis Lab

Sample Designation No.:03/13/4852

Lab Report No.:03/13/201

Client	Messrs Engicon
Address	Amman. Tel. No. 0797031673

Our Reference No.: (0302) 481/55/1/7816
Date: 24/3/2013
Your Reference No.: --------
Date: --/--/----

Type of sample: Sludge samples.
Method of sampling: collected and delivered by your Representative
Date of Receipt: 13/3/2013
Date of end of Test: 24/3/2013

Test	Results/ Sample Code		Unit	Test method
	Mature Compost 11.03.2013	**Fresh Compost 11.03.2013**		
Ca (Dissolved)**	38.2	6.03	mg/Kg(dry weight)	3111 – B*
Mg (Dissolved)**	70.2	27.5	mg/Kg(dry weight)	3111 – B*
Moisture Content	53.6	37.9	%	Gravimetric
T-N	2.46	3.0	%	4500 – Norg. B*
$NO_3 - N$ (Dissolved)**	48.1	3.46	mg/Kg(dry weight)	4110 – B*
TVS	24.4	48.4	%	2540-G*
K (Dissolved)**	703	337	mg/Kg(dry weight)	3111 – B*
TP	5.78	2.50	%	4500 P, C*
E.coli	0.57	1.5×10^7	MPN/g	EPA / 1680(2006) 9221 F*

*: Standard Methods for the Examination of Water & Wastewater, Online.

Notes:
- Samples were received in a good condition.
- Samples for TN & TP tests were prepared according to ICARDA / 2001.
**: Samples were extracted with water (1:2).

Royal Scientific Society RSS Testing

Lab Supervisor: Rula Abu El Hassan

Division Head: Dr. Nisreen Al- Hmoud

Eman

Page (1) of (1)

FORM NO. RSSPMP1302 REV. (1)

تقرير الفحص غير رسمي مالم يحمل التوقيع المعتمد وختم القسم

لا ينسخ التقرير بشكل مجزأ إلا بأخذ موافقة خطية من الجهة المصدرة للشهادة

نتائج الفحص تمثل العينة المفحوصة فقط

أي كشط او تعديل يلغي هذا التقرير

Test report is only valid with devision-stamp and signature

Test report shall not be reproduced other than in full, except with the written approval of the issuing party

The test results relate only to the items tested

Any erasure or attrition in the report will invalid it

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Annex 5: Disclaimer Letter

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Institute of Environmental and Water Studies

Birzeit University – West Bank

Palestinian Territories

Management of Water Resources Programme

Daniel Busche
Moh'd Baseem Alkhammash Str. 13
P.O.Box 926238 Amman 11190, Jordan
T ++962 6 5690051
F ++962 6 5685389
E daniel.busche@giz.de

Your reference		Telephone	
Our reference		Fax	
Email	elke.zimmermann@giz.de	Date	25.09.2013

Subject: develoPPP.de / Madaba wastewater Treatment Plant for Improving Energy Efficiency and Sludge Management

To whom it may concern,

Kindly note that the German-Jordanian Programme "Management of Water Resources" implemented by GIZ and the Project Management Unit / Water Authority of Jordan allow Mr. Feras Matar to use and analyze the available data of the "Implementation of a Development Partnership with the Private Sector for Madaba Wastewater Treatment Plant for Improving Energy Efficiency and Sludge Management" – which is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) – in his master thesis for scientific purposes.

Sincerely Yours

Mr. Daniel Busche
Head of German-Jordanian Programme
Management of Water Resources
Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH

Eng. Iyad Dahiyat
Director, Programme Management Unit (PMU)
Water Authority of Jordan (WAJ)

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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