

UNIVERSITY OF BAHRAIN

College of Engineering



**Department of
Mechanical Engineering**

Wastewater Management in the Kingdom of Bahrain: A Case Study using Analytic Network Process in SWOT Analysis for a Textile Facility

Thesis submitted in partial fulfillment of the requirements for degree of
M.Sc in Engineering Management

Prepared by
Fatima Ahmed Mohammed
ID Number : 20000261

Supervised By
Elamin M. Elkanzi
Professor of Chemical Engineering
University of Bahrain

Kingdom of Bahrain

December, 2016

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Graduate Studies Council

Thesis Discussion Committee Decision

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The student awarded grade A in the thesis subject IEN 598

- ☐ Without making any changes to the thesis
☒ After making the modifications attached with this decision

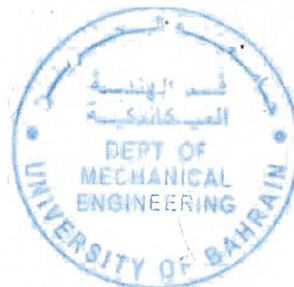
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Abstract

The volume of wastewater generated by domestic, industrial and commercial facilities in the Kingdom of Bahrain has increased with population, urbanization, and industrial development. Centralized and de-centralized approaches to wastewater management are evaluated and contrasted through SWOT analysis and analytic network process (ANP). Data were collected from different sources including governmental reports, relevant environmental regulations, wastewater treatment facilities and were evaluated through structured questionnaire with responses of 25/38 and 9 personal interviews with experts conducted to both systems practiced in Kingdom and the enforcement of the national wastewater management regulations. The research found that wastewater legislations need to be reviewed and updated. SWOT tool was used to evaluate strengths, weaknesses, opportunities and threats factors for both decentralized and centralized wastewater management systems represented by a textile facility and Tubli STP. The SWOT sub-factors were identified and the alternative strategies (SO-WO-SW-WT) were developed in which SO uses strengths to maximize opportunities, WO minimizes weaknesses by taking advantage of opportunities. ST uses strengths to minimize threats and WT minimizes weaknesses and avoid threats. Since SWOT possesses deficiencies in the measurement and evaluation steps, the Analytical Network Process (ANP) approach was used to measure the dependency among strategic factors and sub-factors that will reflect both the weight and change of the strategic priorities. The ANP analysis for the local textile facility indicated that reusing 100% of the treated wastewater on the production process is the best strategy (ST) to reduce the water consumption with highest priority value of 0.804. For centralized wastewater management system Tubli STP, the ANP indicated that the (ST) is the best strategy with priority value of 0.680. Therefore, Tubli needs to upgrade its wastewater treatment plants in order to improve the wastewater effluents and fulfill legislation limits for the disposal in Tubli bay . Both management systems were found effective and appropriate and the best alternative strategy is ST that will enhance and improve their management to ensure a better reuse of the treated wastewater.

Dedication

I dedicate this work to my family and friends for their support and patience. I thank them for inspiring me and for their continuous encouragement

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I would like to acknowledge the patience and guidance of my supervisor Prof. Elamin M. Elkanzi , who worked hard with me from the beginning till the completion of the present research.

I would like to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive along the way of doing my thesis and to express my wholehearted thanks to my family for their generous support they provided me throughout my entire life and particularly through the process of pursuing the master degree. Because of their unconditional love and prayers, I have the chance to complete this thesis.

Finally, I appreciate and thank the personnel of the facilities who participated and spent their valuable time with me in the interview or by filling the questionnaire, their response encouraged me to complete this research.

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Abbreviations

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BOD	Biochemical Oxygen Demand
CFR	Code Of Federal Regulations
COD	Chemical Oxygen Demand
EPA	Environmental Protection Agency
STP	Sanitary Treatment Plant
SWOT	Strength, Weakness , Opportunities and Threat Analysis
TOC	Total Organic Carbon
TSS	Total Suspended Solids
WWM	Wastewater Management

WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant

Chapter 1

Introduction

- 1.1 Introduction
- 1.2 Research Problem
- 1.3 Research Objectives
- 1.4 Research Significance
- 1.5 Research Settings
- 1.6 Research Terminologies

Chapter 1

Introduction

1.1 Introduction

“The wastewater challenge is not only a threat, but a challenge where we can find opportunities for green employment, social well-being and ecological health”
(Corcoran & Savelli, 2010)

The world is facing a global water quality crisis. The continuing population growth, urbanization and rapid industrialization are all putting pressure on fresh water resources. Moreover, the increasing unregulated or illegal discharge of contaminated water within and beyond national borders puts burden on the environment. In 2015 world population reached 7.3 billion and over the next two decades, global populations is expected to increase and exceed nine billion by 2050 (United Nations, 2015). Growing demands are projected to push all countries into water scarcity conditions. Although, the absolute quantities of freshwater on earth have always remained approximately constant, the uneven distribution of water and human settlement continues to create growing problems in freshwater availability and accessibility. Therefore, it is important to consider the role of wastewater treatment and its impact on the environment; preventing the contamination of freshwater and increasing its quantity(Engelman & Gardner-Outlaw, 1997).

The term “wastewater” has many definitions, (Metcalf and Eddy, 2003) defined it as "a mixture of wastewater from domestic residences, commercial properties, industry, and/or agriculture discharge to sewers and rainwater run-off from roads and other impermeable surfaces draining to sewers". It encompassed a wide range of contaminants with

different concentrations that might affect the physical, chemical and biological characteristics of water. Wastewater is often referred to as 'sewage', but in this research the term 'wastewater' will be used.'

Wastewater treatment is relatively a modern practice. While sewers were commonly used in ancient Rome to remove foul-smelling water, in the 19th century communities began to realize the importance of reducing the amount of pollutants in the used water they were discharged to the environment. Despite large supplies of fresh water and the natural ability of water to cleanse itself over time, populations had become so concentrated by 1850 that outbreaks of life-threatening diseases were traced to bacteria in the polluted water. Since that time, the practice of wastewater collection and treatment has been developed and perfected, using some of the most technically sound physical, mechanical, chemical, and biological techniques available. As a result, public health and water quality are better protected today than ever before. (WCT, 2007)

In the past, the Arab nations played a leading role in the development of innovative water solutions with noteworthy achievements including global leadership in desalination, dam infrastructure and drip irrigation. Until recently, planned wastewater management in the Arab region focused on the conventional objectives of protecting public health and the environment. Pervasive water scarcity, urbanization and the increasingly obvious impacts of climate change to a shift in local perceptions on the importance of proper use of reclaimed water (WRITAW, 22–24 May2011). Arab representatives attending "Expert consultation on Wastewater Management in the Arab World" conference held in May 2011 agreed that, reusing water by most Arab nations will have a great potential in increasing available water resources. Arab states currently produce an estimated 10.8 km³/year of wastewater and around 10.85x10⁶ km³/year of domestic wastewater, 55% are reported to be

treated of which only 15% are reused in agriculture, landscape irrigation, industrial cooling and environmental protection. Demographic growth, economic and social development across Arab countries have contributed to significant increases in water demand (World Bank, 2007). Rapid urbanization across most Arab countries causes further challenges and need more efforts to meet increasing domestic water demands, especially for those countries with scarce public funds (WRITAW, 22–24 May2011). The annual untreated wastewater discharged in the Arab countries is 4.36 km³, equivalent to 40% of the total reported wastewater produced in the region.

1.2 Research Problem

The Kingdom of Bahrain is one of the countries facing fresh water scarcity. Treated sewage effluent (TSE) can give 9.7% of usable water source in Bahrain. Therefore, an evaluation of the current applied centralized and decentralized wastewater management approaches practiced in Bahrain could lead to a better management.

1.3 Research Objectives

The main objective of this research is to evaluate the wastewater treatment management approaches applied in the Kingdom of Bahrain. Centralized and decentralized wastewater treatment approaches are evaluated and contrasted using SWOT analysis supported with analytic network process method to provide a measurable analytical means that determines the best alternative strategies that can be used to improve and enhance the existing management system and propose the appropriate management approach to reuse the treated wastewater as a source of usable water.

Finally, the enforcement of current wastewater regulations applied in the Kingdom of Bahrain will be evaluated in order to prevent any illegal discharge of contaminated water in the Kingdom's seacoast

1.4 Research Significance

This research will provide the centralized and decentralized wastewater establishments a tool to evaluate their wastewater management system.

1.5 Research Setting

This research was carried out for centralized and decentralized wastewater establishments and relevant governmental authorities in Kingdom of Bahrain.

A case study for a local textile facility was chosen to represent decentralized wastewater management system and Tubli sanitary treatment plant (STP) as centralized wastewater management system.

1.6 Research Terminologies

The following are basic research terms and definitions:

Analytic Hierarchy Process (AHP): is a process that uses hierarchical decomposition to deal with complex information in multicriterion decision making.

Analytic Network Process (ANP): is a multi-criteria decision analysis tool that structures the decision problem (goal, decision criteria, and alternatives) into a network with dependence and feedback, then use a

system of pairwise comparisons to measure the weights of the components of the structure, and finally rank the decision alternatives.

Centralized Wastewater Management: consists of centralized collection system that collects wastewater from many wastewater producers: households, commercial areas, industrial plants and institutions, and transports it to centralized wastewater treatment plant in an off-site location and usually dispose/reuse the treated effluent far from the point of origin.

Decentralized Wastewater Management: is a concept in which wastewater is managed: collected, treated and disposed/reused at or near the point of generation .

Domestic wastewater: wastewater generated from residential settlements and services, such as houses; and which originates predominantly from toilets, bathrooms and kitchens.

Industrial wastewater: wastewater generated from industrial operation and activities.

Wastewater: is combination of the liquid and water carried waste removed from residences, institutions, commercial and industrial establishments, together with groundwater, surface water, and stormwater" .

Wastewater Treatment: The process of removing pollutants from water that has been used. There are three different stages of treatment. Primary treatment involves screening the water to remove the largest solids and then letting the water sit in tanks so that smaller particles can be removed when they sink to the bottom. Secondary treatment uses bacteria and other microscopic organisms to biodegrade the organic pollutants that were not removed during primary treatment. During tertiary treatment, the water passes through a filter. Following treatment the water is

disinfected and released back into environment. Water that leaves wastewater treatment plants must meet strict national requirements.

Wastewater Treatment Plant: The facility where the wastewater treatment process is carried out.

SWOT Analysis: Simple management tool to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or in a business. It can be carried out for a product, place, industry or even a person.

Chapter 2

Theoretical Framework & Review of Literature

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 - 2.1.1 Wastewater Sources
 - 2.1.2 Wastewater Characteristics
 - 2.1.3 Wastewater Treatment Processes
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- 2.5 Commentary on Literature Review

Chapter 2

Theoretical Framework & Review of Literature

2.1 Wastewater Background

Water is crucial for all aspects of life. It is a defining feature of our planet, 97.5% of the earth water was found in the oceans, while the remaining 2.5% is fresh water. Only 1% of the fresh water is available for withdrawal and human use (Corcoran & Savelli, 2010). In any community, water demand varies on a seasonal, daily, and hourly basis. As the demand of water is increased, the intention of wastewater treatment is developed toward expanding water resources (Martins, G. et al, 2013). In addition, Jhans & Mishra (2013) and Defra (2012) proved the importance of wastewater treatment to recover energy, nutrients, water, and other valuable resources. Wastewater can mean different things to different people with a large number of definitions in use. However, in this research wastewater will be define as combination of the liquid and water carried waste removed from residences, institutions, commercial and industrial establishments, together with such groundwater, surface water, and storm water" (Metcalf and Eddy, 2003).

2.1.1 Wastewater Sources

The components that make up the wastewater from a community depend on the type of collection system used, wastewater source, the local conditions and the time of the year (Rosenwinkel, Austermann-Haun, & Meyer, 2005). Metcalf and Eddy (2003) summarized, wastewater sources and grouped them into four; domestic, industrial, infiltration/inflow and storm water that are described as follows:

- a) Domestic (also called sanitary) wastewater: wastewater discharged from residences and from commercial, institutional, and similar facilities.
- b) Industrial wastewater: Wastewater in which industrial wastes predominate.
- c) Infiltration/Inflow (I/I): Water that enters the sewer system through indirect and direct means. Infiltration is extraneous (not directly connected) water that enters the sewer system through leaking joints, cracks and breaks, or porous walls. However, inflow is storm water that enters the sewer system from storm drains connection roof connection, leaders, or through the manhole covers.
- d) Storm water: Runoff resulting from rainfall and snowmelt (in cold countries).

Tables (2-1), (2-2) and (2-3) show the typical wastewater generated from residential, Institutional and Recreational sources.

Table (2-1) Typical Wastewater Generated from Residential Sources

Source	Unit	Flow , Gallons/Unit . d	
		Range	Typical
Apartment, High-Rise	Person	35-75	50
Low Rise	Person	50-80	65
Hotel	Guest	30-55	45
Individual Residence			
Typical Home	Person	45-90	70
Better Home	Person	60-100	80
Luxury Home	Person	75-150	95
Older Home	Person	30-60	45
Summer Cottage	Person	25-50	40
Motel			
with Kitchen	Unit	90-180	100
without kitchen	Unit	75-150	95
Mobile Home Park	Person	30-50	40

(Source: Metcalf and Eddy, 2003)

For many residential areas, wastewater flowrates are commonly determined on the basis of population density and average per capita contribution of wastewater.

Table (2-2) Typical Wastewater Generated from Institutional Sources

Source	Unit	Flow , Gallons/Unit . d	
		Range	Typical
Hospital, Medical	Bed	125-240	155
	Employee	5-15	10
Hospital, Mental Health	Bed	75-140	100
	Employee	5-15	10
Correctional Institution (Prison)	Inmate	75-150	115
	Employee	5-15	10
Rest Home School, day	Resident	50-120	85
w/ cafeteria, gym, & showers	Student	15-30	25
w/ cafeteria only	Student	10-20	15
no cafeteria; no gym	Student	5-17	11
School, boarding	Student	50-100	75

(Source: Metcalf and Eddy, 2003)

Wastewater flowrates from many recreational facilities are seasonal, while the average unit-flowrate allowance for commercial development normally range 800-1500 gal/acre. d. Metcalf and Eddy(2003) clearly explained that nondomestic wastewater flowrate from industrial sources vary with the type and the size of facility. The typical design value for estimating the flows from industrial areas with light industrial developments which have no or little wet process type industries are 1000 to 1500 gal/acre. d. while the estimated flows for medium industrial developments are 1500 to 3000 gal/acre. d .

Table (2-3) Typical Amount of Wastewater Generated from Recreational Sources

Source	Unit	Flow , Gallons/Unit . d	
		Range	Typical
Apartment, Resort	Person	50-70	60
Cabin, Resort	Person	8-50	40
Cafeteria	Customer	1-3	2
	Employee	8-12	10
Campground (developed)	Person	20-40	30
Cocktail Lounge	Seat	12-25	20
Coffee Shop	Customer	4-8	6
	Employee	8-12	10
Country Club	Member Present	60-130	100
	Employee	10-15	13
Day Camp (no meals)	Person	10-15	13
Dining Hall	Meal Served	4-10	7
Dormitory	Person	20-50	40
Hotel, Resort	Person	40-60	50
Store, Resort	Customer	1-4	3
	Employee	8-12	10
Swimming Pool	Customer	5-12	10
	Employee	8-12	10
Theatre	Seat	2-4	3
Visitor Center	Visitor	4-8	5

(Source: Metcalf and Eddy, 2003)

For industries without internal recycling or reuse programs it can be assumed that 85-98 percent of the water used in the various operations and processes will become wastewater (Metcalf and Eddy, 2003).

Metcalf and Eddy (2003) suggested for large industries with internal water reuse programs, a separate estimates must be made.

As for Bahrain, the amount of wastewater generated in the Kingdom depend on several factors such population size and water consumption. Bahrain known to have a total area of 665km² but due to land reclamation, the area increased to 780km² . It was often described as an archipelago of 33 islands, extensive land reclamation projects have changed this fact. In 2008 the number of islands and island groups had increased to 84. Bahrain's largest islands are Hawar, Muharraq, Umm an Nasan, and Sitra islands.

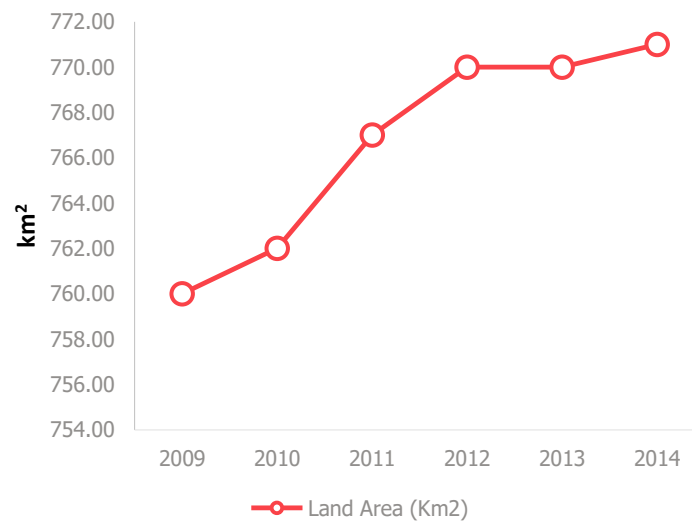


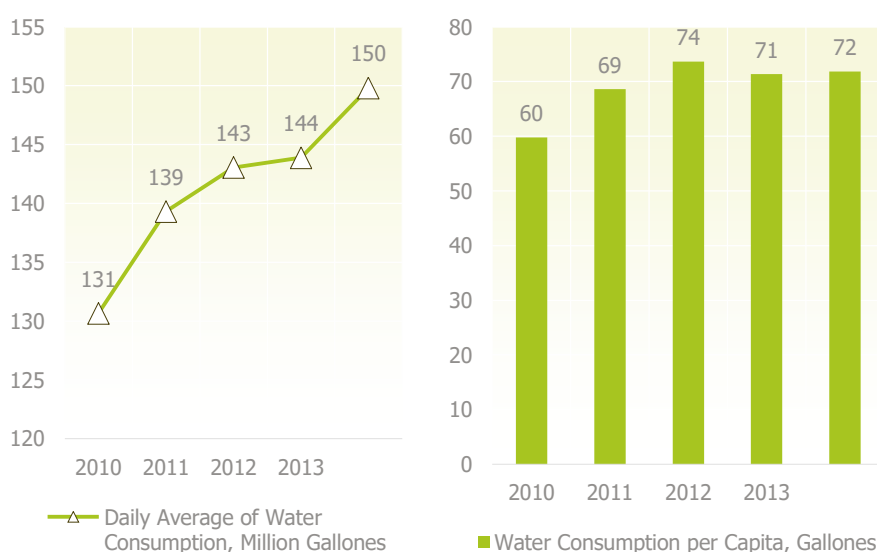
Figure (2-1)
The Land Area of Kingdom of Bahrain (2009-2014)
 (Source: Bah CIO, 2014)

By the end of 2014, Bahrain population reach 1,314,562 people, which represents an increase of 61,371 people compared to 2013 with a population growth rate of 2.49%. As population and development continue to rise, water consumption increases and demand for additional water resources increased. In a recent article done by Al Ansari in 2013 (Al.Ansari, 2013), the water demand in Bahrain has increased nearly three times from what it was in 1952, when the demand was at 116.68 Mm³ per year. In 2011, the water demand was calculated to be more than 354.6 Mm³. Al Ansari explained the demand increase in Bahrain to three main reasons: the growth rate of the population, living standards and the development of industry and commerce throughout the Kingdom. (Al.Ansari, 2013). In 2013, the total water consumption of the domestic sector represented 77%, whereas the industrial and commerce sectors used 3 and 20%, respectively. The extent of increase of the amount water consumed during the past four years is illustrated in table (2-4).

Table (2-4) Water Consumption in Kingdom of Bahrain by Sector

Water Consumption by Sector Million Cubic Meters	2010	2011	2012	2013
Industrial Sector	1,622.00	2,969.00	2,397.00	4,729.00
Commercial Sector	24,541.00	24,951.00	30,235.00	30,578.00
Domestic Sector	115,944.00	118,919.00	116,014.00	119,182.00
Total	142,107.00	146,839.00	148,646.00	154,489.00

(Source: Bah CIO, 2014)



(a)

(b)

Figure (2-2)
Water Consumption (a) Daily Average (b) Water Consumption per Capita

Bahrain is characterized by scarce, erratic rainfall, the average annual rainfall for the past five years was 56.36 mm with limited surface water resources and poor groundwater recharge. Thus, its economic development is dependent on fresh groundwater available mainly in Dammam formations extending from Saudi Arabia. The other groundwater aquifers found in the two geologically-older formations of Russ and Umm Er Radhuma are semi-saline, thereby being unsuitable for use unless desalinated (Amal, 2015).

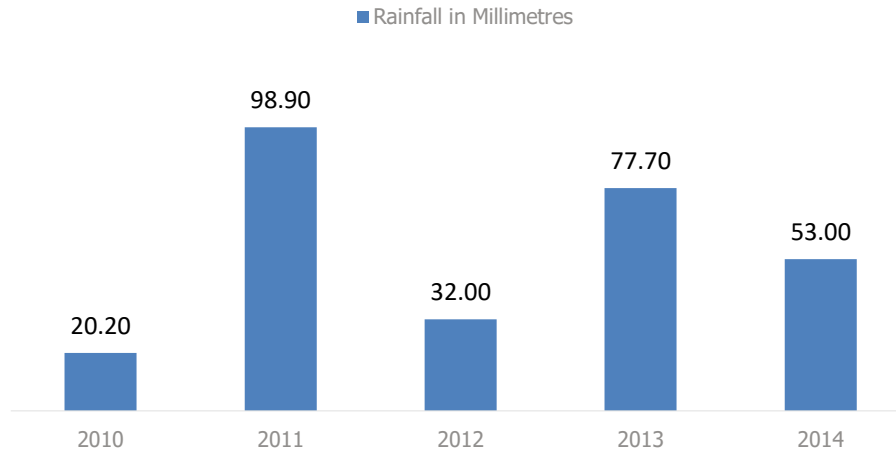


Figure (2-3)
Rainfall in Bahrain 2010-2014 (Source: Bah CIO,2014)

Environmental issues facing Bahrain include desertification resulting from the degradation of limited arable land, coastal degradation (damage to coastlines, coral reefs, and sea vegetation) resulting from oil spills and other discharges from large tankers, oil refineries, distribution stations, and illegal land reclamation at places such as Tubli Bay. Therefore, It has become necessary, to secure water from different sources, such as desalinated water and treated wastewater. The use of treated wastewater started in 1980s and has been increasing ever since. Currently 30% of sewage effluent resulted from main treatment facilities is tertiary treated and being used in watering forage crops and landscapes. In 2010 government of Bahrain utilized 200,000 m³/day treated wastewater, which will saved 20% of annual abstract. Officials are very much cautious about the use of treated wastewater in agriculture. All necessary precautionary measures have been taken to rationalize such use in order to minimize the impact of soil and groundwater pollution on human health. This could significantly reduce water extraction, reserving the limited freshwater resources for potable supply and other priority uses.

Table (2-5) Non-conventional water sources in Kingdom of Bahrain

Nonconventional water sources	Year	Value	Unit
Produced wastewater	1991	44.9	10 ⁶ m ³ /yr
Treated wastewater	2005	61.9	10 ⁶ m ³ /yr
Reused treated wastewater	2005	16.3	10 ⁶ m ³ /yr
Desalinated water produced	2003	102.4	10 ⁶ m ³ /yr
Reused agricultural drainage water	2001	3	10 ⁶ m ³ /yr

Sources: FAO AQUASTAT Database, 2008

Table (2-5) shows, that in 2005 the treated wastewater amounted to be about 62 million m³/year (secondary treatment) against about 45 million m³ in 1991. Despite an increase of 100 percent compared with 1991, only 16.3 million m³/year received tertiary treatment and part was used for irrigation purposes in government farms and some private farms, while the rest was discharged to the sea (MoW, 2002).

Based on estimates by the Food and Agriculture Organization of the United Nations (FAO AQUASTAT), the cost of tertiary treated effluent is about US\$0.317/m³ less than the cost of desalinated water which is about US\$0.794/m³ (FAO/WHO, 2001).

2.1.2 Wastewater Characteristics

Understanding the wastewaters nature is essential in the design and operation of collection, treatment, and reuse of wastewater facilities, and in the engineering management of environmental quality. The wastewater is characterized in terms of physical, chemical, and biological Characteristics (Rabah, 2015) and (Metcalf and Eddy, 2003).

2.1.2.1 Physical Characteristics

Wastewater physical characteristics could be generally summarized into total solids content, which is composed of floating matter, settleable matter, colloidal matter, and matter in solution. There are other important physical characteristics such as odor, temperature, color, and turbidity. The fresh wastewater have a light brownish gray color, with time it will become dark gray, while the aged, septic wastewater have black color. Some wastewater have a pink color due to algae or the discharging of industrial colors (Davis, 2010). Davis and Rabah have demonstrated that the fresh, aerobic, domestic wastewater have the kerosene odor, while the aged, septic sewage have the characteristic rotten-egg odor due the existence of hydrogen sulfide and the mercaptans is indicative of septic sewage (Davis, 2010;Rabah, 2015). The wastewater temperature is important because it affects; chemical reactions during the treatment process, aquatic life and the oxygen solubility. Wastewater temperatures normally range between 10°C and 20°C depend on country location. Generally, wastewater temperature is higher than that of the water supply due the addition of warm water (Davis, 2010; Rabah, 2015).

2.1.2.2 Chemical and Biological Characteristics

The chemical and microbiological composition of the wastewater must be monitored in order to safeguard downstream users. Rabah (2015) states that the the chemical characteristics of wastewater are organic matter, inorganic matter, dissolved gases and pH. The characteristics of wastewater from different sources were listed in table (2-6), many parameters are interrelated (Metcalf and Eddy, 2003).

Table (2-6) Physical, Chemical, and Biological Characteristics of Wastewater and their Sources (Source: Metcalf and Eddy, 2003)

Characteristic	Sources
Physical characteristics:	
Color	Domestic and industrial wastes, natural decay of organic materials
Odor	Decomposing wastewater, industrial wastes
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, inflow/infiltration
Temperature	Domestic and industrial wastes
Chemical constituents:	
- Organic:	
Carbohydrates	Domestic, commercial, and industrial wastes
Fats, oils, and grease	Domestic, commercial, and industrial wastes
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic, commercial, and industrial wastes
Priority pollutants	Domestic, commercial, and industrial wastes
Surfactants	Domestic, commercial, and industrial wastes
Volatile organic compounds	Domestic, commercial, and industrial wastes
Other	Natural decay of organic materials
- Inorganic:	
Alkalinity	Domestic wastes, domestic water supply, groundwater infiltration
Chlorides	Domestic wastes, domestic water supply, groundwater infiltration
Heavy metals	Industrial wastes
Nitrogen	Domestic and agricultural wastes
pH	Domestic, commercial, and industrial wastes
Phosphorus	Domestic, commercial, and industrial wastes, natural runoff
Priority pollutants	Domestic, commercial, and industrial wastes
Sulfur	Domestic water supply; domestic, commercial, and industrial wastes
- Gases:	
Hydrogen sulfide	Decomposition of domestic wastes
Methane	Decomposition of domestic wastes
Oxygen	Domestic water supply, surface-water infiltration
Biological constituents:	
Animals	Open watercourses and treatment plants
Plants	Open watercourses and treatment plants
Protists:	
- Eubacteria	Domestic wastes, surface-water infiltration, treatment plants
- Archaeobacteria	Domestic wastes, surface-water infiltration, treatment plants
- Viruses	Domestic wastes

a) Organic Matter ($C_aH_bO_c$)

Organic matter is derived from animals & plants and man activities, 75% of Suspended Solids (SS) and 40 percent of filtered Solid (FS) are organic. The organic matter composed of 40-60 percent Proteins, 25-50 percent Carbohydrates and 10 percent Fats, Oils, and Grease. Metcalf and Eddy (2003) and Rabah (2015) summarized the main parameters have been used to measure the concentration of organic matter in wastewater are Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Total organic carbon (TOC) and Theoretical oxygen Demand (ThOD). BOD is the oxygen equivalent of organic matter. It is determined by measuring the dissolved oxygen used by microorganisms during the biochemical oxidation of organic matter in 5 days at 20°C (Rabah, 2015). COD is the oxygen equivalent of organic matter. It is determined by measuring the dissolved oxygen used during the chemical oxidation of organic matter in 3 hours (Rabah, 2015). TOC is a method that measures the organic carbon existing in the wastewater by injecting a sample of the WW in special device in which the carbon is oxidized to carbon dioxide then carbon dioxide is measured and used to quantify the amount of organic matter in the WW. This method is only used for small concentration of organic matter (Rabah, 2015). ThOD is computed as the amount of oxygen needed to oxidize the organic carbon to carbon dioxide and a other end products (Rabah, 2015).

b) Inorganic Matter

The main inorganic materials concerned in wastewater treatment are chloride, nitrogen, Phosphorus, Sulfur and heavy metals (Rabah, 2015). High chlorides concentrations indicate that the water body has been used for waste disposal which affects the biological process. Nitrogen represents a measure of the total organic and ammonia nitrogen in the

wastewater. Phosphorus may appear in many forms in wastewater such as orthophosphates, polyphosphates, and organic phosphate. Together, referred to as total phosphorus. Sulfur exist in waste water as Sulfate, and it is necessary for synthesis proteins organic matters. Some toxic inorganic compounds presented such as; Copper, lead, silver, chromium, arsenic, boron. In addition to that heavy metals like Nickels, Mn, Lead, chromium, cadmium, zinc, copper, iron, mercury are available with appreciated amounts.

c) Gases and hydrogen-ion concentration (pH)

The main gases of concern in wastewater treatment are; N_2 , O_2 , CO_2 , H_2S , NH_3 , CH_4 . As for PH, it is an important parameter in both natural waters and wastewaters. It is a very important factor in the biological and chemical wastewater treatment (Rabah, 2015). Water and wastewater can be classified as neutral , alkaline or acidic if the PH ranges are 7, >7 and <7 respectively. Metcalf and Eddy illustrated that the knowledge of the biological characteristics of wastewater is a significant factor in wastewater treatment. The principal of grouping classification of microorganisms such as Bacteria, Fungi, Algae, Viruses,..etc, and the pathogenic found in wastewater must be known to evaluate the toxicity of treated wastewater (Metcalf and Eddy, 2003).The industrial processes generate a wide varieties of wastewater pollutants. Most researches confirmed that the characteristics and levels of pollutants in the wastewater vary significantly from industry to industry (Defra,2012; Tajrishy M, 2012).

The main concerns of wastewater contaminants are summarized in Table 2-7.

Table (2-7) Important Contaminants of Concern in Wastewater

Contaminants	Reason for importance
Oxygen consuming organic matter	Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most commonly in terms of BOD and COD . If discharged untreated to the environment, their biological stabilization can lead to the depletion of natural oxygen resources and to the development of septic conditions.
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.
Nutrients	Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life..
Priority pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of these compounds are found in wastewater.
Refractory organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused.
Pathogens	Communicable diseases can be transmitted by the pathogenic organisms in wastewater.
Dissolved inorganics	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.

(Source: Metcalf and Eddy, 2003)

On the other hand, the Environmental Protection Agency (EPA) has grouped the pollutants into three categories Toxic (Priority) pollutants, Conventional and Nonconventional (Davis, 2010).

126 pollutants were listed by EPA's as priority(toxic) pollutant listed on appendix A. The conventional and nonconventional pollutants are listed in Table 2-8 .

Table (2-8) EPA's Conventional and Non-conventional Pollutant Categories

Categories	Pollutants
Conventional	Biochemical oxygen demand (BOD ₅)
	Total suspended solids (TSS)
	Oil and grease
	Oil (animal, vegetable)
	Oil (mineral)
	pH
Nonconventional	Ammonia (as N)
	Chromium VI (hexavalent)
	Chemical oxygen demand (COD)
	COD/BOD ₇
	Fluoride
	Manganese
	Nitrate (as N)
	Organic nitrogen (as N)
	Pesticide active ingredients (PAI) Phenols, total
	Phosphorus, total (as P) Total organic carbon (TOC)

(Source: Code of Federal Regulations 40 CFR §413.02, 464.02, 467.02, and 469.12)

In Bahrain, MoW implement a standard characteristic for influent wastewater are stated by in ministerial order no. 10 for 2009 executive regulations of the law No. 33 for 2006 with regards to wastewater surface wastewater. In Table (2-9) a group of contaminants was clearly illustrated with limited value.

Table (2-9) Bahrain criteria applied for wastewater influent characteristics

Contaminants	Value	Unit
PH	6-9	mg/l
TSS	400	mg/l
Turbidity	35	mg/l
F.O.G	50	mg/l
Ammonia-N	30	mg/l
Total Nitrogen-N	50	mg/l
Total Phosphorous-P	10	mg/l
Phosphate-P	5	mg/l
BOD	400	mg/l
COD	600	mg/l
Sulphate	400	mg/l
Sulphide	10	mg/l
MBAS	30	mg/l
Aluminum	5	mg/l
Arsenic	2	mg/l
Boron	2	mg/l
Cadmium	0.5	mg/l
Chromium	2	mg/l
Copper	2	mg/l
Iron	5	mg/l
Lead	5	mg/l
Mercury	0.001	mg/l
Molybdenum	1	mg/l
Nickel	1	mg/l
Zinc	5	mg/l

Source: BAH MO No. 10 for 2009

Wastewater in Bahrain has low concentration of 5-day biochemical oxygen demand (BOD₅) which is less than 220 milligrams per liter, chemical oxygen demand (COD) is less than 500 milligrams per liter and total suspended solids (TSS) is less than 220 milligrams per liter. Effluent characteristics clearly demonstrate its high quality and suitability for unrestricted irrigation from a microbiological viewpoint provided that intestinal nematode eggs are duly removed by the sand filter as would be expected. Nonetheless, from a chemical perspective, the high salinity in the effluent imposes a medium to severe restriction on the irrigation of salinity-sensitive crops and plants. High salinity levels and helminth eggs are two major concerns encountered in the

wastewater treatment and reuse sector in Bahrain. While the latter can be dealt with, albeit expensively, using sand filters, the high salinity requires desalination, which certainly implies further technical complications and even higher costs. (WHO, 2005).

Table (2-10) Typical influent and effluent characteristics: Tubli wastewater treatment plant

Parameter	Influent mg/l	Effluent, mg/l	
		Average	Range
Chemical oxygen demand	410	42	12–88
5-day biological oxygen demand	219	2	0–23
Total suspended solids	179	3	1–13
Volatile suspended solids	ND	1	0–4
Ammonia	24	1.4	0–16
Electrical conductivity ($\mu\text{S}/\text{cm}$)	ND	5200	3200–8600
Hydrogen Ion (pH)	ND	7.5	7.0–8.2
Alkalinity	ND	158	137–178
Calcium	ND	202	183–228
Magnesium	ND	110	89–136
Sodium	ND	633	515–733
Chlorine	ND	1493	1110–1665
Iron	ND	0.19	0.03–0.48
Copper	ND	0.11	0.02–0.28
Zinc	ND	0.2	0.13–0.31
Lead	ND	0.15	0.01–0.23
Nickel	ND	0.1	0.06–0.15
Cadmium	ND	0.01	0.02–0.03
Thermo-tolerant coliform count (MPN/100ml)*	ND	ND	0–2.5

ND: not determined

Source: WHO,2005

2.1.3 Wastewater Treatment Processes

Since the 19th century, many technologies have been developed for the wastewater treatment. The most widely used of these is the conventional activated sludge process (Metcalf and Eddy, 2003). Many other technologies have been developed that employ various treatment processes, both aerobic and anaerobic, highly mechanized to not highly mechanized, including trickling filters and bio-towers, upflow anaerobic

sludge blanket (UASB) reactors, rotating biological contactors (RBC), aerated lagoons, sequential batch reactor (SBR), and many others (Metcalf and Eddy, 2003). The recent developments in wastewater treatment technologies provide many options for treating (Kalbar, Karmakar and Asolekar, 2012).

Giovanni Libralato in (2011) mentioned that the treatment technologies should be efficient and reliable, with low construction costs, management and maintenance that support self sufficiency and acceptance by stakeholders and the general public (Giovanni Libralato, 2011).

The most appropriate technology is choosing for wastewater treatment is difficult task but it could reduce future risk, problems and failures. Moreover, Implementing the appropriate technology is very critical issue in the success or failure of most treatment process (Chan Chong Law & Hassell, 2009). Key issues should be considered in choosing the treatment technology are shown in Figure 2-4 .

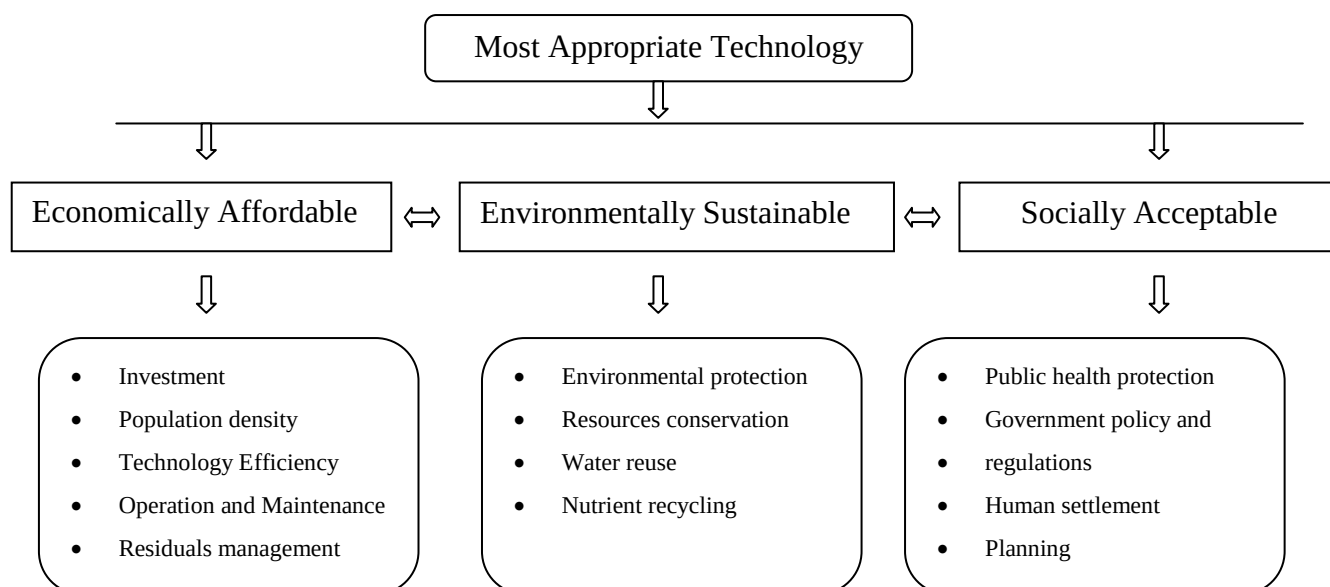


Figure (2-4)
Criteria of Selecting Appropriate Wastewater Treatment Technologies
 (Source: Massoud, Tarhin, & Nasr, 2009)

Wastewater treatment is related more to the standards and/or expectations set for the effluent quality. Therefore all the treatment processes are designed to improve the wastewater quality (Defra, 2012 ; Davis, 2010). Wastewater treatment take place over three levels: primary, secondary, and tertiary (or advanced).

2.1.3.1 Preliminary Treatment

The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater. Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units (Davis, 2010). Preliminary treatment operations typically include coarse screening, grit removal and, in some cases, combination of large objects. In grit chambers, the velocity of the water through the chamber is maintained sufficiently high, or air is used, so as to prevent the settling of most organic solids. Comminutors are sometimes adopted to supplement coarse screening and serve to reduce the size of large particles so that they will be removed in the form of a sludge in subsequent treatment processes (Tajrishy, 2012). Flow measurement devices, often standing-wave flumes, are always included at the preliminary treatment stage (Davis, 2010).

2.1.3.2 Primary Treatment

Primary (mechanical) treatment is designed to remove gross, suspended and floating solids from raw sewage (Davis, 2010). It includes screening, settling basins and filtering, to trap solid objects and sedimentation by gravity to remove suspended solids. This level is sometimes referred to as “mechanical treatment”, although chemicals are often used to accelerate the sedimentation process (Tajrishy, 2012; Defra,

2012). Primary treatment can reduce the BOD of the incoming wastewater by 20-30% and the total suspended solids by some 50-60% (Davis, 2010).

2.1.3.3 Secondary (Biological) Treatment

The objective of the secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. (Matiasi, 2013) Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2 , NH_3 , and H_2O). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter (Davis, 2010) (Defra, 2012) (Rosenwinkel, 2005). High-rate biological processes are characterized by relatively small reactor volumes and high concentrations of microorganisms compared with low rate processes (Defra, 2012). Consequently, the growth rate of new organisms is much greater in high-rate systems because of the well controlled environment. The microorganisms must be separated from the treated wastewater by sedimentation to produce clarified secondary effluent. The sedimentation tanks used in secondary treatment, often referred to as secondary clarifiers (Davis, 2010). The biological solids removed during secondary sedimentation, called secondary or biological sludge, are normally combined with primary sludge for sludge processing. Common high-rate processes include the activated sludge processes, trickling filters

or biofilters, oxidation ditches, and rotating biological contactors (RBC). A combination of two of these processes in series (e.g., biofilter followed by activated sludge) is sometimes used to treat municipal wastewater containing a high concentration of organic material from industrial sources (Metcalf and Eddy, 2003), (Davis,2010), (Defra, 2012) (Rosenwinkel, 2005).

2.1.3.4 Tertiary Treatment

Tertiary treatment can remove more than 99% of all the impurities from sewage, producing an effluent of almost drinking-water quality. The related technology can be very expensive (Defra, 2012) (Rosenwinkel, 2005), requiring a high level of technical know-how and well trained treatment plant operators, a steady energy supply, and chemicals and specific equipment which may not be readily available. An example of a typical tertiary treatment process is the modification of a conventional secondary treatment plant to remove additional phosphorus and nitrogen (Davis,2010; Defra 2012). Disinfection can be the final step before discharge of the effluent. Disinfection normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15mg/l are common (Metcalf & Eddy, 2003). Ozone and ultra violet (uv) irradiation can also be used (Defra, 2012). However, some environmental authorities are concerned that chlorine residuals in the effluent can be a problem in their own right, and have moved away from this process. Disinfection is frequently built into treatment plant design, but not effectively practiced, because of the high cost of chlorine, or the reduced effectiveness of ultraviolet radiation where the water is not sufficiently clear or free of particles or disinfection but these methods of disinfection are not in common use (Tajrishy M, 2012).

2.2 Wastewater Management Background

At the beginning of the 21st century, the world faced a water crisis caused by continuous population growth, industrialization, increased living standards and poor water use strategies (Daigger, 2007;Corcoran & Savelli, 2010). Therefore, It's essential to consider wastewater management as a part of integrated, ecosystem-based management which operates across sectors and borders, freshwater and marine (Corcoran & Savelli, 2010) . United States Environmental Protection Agency (EPA, 2010) defines Wastewater management as a broad range of efforts that promote effective and responsible water use, treatment, and disposal and encourage the protection and restoration of their nation's watersheds. In the other hand, Metcalf and Eddy (2003) and Kazmi & Furumai (2005) emphasized on this concept by considering the wastewater management as ultimate goal to protect the environment, In a manner, commensurate

In 2005, a case study was done in suburban Bangkok, Thailand by Sujaritpong where the critical factors influencing wastewater management performance at HEs in suburban Bangkok were found using multiple regression analysis. Three significant factors encompassing financial, social, institutional and general aspects were identified for each type of WWM system (centralized and decentralized). The importance of having a WWM that employs an integrated approach rather than focusing on specific aspects in isolation from other factors. WWM performance could be improved if significant factors indicating high priority concerns were to be identified and properly applied. Addressing the priority concerns could, consequently, contribute to the development of appropriate environmental management measures, plans, and policies related to HE WWM. The factors that were assessed encompass general, social, financial and institutional aspects.

Authors found half of the performance aspects assessed in this study were classified as poor. There are several institutional factors that act as barriers to improvement in community WWM, including inadequate monitoring and enforcement, fragmentation and poor communication among authorities, inadequate capacity of responsible agencies, lack of interest in WWM from LGAs and HE residents, lack of organization for monitoring and maintenance of public facilities and insufficient funds for WWM in HE management.(Sujaritpong & Nitivattananon, 2009)

More recent research was done to find an infrastructure development strategy for sustainable wastewater system by using SEM Method to the reason of undeveloped wastewater infrastructure and its obstacle issues, the research conducted to society, management, and the government as decision maker. This research concluded that the institutions, environment, technology selection, financial/economy and socio-cultural conjointly affect the sustainability. Authors found that the coefficients of the variables that affects sustainability are used to prepare the strategies for the provision of wastewater infrastructure, which are the implementation of legislation and legal sanctions, saving and recycling wastewater, the selection of appropriate technology for limited space and the necessity for investment and society involvement. they observed 83,3% of the society members sampled agree that sewerage system makes the environment and health better (Setiawatia, Notodarmojo, Soewondo, Effendid, & Otok, 2013).

In Bahrain, the Management of Industrial and domestic wastewater was developed over decades. The wastewater treatment technology have gone through several development stages of applied methods and patterns, starting with ground seepage, filtration using septic tanks, the

construction of drainage networks and ending with primary and secondary treatment of wastewater before it returns to the environment, while tertiary treatment is done as part of the wastewater for reuse and comply with the environment standards .The management of domestic wastewater hold by Sanitary Engineering Planning & Projects Directorate (SEPPD) and Sanitary Engineering Operations & Maintenance Directorate (SEOMD) at Ministry of work, Municipalities Affairs and Urban Planning (MOW).

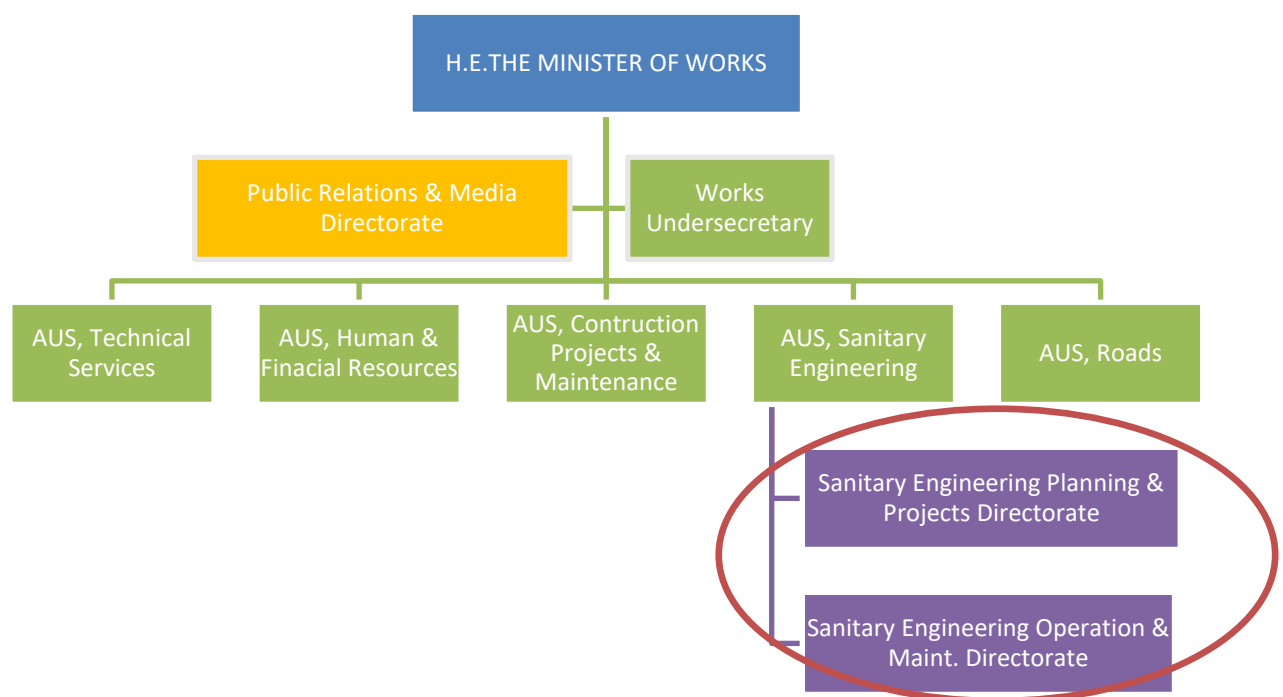


Figure (2-5)
Organizational Chart of Ministry of Work, Municipalities Affairs and Urban Planning

SEPPD Directorate is responsible on setting plans, designs and construct the sanitary water network across the Kingdom and in charge of rehabilitation and upgrade of old network and sewage treatment systems its work encompasses treatment stations, rain water drainage network and agriculture water drains. It function as the regulatory body which governs technical specifications related to sanitary works, amends relevant regulations and oversees work by advisory companies and contractors to

ensure the compliance to specification. According to the annual report of ministry of work for 2010, SEOMD Directorate is responsible of managing and supervising the operation and maintenance of more the 566 pumping stations,11 water treatment plant,18 treated sewage effluent reservoirs more than 2,00 kilometer of pipe network. There are 13 governmental sanitary treatment plants covering all residential areas in Bahrain two major sanitary plant (STP), Tubli and Muharraq sanitary plant STP and 11 Minor sanitary treatment plants to treat domestic wastewater are listed in table (2-12) with their wastewater capacity .

Table (2-11) List of the Governmental Sanitary Wastewater Plant and Their Capacity

No.	Facility Name	Type of wastewater	Design Flow capacity m ³ /d
1	Tubli STP	Domestic	200,000
2	Mahharq STP	Domestic	100,000
3	Sitra STP	Domestic /Partial Industrial	16500
4	Al Hidd STP	Domestic /Partial Industrial	2325
5	Ma'mair STP	Domestic /Partial Industrial	2250
6	Alba STP	Domestic /Partial Industrial	900
7	UOB STP	Domestic	504
8	Jau STP	Domestic	408
9	Jasrah STP	Domestic	340
10	Askar STP	Domestic	288
11	Hamala STP	Domestic	250
12	Al dour STP	Domestic	70
13	Jeddah STP	Domestic	25

(source : Sitra STP reports)

The Tubli santairy treatment plant (STP) processes over 310,000 cubic meters per day. 90% of the treated wastewater is discharged to sea (Tubli Bay) and only10% is used by agriculture for irrigation. Muharraq Sewage Treatment Plant (STP), implemented by a coalition of three private sector institutions - Samsung Engineering, Invest AD and United Utilities as part of the ministry of work strategic plan for sanitary services. It has a provision for future expansion to treat 160,000m³ per day. The joint

venture between Samsung Engineering and United Utilities will operate and maintain the facilities for its 25 year lifespan. The other smaller STPs predominantly discharge the treated wastewater to sea. A Master Plan have been applied by Minintry of Work (MOW reports, 2010-2014) for the domestic wastewater network to identify the investment requirements in the domestic wastewater network and those for the treated effluent system for the next 30 years. It will determine the most cost-effective solution and timing for augmentation of the domestic wastewater treatment capacity, the domestic wastewater collection system and the wastewater reuse system. Minintry of work aimed to cover domestic wastewater network on their master plan which consist of the following issues:

- Domestic wastewater System
- Surface water drainage system
- Wastewater treatment plants
- Treated sewage effluent (TSE) and sludge reuse systems

Bahrain's Supreme Council for the Environment (SCE) is in charge of monitoring the quality of the discharge treated wastewater into sea and preventing any illegal discharge of harmful waste with bed impact on the environment. Supreme Council for the Environment (SCE) Legislative Decree No. 21 for 1996 on the environment contain very important articles witch give clear framework to industrial sector such as :

- Article No. 13: The national legislation prevent any unauthorized discharge of wastewater
- Article No. 28: Clear Inspection procedure
- Article No. 29: Fair Sanctions

In the other hand, Ministerial Order No.10 For 1999:Environmental Standards for Air and Water was published to control and monitor the quality of air and water discharge to the environment.

In 2001 two amendment follow this ministerial order to add more details and mandatory requirements and limits to discharge air and wastewater:

Part 3 of MO No. 10 is concerning about the conformity requirement for Air And Water Standards such as:

- Article No. 7: The national legislation prevent any unauthorized discharge.
- Article No. 8: Promote a suitable treatment technology.
- Article No. 9: Encourage using a control equipment.

Part 6 cover the standards & measurement related to the sources of water pollution

- Article No. 20: Demand a quality of the discharged wastewater
- Article No. 22:Treatement & Complying with Standards
- Article No. 22 Repeated: Set a fair requirement for the discharge area

Part 7:General Requirements

Article No. 25:demand providing reports and tests

Bahrain's Supreme Council for the Environment has working mechanism to monitor the pollutant discharge from factories as shown in figure (2-6). However, any valuation done by the factories put them through legal repercussions.

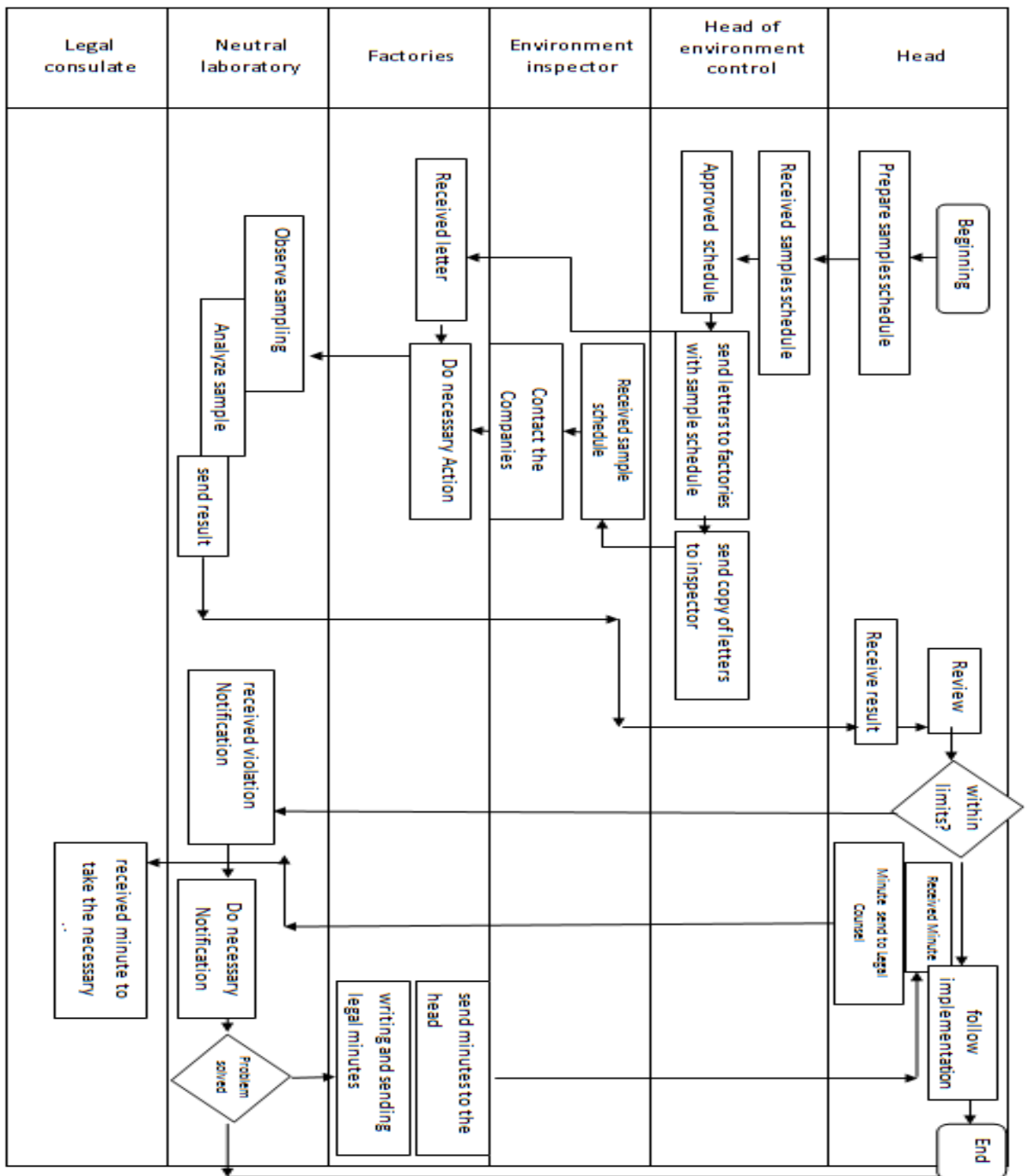


Figure (2-6)
SCE mechanism to implement the law
 (Source : interview with SCE)

2.2.1 Sustainable Wastewater Management

Definition of sustainable development is often quoted from the World Commission on Environment and Development (WCED, 1987): ‘development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs’. The fundamental principle behind this definition is to accept that all human individuals have equal rights, whether living today or in future. The multi-dimensional character (economic, environmental, and social) of sustainability which include is fundamental (Balkema, 2002,-Furumai, 2005). The long-term viability of the natural environment should be maintained to support long-term development. Environmental sustainability refers to the ability of the functions of the environment to sustain the human ways of life. It mainly depends upon the ethical basis: to what extent should policies be anthropocentric and to what extent does nature have endogenous qualities and efficient utilization of environmental resources (Balkema, 2002). This is in line with the vision of the Scientific Council for Governmental Policies (Balkema, 2002). The basic philosophy of this council is that when implementing the concept of sustainability, one cannot ignore the uncertainties and the mutual dependencies between the environment and the society. The forthcoming risks for the environment and for the economy will have to be balanced. A number of researchers in the 3rd International Conference "Sustainable Future for Human Security" (Sustain, 2012), discussed the infrastructure development strategy needed for a sustainable wastewater system in Setiabudi and Tebet Districts, South Jakarta by using SEM Method (Setiawati et al, 2013). They noticed that there was no significant progress in wastewater infrastructure development and to find out obstacles facing wastewater infrastructure, they conducted a research to

society, management, and the government as decision maker. They concluded that the institutions, environment, technology selection, financial/economy and socio-cultural conjointly affect the sustainability . Setiawati et al (2013) prepared the strategies for the provision of wastewater infrastructure, which are the implementation of legislation and legal sanctions, saving and recycling wastewater, the selection of appropriate technology for limited space and the necessity for investment and society involvement.

2.2.2 Centralized and De-centralized Wastewater Management

Wastewater treatment approaches vary from the conventional centralized systems to the entirely onsite decentralized and cluster systems. An integrated management approach ensures that all the perspectives of effective management are considered including economical, social, technical and environmental dimensions (Gaulke & Stensel, 2008; Setiawati et al, 2013). It's important to note that the needs and conditions of wastewater management vary from one country to another and sometimes within the same country (Massoud et al, 2009). Using appropriate managing system protect the public health and local water sources and will avoid expensive repairs. These management systems should address the major problems related to wastewater treatment approaches particularly in developing countries such as; limited funding, awareness and involvement of public, inappropriate system design and selection processes and inadequate inspection, monitoring and program evaluation component (May, 2009; Sitzenfrei, 2014).

2.2.2.1 Centralized Wastewater System

The Centralized Wastewater System is defined as a network of sewers designed to collect wastewater from multiple sources in a service area for treatment at a single wastewater facility that typically discharges to a surface water body, as shown in Figure 2-7 (Massoud et al, 2009).

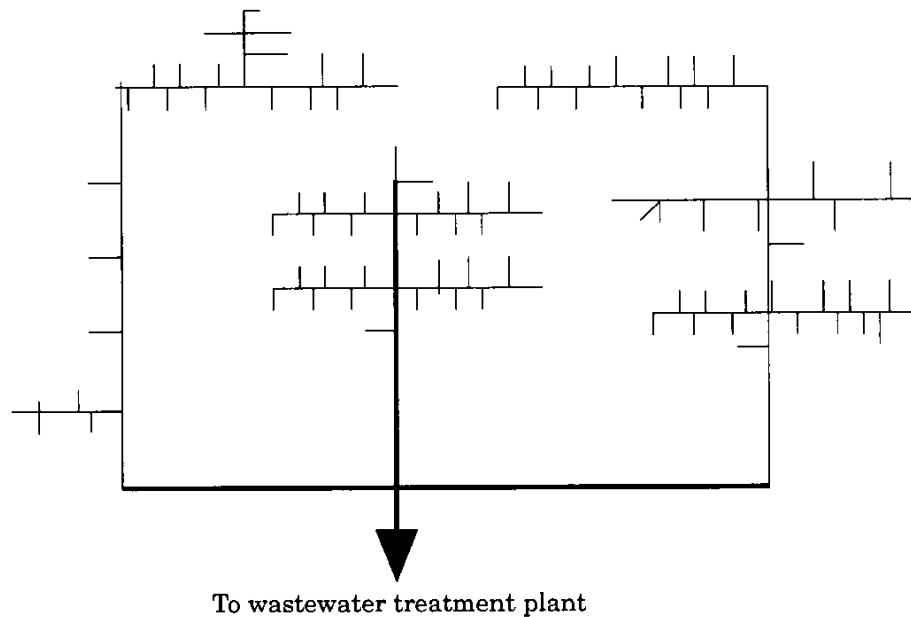


Figure (2-7)
Schematic diagram of centralized wastewater collection and treatment (off-site)
(Massoud et al, 2009)

Bowen Du (2014) performed analysis to influents from centralized and on-site wastewater treatment system receiving common influents. Bowen concluded in his research that centralized management is different from the decentralized wastewater treatment and it should be inspected and maintained regularly .

2.2.2.2 Decentralized Wastewater System

Decentralized Wastewater System is individual or clustered system(s) used to collect, treat, and disperse or reclaim wastewater from a small community or service area (Massoud et al, 2009). Onsite

Wastewater Treatment System is relying on natural processes or mechanical components to collect, treat, and disperse or reclaim wastewater from a single dwelling or building (Sitzenfrei, 2014).

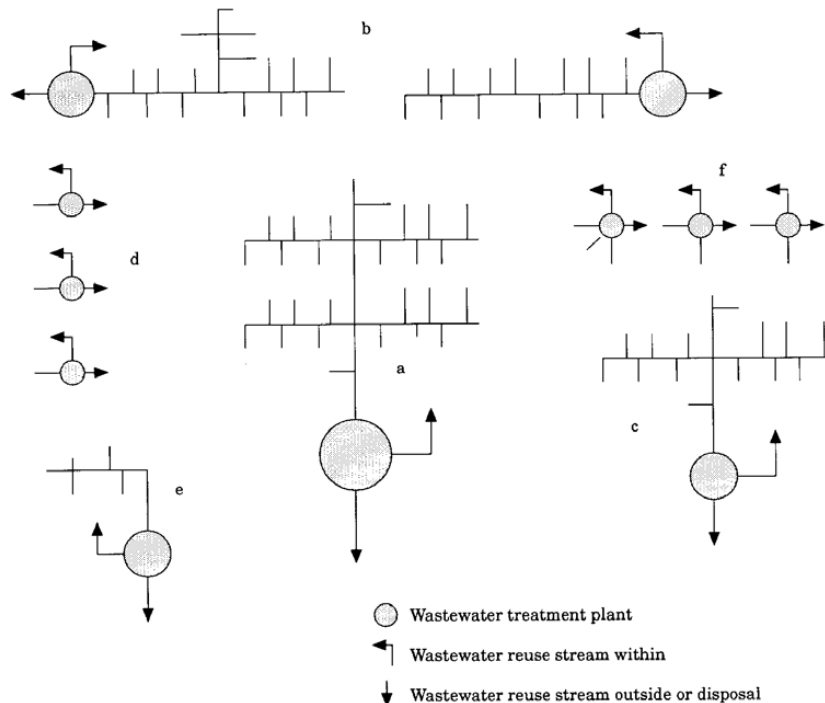


Figure (2-8)
Schematic diagram of decentralized wastewater management (on-site)(a)
subsystem for residential and commercial center; (b) subsystems for residential
neighborhoods;(c) subsystems for industrial development; (d) subsystem for
individual residence; (e) subsystem for new development;
(f) subsystems for establishments or clusters
of homes (Massoud et al, 2009)

The decentralized system is not only a long-term solution for small communities but is more reliable and cost effective. The authors of this research present a review of the various decentralized approaches to wastewater treatment and management in figure (2-8) (Massoud et al, 2009;Hophmayer-Tokich, 2014).

2.2.2.3 Centralized versus Decentralized

Most communities are facing decisions regarding centralized versus decentralized wastewater treatment and the criteria used to evaluate each system involve; data availability, ease of use, capture of relevant environmental, economic, and social factors, and interest of decision makers. Some researchers studied the differences between the Centralized and decentralized/Onsite Wastewater System (Bowen Du, 2014;R. Sitzenfrei, 2014;Giovanni Libralato, 2011). Giovanni Libralato (2011) overviewed recent wastewater management trends proposed concerning the role of centralization and decentralization in wastewater treatment. (Bowen Du, 2014) Giovanni conclude in his research that decentralized systems will allow treated wastewater recovery and reuse, making them a stable and sustainable water source, especially for those areas that historically suffer or have recently been suffering from water scarcity.

Sitzenfrei (2014) discussed in his article the transitions from centralized to decentralized solutions estimating the impact of transitions of centralized water infrastructure to decentralized solutions but also to assess the impact of population decrease or water demand reductions. With the geographic information systems (GIS) based sensitivity analysis, where results communicated to stakeholders and decision makers. Sitzenfrei summarized the objections to decentralized management systems, by many water authorities and engineers, are based on two arguments: first, low performance – this argument is obvious when taking into account the low treatment level achieved by most of the decentralized technologies commonly used, such as septic tanks, and the poor and mostly unprofessional attention on-site facilities usually received. Usually, household owners and persons in charge of small enterprises are expected to maintain these facilities. They rarely have the

knowledge nor are they motivated to efficiently maintain the system. Second, cost building and operating a great number of small on-site systems is assumed to be far more expensive than one large central system. Also, the operation and maintenance requirements of many small systems will be more than those of one central system (Sitzenfrei, 2014). Unpublished research done by Ali M. AlAswad at Arabian gulf university where comparison was done between centralized and decentralized in the management of wastewater in Bahrain. This researcher discussed and summarized the main advantages, criticisms and limitations considering social, economic and environmental issues.

AlAswad indicated that the Ministry of Public Work is debating the option of expanding the capacity of Tubli plan to reach 350,000 cm/day by the year 2015 and is also evaluating the option of implementing a decentralized schemes for different size plants to be located in different region of Bahrain as well as the design option of a new plant at Al Maharraq with a daily capability of 100,000 cm/day by the year 2013. He summarized the major advantages of centralized system are the economy of scale in terms of low treatment cost estimated at US\$0.13/m³, transportation cost of US\$0.04/m³ in comparison to the water supply production cost of US\$0.79-0.87/m³, the availability of reuse irrigation network and the availability of large volume of treated wastewater at a one location.

Decentralized management system options in different parts of the world are receiving increased recognition as an effective wastewater management alternative including Bahrain. The advantage of decentralized system may consist of low investment in construction and maintenance costs, where less number of pumping stations and network collection pipes, better maintenance and control of leakage due to the age of network, future expansion follow the normal population trends,

optimal reuse program, enhanced recharging well spacing for disposal of excess treated wastewater, less odor from low generated volumes and smaller size land requirement. The implementation of decentralized system could pose a challenge in terms of design criteria, administrative measures and cost . AlAswad recommended the evaluation of the current wastewater treatment policy and program to assess the current practices and undertake detailed analysis to evaluate the option of decentralized small size wastewater treatment projects taking into consideration population growth, future urban plan and the availability of adequate financial and human resources (AlAswad,2013).

2.2.3 Wastewater Reuse versus Disposal

The growing environmental problems, including the diminishing natural water resources, greater water demand triggered by population growth and urbanization, deteriorated water quality, and highly changing climate. Therefore,its importance to exploit all other possible water sources before using-up limited surface water and groundwater supplies (Oron, 1998; Mortins et al, 2013). Recycled water, which is the wastewater being treated to a specified quality in order to be reused again, has been increasingly considered as a supplementary water supply (Karl-Heinz Rosenwinkel, 2005) (Oron, 1998;Venkatesh, Quaff & Pandey, 2013; Chen, 2014; Furumai, 2005; Tajrishy, 2012).

Treated wastewater reuse must meet certain controls, first, wastewater treatment to reduce pathogen concentrations must meet the WHO (1989) guidelines, second, crop restrictions must be specified to prevent direct exposure to those consuming uncooked crops as well as defining application methods (irrigation) that reduce the contact of wastewater with edible crops, finally, control of human exposure is

needed for workers, crop-handlers, and final consumers (Chen, 2014; Furumai, 2005). Matiasi (2013) summarized the main advantages and disadvantages of wastewater reuse in the following points:

- It reduces the demand on potable sources of freshwater.
- It may reduce the need for large wastewater treatment system, if significant portions of the waste stream are reused or recycled.
- the technology may diminish the volume of wastewater discharged, resulting in beneficial impact on the aquatic environment.

Capital costs are low to medium for most systems and are recoverable in a very short time; this excludes systems designed for direct reuse of wastewater. Operation and maintenance are relatively simple except in direct reuse systems where more extensive technology and quality control are required. Provision of nutrient rich wastewaters can increase agricultural production in water poor areas. Pollution of rivers and groundwater may be reduced. Lawn maintenance and golf course irrigation is facilitated in resort areas. In most cases, the quality of the wastewater, as an irrigation water supply, is superior to that of well water. If implemented on a large scale, revenues to water supply and wastewater utilities may fall as the demand for potable water for non-potable uses and the discharge of wastewater is reduced. Reuse of wastewater may be seasonal in nature, resulting in the overloading of treatment and disposal facilities during the rainy season; if the wet season is of long duration and or high intensity, the seasonal discharges of raw wastewaters may occur. Health problems, such as waterborne diseases and skin irritations, may occur in people coming into direct contact with reused wastewater. Gases, such as sulfuric acid, produced during the treatment process can result in chronic health problems (Qadir, 2010). In some cases, reuse of

wastewater is not economically feasible because of the requirements for an additional distribution (Matiasi, 2013). In 2010, Qadir and other researchers stated in their article that , there are several opportunities for improving wastewater management via improved policies, institutional dialogues and financial mechanisms, which would reduce the risks in agriculture. they also suggested the effluents standards should be combined with incentives or enforcement can motivate improvements in water management by household and industrial sectors discharging wastewater from point sources. Segregation of chemical pollutants from urban wastewater facilitates treatment and reduces risk. Strengthening institutional capacity and establishing links between water delivery and sanitation sectors through inter-institutional coordination leads to more efficient management of wastewater and risk reduction (Qadir, 2010).

2.2.4 Wastewater Environmental Impact

The environmental impact of uncontrolled disposal of municipal, industrial and agricultural liquid, solid, and gaseous wastes constitutes one of the most serious threats to the sustainability of human civilization by contaminating the water, land, and air and by contributing to global warming. A safe disposal of wastewater is essential to preserve public health and reduce intolerable levels of environmental degradation.

2.3 Management and Analytical Tools

2.3.1 SWOT Analysis

Wheelen & Hunger defined SWOT analysis as simple tool to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or in a business. It can be carried out for a product, place,

industry or even a person (Wheelen & Hunger, 2012). SWOT analysis technique is credited to Albert Humphrey (Wheelen & Hunger, 2012), he devised this technique while working for the Stanford Research Institute (SRI International) in the 1960s and 1970s using data from Fortune 500 companies. It is used as a strategic planning method to identify strategic factors - those external and internal elements that will determine the future of any corporation, (Wheelen & Hunger, 2012). Wheelen & Hunger (2012) explained SWOT analysis in their book titled "Strategic Management and Business Policy- Achieving Sustainability", as the simplest way to conduct environmental scanning. The external environment consists of variables (Opportunities and Threats) that are outside the organization and not typically within the short-run control of top management. These variables form the context within which the corporation exists. They may be general forces and trends within the natural or societal environments or specific factors that operate within an organization's specific task environment often called its industry (Wheelen & Hunger, 2012). The internal environment of a corporation consists of variables (Strengths and Weaknesses) that are within the organization itself and are not usually within the short-run control of top management. These variables form the context in which work is done. They include the corporation's structure, culture, and resources. Key strengths form a set of core competencies that the corporation can use to gain competitive advantage.

2.3.2 Illustrative Application of SWOT Analysis

SWOT analysis is widely used as a research tool applied in many business management. There have been several examples of the successful application of SWOT analysis in many fields. Many

researches, applied the SWOT as tool to evaluate the strengths, weaknesses, opportunities, and threats (Souza & Silva, 2014), (Jang, Lee, & Choi, 2014), (Martins, et al., 2013), (Wheelen & Hunger, 2012) (Mainali, Ngo, Guo, Pham, & Johnston, 2011), (Yuan, 2011) , (Yuksel & Dagdeviren, 2007), (Paliwal, 2006) and (Sin, Hulle, Pauw, Griensven, & Vanrolleghem, 2005) . It was used for Water Market: (Jang, Lee, & Choi, 2014), Water resources management (Martins, et al., 2013), Environmental Impact Assessment: (Paliwal, 2006), comparison of systematic calibration protocols for activated sludge models (Sin, Hulle, Pauw, Griensven, & Vanrolleghem, 2005). In the 12th International Conference on Computing and Control for the Water Industry , SWOT analysis and Balanced Scorecard was been used to put a management proposal to improve the efficient use of water resources in water supply systems (Souza & Silva, 2014). In 2011,Yuan used SWOT analysis to help him understand the status quo of construction waste management of Shenzhen city in south China and to develop and promote its future waste management at the strategic level (Yuan, 2011). In the case of wastewater treatment and reuse, in Australia, a number of researchers successfully applied SWOT analysis as a tool to identify the feasibility of using recycled water in washing machines (Mainali, Ngo, Guo, Pham & Johnston, 2011). They identified the strengths and weaknesses of the new end use recycled water for washing clothes followed by the associated external opportunities and threats. Focus should be on the field trials investigating customer acceptance, their specific concerns towards this new end use and implementation issues as well as washing machine durability and longevity. The required recycled water quality for washing machine use without compromising the health of the people and the aesthetics of clothes as well as assuring the machine durability can be experimentally verified. The formulation of an appropriate criteria and

parameters for recycled water use in washing machines together with the identification of the community perceptions and all specific concerns can be studied. An assessment model for the new recycled water application can be developed. An overall risk assessment can be undertaken to determine the value of this new end use.

In 2007 Yuksel & Dagdeviren presented a very interesting article they described the limitation of (SWOT) analysis for textile facility, as it does not provide an analytical means to determine the importance of the identified factors or the ability to assess alternative decisions according to these factors (Yuksel & Dagdeviren, 2007). When used properly, SWOT can provide a good basis for strategy formulation (Wheelen & Hunger, 2012), (Yuksel & Dagdeviren, 2007). However, SWOT analysis does not provide an analytical means to determine the relative importance of the factors, or the ability to assess the appropriateness of decision alternatives based on these factors. But it does pinpoint the factors in the analysis and allows analysts to categorize factors as being internal (Strengths, Weaknesses) or external (Opportunities, Threats) in relation to a given decision, and thus enables us to compare strengths and weaknesses with opportunities and threats. Therefore, in this research a suitable analytical tool was found to determine the relative importance of the factors by using Analytic Network Process (ANP) .

2.3.3 Analytic Network Process Background

Many decision-making issues cannot be structured hierarchically, because of the existence of interactions and dependencies between the elements. Thomas L. Saaty (Saaty, 1996, 2005, 2006) proposed the Analytic Network Process (ANP) model, a generalization of the Analytic Hierarchy Process (AHP) method. In order to take into account the real-

world problems complexities. AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structured as a network. Both of them use a system of pairwise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision (Saaty, 1996, 2005, 2006). The ANP represents the decision problem as a network of criteria and alternatives (called elements), grouped into clusters. All the elements in the network can be related in any possible way, considering feedbacks and interrelationships within and between clusters.

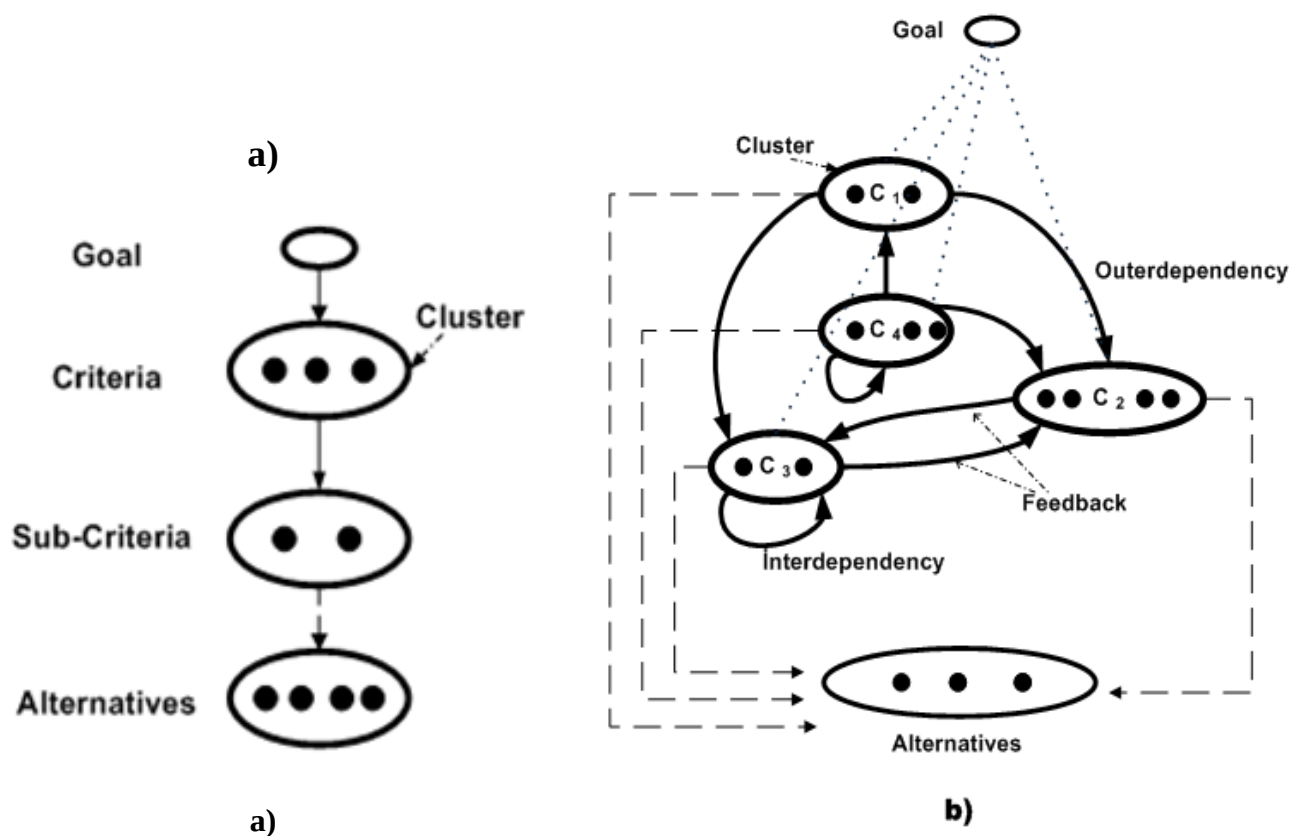


Figure (2-9)
Structural Difference between Hierarchy(a) and
Network (b)

The ANP helps to measure inter-dependencies among criteria and the alternatives. It extends the applications of the AHP to cases of

interdependent relationships between the assessment elements. The ANP requires a network structure to represent the problem, as well as a pairwise comparison to establish the relationships within the structure (Bottero, Comino, & Riggio, 2011). The ANP is composed of four major steps (Ali GÖRENER, 2012) (Yuksel & Dagdeviren, 2007):

Step 1: Model construction and problem structuring: The problem should be stated clearly and be decomposed into a rational system, like a network. This network structure can be obtained by decision-makers through brainstorming or other appropriate methods.

Step 2: Pairwise comparison matrices and priority vectors: Similar to the comparisons performed in AHP, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. The clusters themselves are also compared pairwise with respect to their contribution to the objective. Decision-makers are asked to respond to a series of pairwise comparisons of two elements or two clusters to be evaluated in terms of their contribution to their particular upper level criteria. In addition, interdependencies among elements of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector.

The relative importance of values are determined with Saaty's 1–9 scale (Table 2-12)

Table (2-12) Saaty's 1-9 Scale for AHP preference

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over another
5	Strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocal of above non-zero numbers	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

(Source :Yuksel & Dagdeviren, 2007)

where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix).

Let $C = \{C_j \mid j = 1, 2, \dots, n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an $(n \times n)$ evaluation matrix A in which every element a_{ij} ($i, j = 1, 2, \dots, n$) is the quotient of weights of the criteria. A reciprocal value is assigned to the inverse comparison:

$$a_{ij} = 1/a_{ji}, \quad \text{E(2-1)}$$

Where a_{ij} (a_{ji}) denotes the importance of the i th (j th) element. The pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative

importance associated with the elements (or clusters) being compared by solving the following equation:

$$A \cdot w = \lambda_{\max} \cdot w \quad \text{E(2-2)}$$

where A is the matrix of pairwise comparison, w is the eigenvector, and $\lambda_{\max}$ is the largest eigenvalue of A .

$$A = (a_{ij}) = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ a_{m1} & \cdot & \cdot & a_{mn} \end{bmatrix} \quad \text{E(2-3)}$$

Saaty proposed several algorithms to approximate w . In this research , a spread sheet in Microsoft Office Excel 2007 will be used to compute the eigenvectors from the pairwise comparison matrices and to determine the consistency ratios.

Step 3: Supermatrix formation: To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix.

Step 4: Selection of the best alternatives: If the supermatrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises clusters that are interrelated, additional calculations must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be selected, as it is the best alternative as determined by the calculations made using matrix operations.

The calculation of consistency ratio (CR) can conclude whether the evaluations are sufficiently consistent or not. The CR is calculated as the ratio of the CI and the random index (RI), as indicated in Equation (2-4).

$$CR = \frac{CI}{RI} \quad E(2-4)$$

Where random index (RI) is constant value to number of n matrix

Table (2-13) Random Index Values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

(Source: Saaty and Vargas, 1991)

The Consistency Index (CI) can be calculated, using the following formula (Saaty, 1980):

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad E(2-5)$$

where the accepted upper limit for consistency ratio $CR \leq 0.1$, the evaluation procedure has to be repeated to improve consistency.

2.3.4 Illustrative Application of Analytic Network Process

Analytic Network Process (ANP) appear in articles dealing with the decision sciences. There are numerous practical applications of ANP compared to AHP, many of them involving complex decisions about benefits, opportunities, costs and risks. Thomas L Saaty suggested that studying these applications can be very useful in understanding the complexities of the ANP(Saaty, 1996). He also suggested the use of analytic hierarchy process (AHP) to solve the problem of independence among alternatives or criteria and use ANP to solve the problem of dependence among alternatives or criteria (Saaty, 1996). Some Researchers used the Analytic Network Process to propose a decision-making process for assessing best available techniques regarding the

potential pollution in Europe (Giner-Santonja, b, & Niclós-Ferragut, 2012).

In 2011, Bottero, Comino & Riggio used in their article multicriteria analyses (MCAs) techniques articularly, the Analytic Hierarchy Process and its recent implementation the ANP, to a real decision problem concerning the choice of the most sustainable wastewater treatment (WWT) technology, namely Anaerobic digestion, Phytoremediation and Composting, for small cheese factories. These tools have been considered for prioritizing the different technologies. The models which have been suggested by Bottero and his Colleagues enable all the elements of the decision process such environmental aspects, technological factors and economic costs, and to compare them to find the best alternative (Bottero, Comino, & Riggio, 2011). Aragone Pablo stated in his article that, ANP is a useful tool to help technicians to make their decision process traceable and reliable (Aragone, 2009). Wei-Wen Wu and Yu-Ting Lee raised a critical issue of how companies can better evaluate and select a favorable knowledge management strategy before that implementation. They developed an effective method based on the ANP to help companies that need to evaluate and select knowledge management strategies (Wu & Lee, 2007). In the other hand, Rozann Whitaker is one of the researcher who test the validation of the Analytic Hierarchy Process and Analytic Network Process (Whitaker, 2007). In the Analytic Hierarchy Process (AHP) this usually means, finding examples with measures in an already known scale. To validate AHP priority vectors against measures from known scales the measures must be first normalized by dividing by their sum. When the two vectors are the same, or close, then one can say the results of the AHP model have been validated (Whitaker, 2007). The AHP and its generalization, the Analytic Network Process (ANP), can be validated at several levels ranging from priority vectors derived from

pairwise comparison matrices to the synthesized priorities for a hierarchical model, to the priorities derived for the elements in an ANP network from the limiting supermatrix (perhaps most impressively validated by estimating market share of companies using intangible factors), to the overall results from complex ANP models involving several levels of networks. Many validation examples are presented along with a discussion of the compatibility index that can be used to measure closeness of priority vectors. (Whitaker, 2007). This analysis successfully pinpoints the factors, individual factors are usually described briefly and very generally. For this reason, SWOT analysis possesses deficiencies in the measurement and evaluation steps. Although the analytic hierarchy process (AHP) technique removes these deficiencies, it does not allow for measurement of the possible dependencies among the factors. The AHP method assumes that the factors presented in the hierarchical structure are independent; however, this assumption may be inappropriate in light of certain internal and external environmental effects (Yuksel & Dagdeviren, 2007) (GÖRENER, 2012). Therefore, Yuksel & Dagdeviren suggested that, it is necessary to employ a form of SWOT analysis that measures and takes into account the possible dependency among the factors. Their article demonstrates a process for quantitative SWOT analysis that can be performed even when there is dependence among strategic factors (Yuksel & Dagdeviren, 2007). They proposed a very interesting algorithm that uses the analytic network process (ANP), which allows measurement of the dependency among the strategic factors, as well as AHP, which is based on the independence between the factors (Yuksel & Dagdeviren, 2007). They observed dependency among the SWOT factors to effect the strategic and sub-factor weights, as well as to change the strategy priorities.

2.4 Wastewater Management in Textile Industry

2.4.1 Textile Wastewater Background

The wastewater effluents from “wet processes”, implemented by the textile finishing industry are highly toxic a serious threat to ground and surface water resources. The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Water is used in as the principal medium to apply dyes and various finishes .

On the average, 90% of the water input in textile finishing operations needs to be treated at the end of the wet operations processes because it is rich in color, residues of reactive dyes and chemicals. Dye bath wastewater generated by textile mills is often rated as the most polluting among all industrial sectors (Sundar, Karthikeyan, & PrabhuIndustry, 2010). The pollution load is characterized by high color content, suspended solids, salts, nutrients and toxic substances such as heavy metals and chlorinated organic compounds. Therefore, it requires proper treatment before being released into the environment (Babu, Parande, Raghu, & Kumar, 2007). A combination of physicochemical processes followed by biological treatment for textile effluent should be considered. Many researchers discussed the environmental impact of textile wastewater (Ghaly, 2014,Venkatesh, Quaff, & Pandey, 2013, Nordin, Amir, & Riyanto, Sundar, Karthikeyan, & PrabhuIndustry, 2010, Dogan, Kerestecioglu, & Yetis, 2010, Aragonés-Beltrán, Mendoza-Roca, Bes-Piá, García-Melón, & Parra-Ruiz, 2009, Vandevivere, Bianchi, & Verstraete, 1998) and all the authors agreed that textile industry is considered to be one of the biggest threats to the environment.

(For Dyeing)

(For Printing)

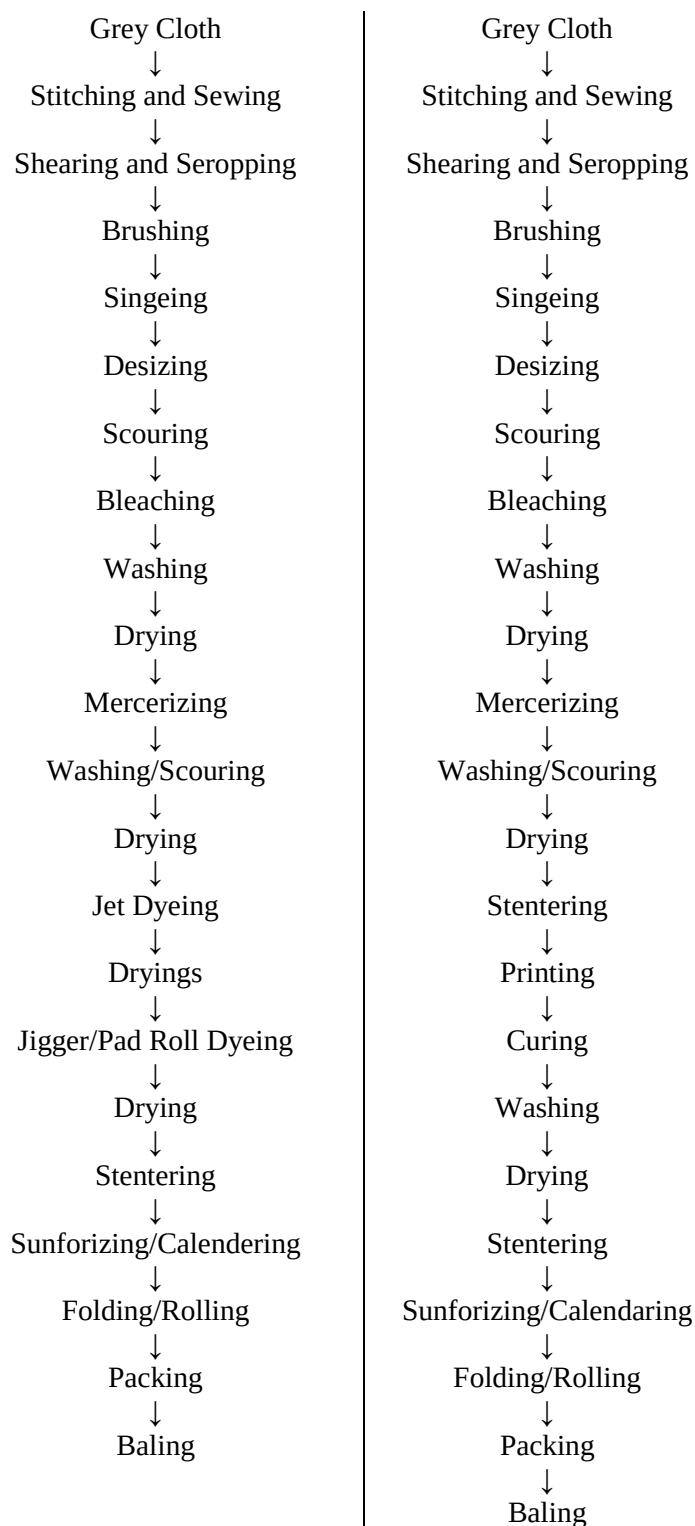


Figure (2-10)
Flowchart of Textile Wet Processing

The various processes carried out in the textile industries produce large amounts of gas, liquid and solid wastes. The wastewater produced during

this process contains large amount of dyes and chemicals containing trace metals such as Cr, As, Cu and Zn which are capable of harming the environment and human health. The textile wastewater can cause hemorrhage, ulceration of skin, nausea, skin irritation and dermatitis. The chemicals present in the water block the sunlight and increase the biological oxygen demand thereby inhibiting photosynthesis and reoxygenation process (Ghaly, 2014). The possible pollutant and the nature of effluents released from each step of the wet process are listed in Table (2-14).

Table (2-14) Sources of Water Pollution at Various Stages of Processing in Textile Industry

Process	Possible Pollutants	Nature of Effluent
Desizing	Starch, glucose, PVA, resins, fats and waxes do not exert a high BOD.	Very small volume, high BOD (30-50% of total), PVA.
Kiering	Caustic soda, waxes, soda ash, sodium silicate and fragments of cloth.	Very small, strongly alkaline, dark colour, high BOD values (30% of total)
Bleaching	Hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids.	Small volume, strongly alkaline, low BOD (5% of total)
Mercerizing	Caustic soda	Small volume, strongly alkaline, low BOD (Less than 1% of total)
Dyeing	Dye stuff, mordant and reducing agents like sulphides, acetic acids and soap	Large volume, strongly coloured, fairly high BOD (6% of total)
Printing	Dye, starch, gum oil, china clay, mordants, acids and metallic salts	Very small volume, oily appearances, fairly high BOD.
Finishing	Traces of starch, tallow, salts, special finishes, etc.	Very small volume, less alkaline, low BOD.

Source: Ghaly, 2014

Ghaly (2014) explained in his research the characteristics of textile effluents vary and depend on the type of textile manufactured and the chemicals used. The textile wastewater effluent contains high amounts of agents causing damage to the environment and human health including suspended and dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD), chemicals, odour and colour. where most of the BOD/COD ratios are found to be around 1:4, this indicates

the presence of non-biodegradable substances. Typical characteristics of textile effluent are shown in Table (2-15)

Table (2-15) Characteristics of the Effluent from Various Wet Textile Processing

Source of effluent generation	Parameters		
	pH	COD (mg/L)	BOD (mg/L)
Process Effluent			
Desizing	5.83-6.50	10000-15000	1700-5200
Scouring	10-13	1200-3300	260-400
Bleaching	8.5-9.6	150-500	50-100
Mercerizing	8-10	100-200	20-50
Dyeing	7-10	1000-3000	400-1200
Wash Effluent			
After beaching	8-9	50-100	10-20
After acid rinsing	6.5-7.6	120-250	25-50
After dyeing (hot wash)	7.5-8.5	300-500	100-200
After dyeing (acid & soap wash)	7.5-8.64	50-100	25-50
After dyeing (final wash)	7-7.8	25-50	
Printing washing	8-9	250-450	115-150
Blanket washing of rotary printer	7-8	100-150	25-50

(Source: Ghaly, 2014)

Desizing have highest the BOD and COD value. The fabric are not able to absorb water or finishing agents to a sufficient degree. A desizing treatment is necessary in order to obtain the polymer the desired quality of the final fabric.

2.4.2 Case Study: Decentralized Management System in a Local Textile Facility

A local textile company was chosen as case study in this research as being a model of decentralized wastewater treatment system. The wastewater management of this company will be evaluated and analyzed using SWOT analysis supported with analytical network process (ANP) and the same mechanism will be repeated again to a centralized wastewater plant. The company was established in 1813, it started with the manufacture of woolen broadcloth to become a home fashion pioneer.

In 2006, its management decided to grow and expand into different markets. It acquired another textile company located in the Kingdom Bahrain and turned it into the largest textile manufacturer in the Gulf region. This facility used state-of-the-art equipment for spinning, weaving, finishing and fabricating a full range of bedding products in an enormous scale. An advanced art dyeing and printing plant for the production of high-quality vat, pigment, and reactive dyeing. This company is equipped with an automated machines to produce millions of sheets and pillowcases with varied finishes and embellishments, while cutting-edge inspection processes help manufacture, package and ship up to 50 million yards annually-while taking advantage of duty free status and free trade agreement with the United States.

A field visit and interview was conducted with the Managing Director of this local textile company, He pointed out that his company's is keen to fulfill all its environmental commitments and responsibilities and claimed that his company manage the chemical use responsibly, ensure wise water use, and continually upgrading its wastewater treatment facilities. Water consumed was reduced by 14% over the last 3 years for the company , while in Bahrain production plant witnessed a drop by 82% in water consumption over the past 6 years. He justified that the production plant reclaim over 50% of consumed water for reuse through their enhanced wastewater treatment.

2.4.3 Wastewater Treatment in Local Textile Facility

Wastewater generated by the production plant of the textile company is a complex mixture of mainly polluting substances associated with dyes and the dyeing process (such as COD, BOD, nitrogen, heavy metals and dyestuffs), wastewater treatment is taken into consideration to ensure a

safe discharge and avoiding serious environmental impact. The company use state-of-the-art equipment to treat the water used for dyeing and finishing operations.

2.4.3.1 Primary Treatment

The first step in wastewater treatment is the removal of suspended solids, excessive quantities of oil and grease and gritty materials such as yarns, lint, pieces of fabrics, fibres and rags using bar and fine screening to help in the reduction of suspended solids in the effluent. Screening is followed by sedimentation which makes use of gravity to settle the suspended particles such as clay or silts present in the effluent. The addition of chemicals to the effluent is necessary to remove colloidal particles. Ferrous sulphate, lime, alum, ferric sulphate and ferric chloride are some of the most commonly used chemicals in the coagulation step . In the other hand, Ferrous Sulphate Heptahydrate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) is used because it has the best decolorization effect than any Fe^{3+} and Al^{3+} coagulated the dye of wastewater and other additives. Mechanical flocculation involves slow mixing of the effluent with paddles bringing the small particles together to form heavier particles that can be settled and removed as sludge. The sludge is held onsite then disposed of at Askar Municipal landfill .

2.4.3.2 Secondary Treatment

The Secondary treatment process is mainly carried out to reduce the BOD, phenol and oil contents in the wastewater and to control its colour. This is biologically done with the help of microorganisms under aerobic

or anaerobic conditions. Aerated lagoons, trickling filter and activated sludge systems are among the aerobic system used in the secondary treatment. In biological treatment processes the effluent of primary treatment is aerated for about 2-6 days where BOD are removed by oxidizing the dissolved organic matter to CO₂ and water and degrade nitrogenous organic matter into ammonia. phosphorous is efficiently removed in this stage and sludge will be formed.

2.4.3.3 Tertiary Treatment

Reverse osmosis (RO) membranes has been used to remove total dissolved solid contents along with ions and larger species from the effluents. In cotton dyeing processes use of electrolytes along with the dyes a neutral electrolyte like NaCl is required to have high exhaustion of the dye. This technology has been used to treat high concentrations of salts . RO membrane process have many cost effective applications in textile industry results from the ability to recover materials with value, recycle water reducing fresh water consumption and wastewater treatment costs, the use of a point source approach for minimum capital costs, small disposal volumes which minimizes waste disposal costs, reduction of regulatory pressures and fines improved heat recovery systems. Membrane systems used will play an important role to recover chemicals which used to go to the sewer network.

2.5 Commentary on Literature Review

Water has precious value and each drop must be accounted for in water scarce regions such as the Middle East and North Africa. Therefore, wastewater has to be reclassified as a renewable water resource rather than waste as it helps increase water availability and, at the same time, prevents environmental pollution. (Jhansi & Mishra, 2013). From the previous literature reviewed, it was found that, most of the researchers were in favor of taking the wastewater as a water source (Tajrishy, 2012), (Jhansi & Mishra, 2013), (Defra, 2012), (Burian, 2000). Since both centralized and decentralized wastewater treatment are implemented in the Kingdom, therefore both systems will be evaluated to improve and enhance these systems for a better wastewater management. Many researchers considered the textile industry to be one of the biggest threats to the environment, therefore local textile company was chosen to evaluate decentralized wastewater management system of this company and analyze it using SWOT analysis with ANP and compare it to centralized facility.

This research will try to implement the work done by Yuksel & Dagdeviren in 2007 and (GÖRENER, 2012) by using SWOT analysis to evaluate the wastewater management practiced in the Kingdom of Bahrain and using the analytic network process (ANP), which allows measurement of the dependencies among the strategic factors (Yuksel & Dagdeviren, 2007).

Table (2-16) is summarizes the most important journals and researches which have been useful to this research:

Table (2-16) Summary of Relevant Research to this Study

Field of Subject	Author	Findings	Comments	Reference
Wastewater Management				
Water demand	Mohammed Saleh Al.Ansari	The Author discuss many factors affect the availability and sustainability of the water supply in Bahrain: climate change, water quality, pollution, and the production capacity of new technologies and non-conventional methods. With growing demand due to climate change, booming industrial complexes and population growth, groundwater abstraction is no longer a sustainable water resource on its own and other methods must be put to increasing use.	The Author demonstrates the non-conventional methods in Bahrain such as desalination and treated sewage effluents (TSE) which are increasingly used to meet the water demand for agricultural, municipal and industrial purposes. Pollution, seawater intrusion and other issues continue to thwart non-conventional water resource methodologies and services, creating a bottleneck for the water demand. As well as the water conservation methods for managing the water demand seem promising in all sectors.	(Al.Ansari, 2013)
	Furumai, A. K.	Introduce the concept of sustainable urban wastewater management in the Asian context. Sewerage systems are key facilities to support public health and sound development in urban areas. They exist in most of the rapidly developing cities of Asia; however, a range of practical, financial, political, and environmental factors mean that provision is	The paper examining some of the range of new and established technologies and methods that can help to minimize the burden and maximize the potential benefits of urban wastewater.	(Kazmi & Furumai, 2005)

Field of Subject	Author	Findings	Comments	Reference
		often inadequate to meet current and projected demand. To meet clean water goals and reduce the environmental impacts of urbanization, sewerage systems should be incorporated properly into watershed management plans.		
Sludge	Nicholas Kathijotes	The management and treatment of sludge in developing countries, from on-site sanitation systems has neither been addressed by problem holders nor by researchers. All septic tanks need to be desludged regularly in order to maintain a certain level of treatment efficiency and minimize ecological and eventual marine pollution incidences. Practices followed in developing countries are discussed and lessons learned are emphasized for promoting a sustainable community development. Stakeholder identification and participation and their cooperation thorough the process, as well as new regulations on service provision and management procedures are addresses in this study.	-	(Kathijotes, 2012)
	J P Rodríguez; N McIntyre; M Díaz-Granados; J P Quijano;	His paper presents a suitable monitoring and modeling framework to support operation and development of the wastewater system of Bogotá (Colombia). Components of the	Monitoring and modeling to support wastewater system management in developing mega-cities to evaluate the performance of management practices	(Rodríguez, McIntyre, Díaz-Granados, Quijano, &

Field of Subject	Author	Findings	Comments	Reference
	Č Maksimović	suggested framework covered: (a) the flow and water quality database, (b) a wastewater pollution load generator, and (c) a semi-distributed sewer network model, which aims at a complexity that matches the information available from the previous two components.	such as water demand management and greywater recycling in Bogotá.	Maksimović, 2013)
Decentralize WWM				
Decentralize WWM	C. Suriyachan V. Nitivattananon, A. Nurul Amin	Three WWM cases were selected for detailed investigation. Residential wastewater user surveys and expert interviews were used to support system performance findings of service providers and recipients, as well as to draw lessons learned. Results show that DWWM is economically and technically efficient, demonstrating potential for sustainable urban development (SUD) in the study area. The competitive cost found is a result of less sewer line, simple technology, and limited additional costs, while the high efficiency is a result of good operation and maintenance. the study recommends using DWWM for new development within both public and private properties based on Bangkok's case as part of long-term urban development.	Authors examine and discuss the potential of Bangkok's current WWM approaches for urban development, focusing on decentralized management approaches	(Suriyachan, Nitivattananon, & Amin, 2012)

Field of Subject	Author	Findings	Comments	Reference
	Massoud, May A.; Tarhin, Akram; Nasr, Joumana A.	This paper presents a review of the various decentralized approaches to wastewater treatment and management. A discussion as to their applicability in developing countries, primarily in rural areas, and challenges faced is emphasized all through the paper. While there are many impediments and challenges towards wastewater management in developing countries, these can be overcome by suitable planning and policy implementation. Understanding the receiving environment is crucial for technology selection and should be accomplished by conducting a comprehensive site evaluation process. Centralized management of the decentralized wastewater treatment systems is essential to ensure they are inspected and maintained regularly. Management strategies should be site specific accounting for social, cultural, environmental and economic conditions in the target area.	It discussed applicability of decentralized approaches to wastewater treatment and management in developing countries	(Massoud, Tarhin, & Nasr, 2009)
Centralized and decentralized WWM				
	Giovanni Libralato; A.Volpi Ghirardini; Francesco Avezzù	An overview of recent trends in wastewater management is proposed concerning the role of centralisation and decentralisation in wastewater treatment. The main advantages, criticisms and limitations considering social,	The Author suggestion is to support the coexistence of various level of centralisation and decentralisation in WWTPs considering the potentiality of the full series of decentralized	(Libralato, Ghirardini, & Avezzù, 2012)

Field of Subject	Author	Findings	Comments	Reference
		economic and environmental issues have been summarised. It resulted that none of the approaches could be excluded a priori, but were generally shown to integrate one another on the basis of the specific required situation.	approaches that are currently showing a highly realistic appeal, The use of decentralized and satellite systems will allow treated wastewater recovery and reuse, making them a stable and sustainable water source, especially for those areas that historically suffer or have recently been suffering from water scarcity.	
	Bowen Du, Amy E. Price, W. Casan Scott, Lauren A. Kristofco, Alejandro J. Ramirez, C. Kevin Chambliss, Joe C. Yelderman, Bryan W. Brooks	A comparative understanding of effluents quality of decentralized on-site wastewater treatment systems, particularly for contaminants of emerging concern (CECs), remains less understood than effluents quality from centralized municipal wastewater treatment plants. Using a novel experimental facility with common influent wastewater, effluents water quality from a decentralized advanced aerobic treatment system (ATS) and a typical septic treatment system (STS) coupled to a subsurface flow constructed wetland (WET) were compared to effluents from a centralized municipal treatment plant (MTP)	Comparison of contaminants of emerging concern removal, discharge, and water quality hazards among centralized and on-site wastewater treatment system effluents receiving common wastewater influent	(Bowen Du, 2014)
Water Reuse				
Water Disposal	M. Aulinas; P. Tolchinsky;	It proposes an argumentation-based model by which to formulate a flexible decision-making	This paper proposes a different way to conceptualize the decision-making	(Aulinas, Tolchinsky,

Field of Subject	Author	Findings	Comments	Reference
	C. Turon; M. Poch; U. Corte	process. An example of the model application describes how experts deliberate the safety of a discharge and adapt each decision to the particular characteristics of the industrial discharge and the WWTP.	process, and offers a reliable way to understand the problems together with possible solutions.	Turon, Poch, & Corte, 2012)
WW Environment Impact				
WW Environment Impact	Sophie Legras	she analyze how wastewater management affects water quality and urban spread, through agents' residential location choice between sewer-serviced suburbia, and septic dependent exurbia. According to the abatement efficiency gap between wastewater treatment technologies, improving water quality may be achieved at the expense of higher or lower urban spread. In this paper, the link between water quality and urban spread is addressed through an analysis of household residential location and the choice of wastewater technology.	This paper give a correlated environmental impacts of wastewater management.	(Legras, 2015)
Textile WW				
Textile effluents	AE Ghaly, R Ananthashankar, M Alhattab and VV Ramakrishnan	Explain the characteristics of textile effluents which contains high amounts of agents causing damage to the environment and human health vary and treatment of textile	He gave very clear critical review in which explained Production, characterization textile effluents and treatment processes.	(Ghaly, 2014)

Field of Subject	Author	Findings	Comments	Reference
		effluents. involves three steps: primary treatment, secondary treatment and tertiary treatment.		
SWOT Analysis and ANP Approach				
<i>Using SWOT analysis with multicriteria decision making techniques (AHP) and (ANP).</i>	Ali GÖRENER,	Successful strategic decisions provide the appropriate operational actions for the right markets at the correct time. Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is a generally used tool which examines strengths and weaknesses of organization or industry together with opportunities and threats of the marketplace environment. SWOT framework provides the basic outline in which to perform analysis of decision situations. In this study, the lack of determination of the importance ranking for the SWOT factors, we proposed to enhance SWOT analysis with multicriteria decision making techniques called Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP). AHP approach achieves pairwise comparisons among factors or criteria in order to prioritize them at each level of the hierarchy using the eigenvalue calculation. In addition to AHP, ANP technique is a general form	He explained how to use the AHP and ANP methods for prioritize of SWOT factors and compare them.	(GÖRENER, 2012)

Field of Subject	Author	Findings	Comments	Reference
		that allows interdependencies, outer dependencies and feedbacks among decision elements in the hierarchical or non hierarchical structures.		
<i>Using SWOT analysis with (ANP for a textile firm.</i>	Ihsan Yuksel and Metin Dagdeviren	Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis does not provide an analytical means to determine the importance of the identified factors or the ability to assess decision alternatives according to these factors. Although the analysis successfully pinpoints the factors, individual factors are usually described briefly and very generally. For this reason, SWOT analysis possesses deficiencies in the measurement and evaluation steps. Although the analytic hierarchy process (AHP) technique removes these deficiencies, it does not allow for measurement of the possible dependencies among the factors. The AHP method assumes that the factors presented in the hierarchical structure are independent; however, this assumption may be inappropriate in light of certain internal and external environmental effects. Therefore, it is necessary to employ a form of SWOT analysis that measures and takes into account the possible dependency	The proposed algorithm uses the analytic network process (ANP) allows measurement of the dependency among the strategic factors.	(Yuksel & Dagdeviren, 2007)

Field of Subject	Author	Findings	Comments	Reference
		among the factors. This paper demonstrates a process for quantitative SWOT analysis that can be performed even when there is dependence among strategic factors.		

Chapter 3

Methods and Procedure

- 3.1 Research Methodology
- 3.2 Research Population
- 3.3 Research Case Study
- 3.4 Data Collections
 - 3.4.1 SWOT Analysis
 - 3.4.2 Analytic Network Process
- 3.5 Research Tools
 - 3.5.1 SWOT Analysis
 - 3.5.2 Analytic Network Process

Chapter 3

Methods and Procedures

3.1 Research Methodology

The research is designed to gather information to analyze the current wastewater management in Kingdom of Bahrain through literature review, questionnaire, interviews and official statistical information involving the following steps:

- Step 1: Critical literature review was conducted in the previous chapter for wastewater treatment and management policies world-wide.
- Step 2: Data collection: Gathering data to support the research derived from multiple channels including governmental reports taken from Bahrain Central Informatics Organization (CIO), regulations related to wastewater management (legislation & legal opinion commission), books and literature, ...etc.
- Step 3: A structured questionnaire will be conducted to evaluate both (1) the wastewater management systems practiced in Kingdom of Bahrain and (2) the enforcement of the national wastewater management regulations.
- Step 4: Analysis of the strengths and weaknesses of the current wastewater management systems and to demonstrate the main challenges to wastewater treatment in the Kingdom of Bahrain.
- Step 5: Data Analysis: The collected data will be analyzed to develop a new strategy for Bahrain's future wastewater management .
- Step 6: Centralized and decentralized approaches of wastewater management will be evaluated using SWOT analysis and

Analytic Network Process (ANP) in order to develop and promote future wastewater management at strategic level. A local textile industry facility in the Kingdom of Bahrain will be taken as a case study of facilities using de-centralized wastewater treatment approach and Tubli STP will represent centralized wastewater management approach.

Step 7: Providing conclusions and recommendations for the best alternative management strategy suitable to the Kingdom of Bahrain and to improve the current wastewater management system.

3.2 Research Population

The research population is 38 establishments that treat wastewater and discharge the treated wastewater to the sea, these establishments are monitored by (SCE). To determine the size sample, the following formula was used for these calculations (Krejcie, Morgan,1970):

$$n = \frac{X^2 \times N \times P \times (1-P)}{(ME^2 \times (N-1)) + (X^2 \times P \times (1-P))} \quad E(3-1)$$

where;

n = Sample size,

X^2 = Chi -square for the specified confidence level at 1 degree of freedom,

N = Population Size,

P = Population proportion (0.50 in Table 3-1)

ME = Desired Margin of Error (expressed as proportion)

This formula is used by Krejcie & Morgan in their 1970 article “Determining Sample Size for Research Activities”(Krejcie; Morgan 1970).

Table (3-1):The recommended sample size for a given population size, level of confidence, and margin of error

Population Size	Confidence = 95.0%				Confidence = 99.0%			
	Degree of Accuracy/Margin of Error				Degree of Accuracy/Margin of Error			
	0.05	0.035	0.025	0.01	0.05	0.035	0.025	0.01
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
900	269	419	568	823	382	541	672	854
1,000	278	440	606	906	399	575	727	943

Source : Krejcie; Morgan(1970)

Assume confidence level of 95% and 5% as a margin of error which is the amount of error that you can tolerate, the sample size for 38 population size will be 35.

Only 25 replies were received which is below the recommend optimum sample size therefore 9 interviews were convened to overcome this deficiency. Interviews were held with the relative governmental authorities (Ministry of Industry and commerce - Ministry of work - Supreme Council for the Environment (SCE)) to get a reliable information and static database of the sanitary treatment plants and

industrial companies which have decentralized (in-house) wastewater treatment.

3.3 Research Case Study

The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. There are 10 textiles companies in Kingdom of Bahrain, only two facilities have wastewater treatment system within the facility. Therefore, Textile sector was chosen as a case study representing de-centralized wastewater treatment.

3.4 Data Collection

The data will be collected through a structured questionnaire and interviews. Responses to the questionnaire were recorded, exported to a spreadsheet in Microsoft office excel 2007 for in-depth analysis. Descriptive statistics were calculated and data relationships were analyzed.

3.4.1 Questionnaire

The questionnaire was designed to cover all the information needed to evaluate the wastewater management of facilities, it structured into six sections as follows:

1st section: Cover General information about the participant facility and its category or business activity.

2nd section (Refer to Part A in the Questionnaire): Cover information related to the operations, processes performed and the basic materials used in these operation in a descriptive manner.

3rd section (Part B): Cover information related to water and wastewater:

- Water sources and consumption.
- Generation of wastewater/sludge.
- Centralized /decentralized (in-house) treatment system.
- Type and volume of wastewater treated.
- Wastewater or sludge treatment processes
- Wastewater Characteristics
- Desired Results and Benefits from wastewater treatment
- Disposal/reuse of Sludge.
- Disposal/reuse of treated wastewater

4th section (Part C): Cover the facility operation, average number of employees and their shifts time.

5th section (Part D): Cover the evaluation of Bahrain's Supreme Council for the Environment (SCE) and current national legislations enforcement related to wastewater management.

6th section (Part E): Evaluation of the establishment wastewater management system. In Section 5 and 6, the questions have a scale of 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree to simplified analysis process. To ensure the validity of the questionnaire, some of the questions were repeated in different sections to be checked later on.

3.4.2 Interviews

Semi-structured interviews with partial pre-planning questions were conducted with experts of nine facilities to identify applied wastewater management system. All interviews were face to face and took place at facility applying centralized and decentralized wastewater treatment systems. Some of the interviews were conducted to ensure the validity of the questionnaire replies. General information was collected at the beginning of each interview regarding the facility operations, processes performed and then went through the mechanism used by facility to treat the wastewater. The data collected during the interviews and questionnaire were accurately analyzed.

Two interviews will be used to evaluate centralized and decentralized wastewater management approach using SWOT analysis and Analytic Network Process (ANP).

3.5 Research Tools

3.5.1 SWOT Analysis

SWOT as a tool is used to evaluate the strengths, weaknesses, opportunities, and threats in the wastewater management system used by the establishment or facility. In Section 6 (Part E of the questionnaire), the questions were designed to discover the internal and the external factors effecting the wastewater management.

3.5.2 Analytic Network Process

The objective of utilizing the ANP within SWOT framework is to systematically qualify SWOT factors and equate their intensities. It will be applied to evaluate decentralized wastewater management for textile facility and centralized wastewater management for Tubli sewage treatment plant (STP). The proposed method is applied through the following steps (Ali GÖRENER, 2012):

- Step 1: The first step is to list the considerable internal (strengths and weaknesses) and external (opportunities and threats) factors for the strategic planning, making-up the SWOT analysis.
- Step 2: The second step applies the pairwise comparisons to capture the weights of each SWOT group.
- Step 3: The third step derives the relative priorities of each SWOT factor and the sub-factors within the groups. Then, the overall factor weight rank is obtained by multiplying the factors local weights by the specific group weight.
- Step 4: Finally, Synthesis of the criteria and alternatives' priorities and selection of the best alternatives: The priority weights of the criteria and alternatives can be found in the normalized supermatrix.

The network model proposed by Yuksel and Dagdeviren(Yuksel & Dagdeviren, 2007) to be used for SWOT analysis is composed of four levels: The goal (best strategy) is indicated in the first level, the criteria (SWOT factors) and sub- criteria (SWOT sub-factors) are found in the second and third levels respectively, and the last level is composed of the alternatives (alternative strategies) as shown in Figure 3-1(Yuksel &

Dagdeviren, 2007). The super matrix of SWOT hierarchy with four levels is as follows:

$$W = \begin{matrix} & \begin{matrix} goal \\ SWOT\ factors \\ SWOT\ Sub-factors \\ alternatives \end{matrix} \end{matrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ w_{21} & 0 & 0 & 0 \\ 0 & W_{32} & 0 & 0 \\ 0 & 0 & W_{43} & I \end{bmatrix} \quad E(3-2)$$

where ;

w_{21} : is a vector which represents the impact of the goal on the criteria,

W_{32} : is a matrix that represents the impact of the criteria on each of the sub-criteria,

W_{43} : is a matrix that represents the impact of the sub-criteria on each of the alternatives,

I : is the identity matrix.

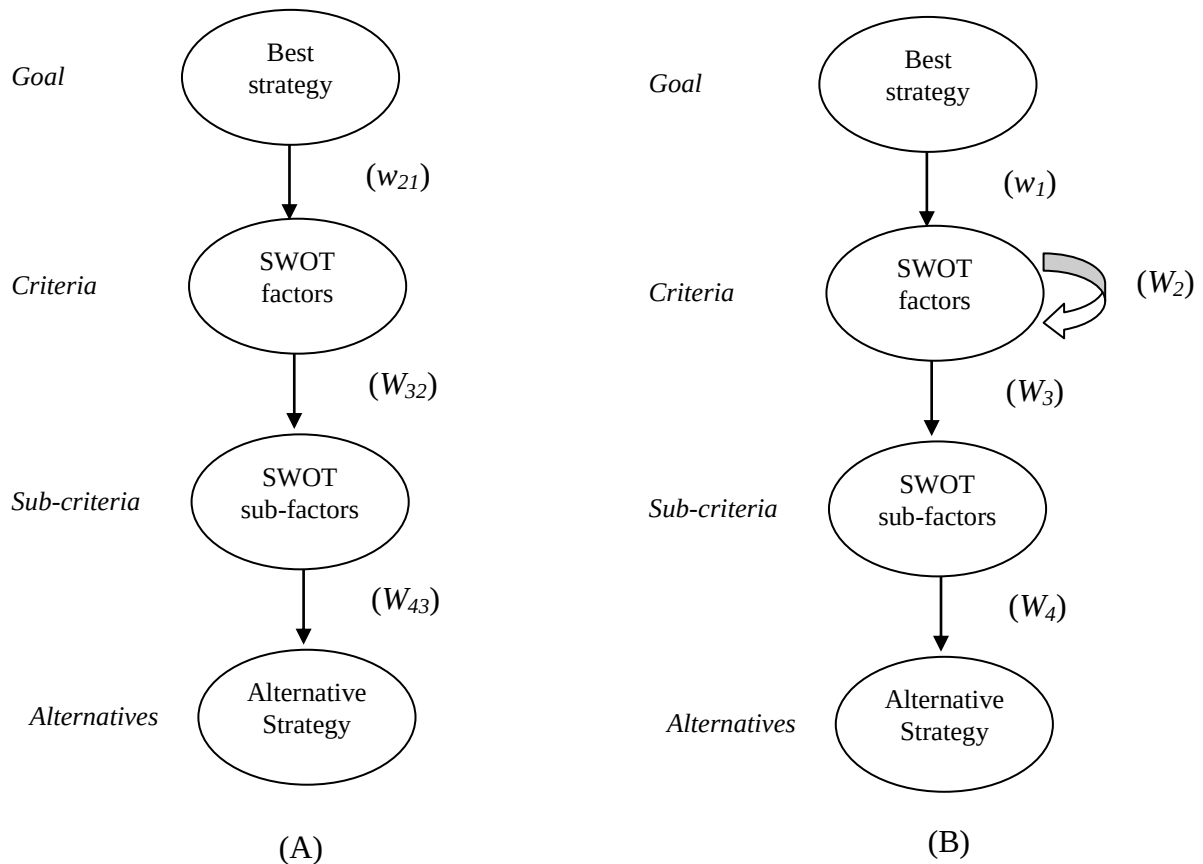


Figure (3-1)
(A)The Hierarchical Representation of the SWOT Model.
(B) The Network Representation of the SWOT Model
Source: (Yuksel & Dagdeviren, 2007)

A hierarchical representation of the SWOT model is given in Figure 3-1A and its general network representation is presented in Figure 3-1B. The network model illustrates the case of a hierarchy with inner dependence within clusters but no feedback. Here, SWOT factors, SWOT sub-factors and strategies are used in place of criteria, sub-criteria and alternatives, respectively, and the SWOT factors have inner dependencies.

$$W = \begin{matrix} & \begin{matrix} goal \\ SWOT\ factors \\ SWOT\ Sub - factors \\ alternatives \end{matrix} \end{matrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ w_1 & W_2 & 0 & 0 \\ 0 & W_3 & 0 & 0 \\ 0 & 0 & W_4 & I \end{bmatrix} \quad E(3-3)$$

where;

w_1 : is a vector that represents the impact of the goal, namely, selecting the best strategy according to SWOT factors,

W_2 : is a matrix that represents the inner dependence of the SWOT factors,

W_3 : is a matrix that denotes the impact of the SWOT factor on each of the SWOT sub-factors,

W_4 : is a matrix that denotes the impact of the SWOT sub-factors on each of the alternatives.

I : is the identity matrix.

Using matrix operations is preferred in order to show the details of the calculations in this algorithm. For ANP, matrix operations will be applied in order to determine the overall priorities of the alternative strategies identified with SWOT analysis, a spread sheet in Microsoft Office Excel 2007 will be used to compute the eigenvectors from the pairwise comparison matrices and to determine the consistency ratios and to

determine the overall priorities of the alternative strategies identified with SWOT analysis, the proposed algorithm is as follows:

Step1: Identify SWOT sub-factors and determine the alternative strategies according to SWOT sub-factors.

The problem is converted into a hierarchical structure in order to transform the sub-factors and alternative strategies into a state in which they can be measured by the ANP technique. The schematic structure established is shown in Figure(3-2).

The aim of “choosing the best strategy” is placed in the first level of the ANP model and the SWOT factors (Strengths, Weaknesses, Opportunities, Threats) are in the second level. The SWOT sub-factors in the third level include: four sub-factors for the Strengths factor, four sub-factors for the Weaknesses factor, four sub-factors for the Opportunities factor, and four sub-factors for the Threats factor. Four alternative strategies developed for this study are placed in the last level of the model.

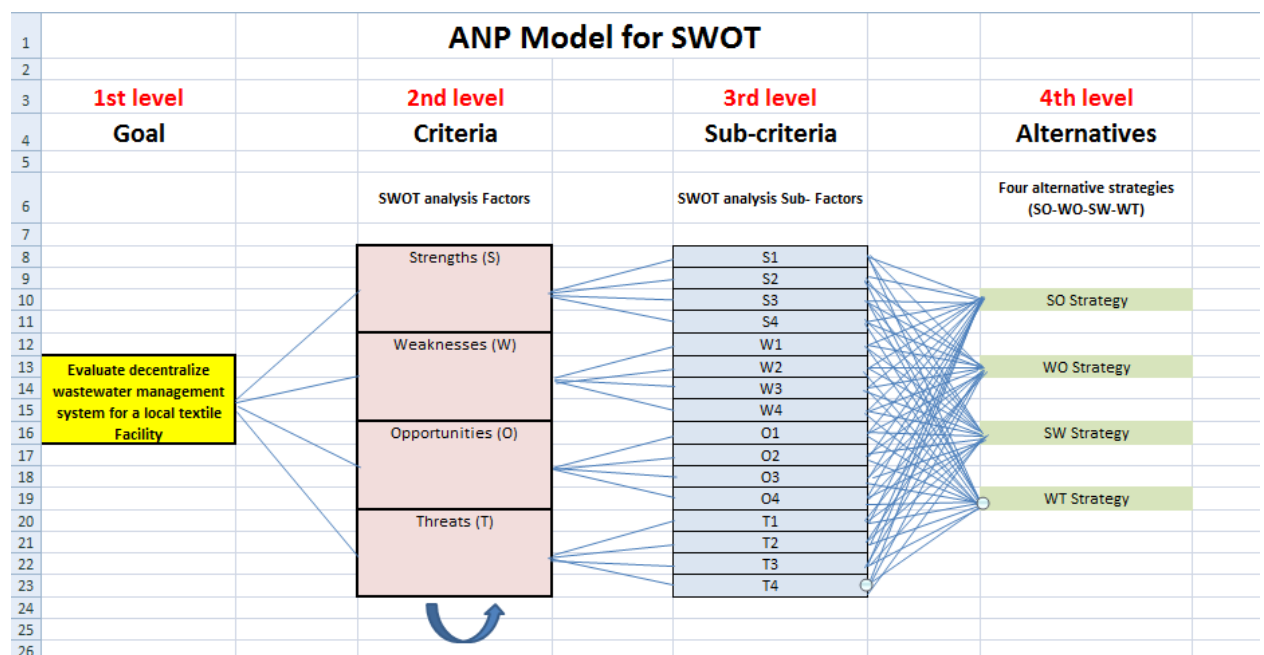


Figure (3-2)
ANP Model for SWOT

Using the SWOT sub-factors, the SWOT matrix and alternative strategies based on these sub-factors are developed (Table 3-2).

Table 3-2: SWOT matrix and alternative strategies

External Factors	Internal Factors	
	Strengths (S)	Weaknesses (W)
Opportunities (O)	SO Strategies	WO Strategies
Threats (T)	ST Strategies	WT Strategies

It can be seen from Table 3-2 that the facility has four alternative strategies. The strategy identified as SO involves making good use of opportunities by using the existing strengths of the organization. The WO strategy seeks to gain benefit from the opportunities presented by the external environmental factors by taking into account the weaknesses of the organization. Similarly, ST is the strategy associated with using the facility's strengths to remove or reduce the effects of threats. The fourth and last strategy is WT in which the facility tries to reduce the effects of its threats by taking its weaknesses into account. In this research, the aim of the SWOT analysis is to determine the priorities of the strategies developed and to determine the best strategy for the textile facility.

Step2: Assume that there is no dependence among the SWOT factors; determine the importance degrees of the SWOT factors with a 1–9 scale (i.e. calculate w_1).

$$w_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} \quad \text{E(3-4)}$$

Table (3-3) Saaty's 1-9 Scale for AHP/ANP preference

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

(Source :Yuksel & Dagdeviren, 2007)

where 2, 4, 6 and 8 are intermediate values used to represent compromise between the priorities.

4	Goal: Evaluate decentralize wastewater management system for a local textile Facility				
5	Criteria: SWOT analysis Factors				
6	Sub-criteria: SWOT analysis Sub- Factors				
7	Alternatives: Four alternative strategies (SO-WO-SW-WT)				
8					
9					
10	Pairwise comparison of SWOT factors				
11	SWOT Factors	S	W	O	T
12	Strengths (S)	1			
13	Weaknesses (W)	#DIV/0!	1		
14	Opportunities (O)	#DIV/0!	#DIV/0!	1	
15	Threats (T)	#DIV/0!	#DIV/0!	#DIV/0!	1
16	Total	#DIV/0!	#DIV/0!	#DIV/0!	1.000
17	Sum of each column				

Figure (3-3)

Pairwise Comparison Model for SWOT Factor Built in Microsoft Office Excel

The normalized matrix is calculated for matrix A by dividing each element by the sum of its column.

18								
19						Average (Normalized inputs) Priority vector		Consistency measure =MMULT()
20	SWOT Factors	S	W	O	T	Importance degrees of SWOT factors	Weight	
21	Strengths (S)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#VALUE!
22	Weaknesses (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
23	Opportunities (O)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
24	Threats (T)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
25		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
26								

Figure (3-4)

Normalized Matrices and Calculations of Importance factor in Microsoft Office Excel

28		CR		CI	RI
29		Consistency Ratio CR=CI/RI		Consistency Index CI=(λ_{max} -n)/(n-1)	Random Index RI for n=4 matrix
30	Is CR ≤ 0.1	#DIV/0!		#DIV/0!	0.9
31					

Figure (3-5)

Calculation of Consistency Ratio Check the feasibility of Priority Matrices

To find the final relative weight the average of each row, Saaty recommends that if the consistency ratio CR value exceeds 0.10, the judgments should be reviewed. If not, that will verify the coherence of the relative weights calculated (Saaty, 2008).

Step 3: Determine, the inner dependence matrix of each SWOT factor with respect to the other factors with a 1–9 scale and interdependent priorities of the SWOT (i.e. calculate W_2), as an example for inner dependence matrix for strengths is illustrated in screenshots Figure (3-6) and (3-7):

13					
14	Innner dependence materics for SWOT factors with respect to "strengths'				
15	Strengths (S)	W	O	T	
16	Weaknesses (W)	1			
17	Opportunities (O)	#DIV/0!	1		
18	Threats (T)	#DIV/0!	#DIV/0!	1	
19	Total	#DIV/0!	#DIV/0!		
20		$CR = \frac{CI}{RI}$			
21	Is $CR \leq 0.1$			#DIV/0!	Yes/No
22					

Figure (3-6)
Calculation the Inner Dependence for SWOT Factors in Microsoft Office Excel

						Consistency measure =MMULT()
Strengths (S)	W	O	T	Relative importance weight	Weight	
Weaknesses (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#VALUE!
Opportunities (O)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!
Threats (T)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!
Total	#DIV/0!	#DIV/0!	#DIV/0!			
For n= 3	RI=					
	CI=					

Figure (3-7)
Normalized Matrices and Calculations of Importance factor for Inner Dependency in Microsoft Office Excel

Step 4: Determine the interdependent priorities of the SWOT factors.

$$w_{factors} = W_2 \times w_1 \quad E(3-5)$$

Step 5: Determine the local importance degrees of the SWOT sub-factors with a 1–9 scale (i.e. calculate $w_{sub-factor(local)}$)

3	Pairwise comparison matrices for SWOT sub-factors local priorities				
4	Strengths (S)	S1	S2	S3	S4...Sn
5	S1	1			
6	S2	#DIV/0!	1		
7	S3	#DIV/0!	#DIV/0!	1	
8	S4 Sn depend on the number of strengths	#DIV/0!	#DIV/0!	#DIV/0!	1
9	Total	#DIV/0!	#DIV/0!	#DIV/0!	1.000
10					
11	Is CR ≤ 0.1	0	Yes/No		

Figure (3-8)
Pairwise Comparison Matrices for the SWOT Sub-factor Local Priorities in Microsoft Office Excel

G	H	I	J	K	L	M	N
							Consistency measure =MMULT()
Strengths (S)	S1	S2	S3	S4...Sn	Local weight	Weight	
S1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#VALUE!
S2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!
S3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!
S4 Sn depend on the	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!
Total	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
For n=	RI=						
	CI=						

Figure (3-9)
Normalized Matrices and Calculations of Importance factor for SWOT Sub-factors in Microsoft Office Excel

Step 6: Determine the overall priorities (global) importance degrees of the SWOT sub-factors (i.e. calculate $w_{sub-factor(global)}$)

$$w_{sub-factor(global)} = w_{factors} \times w_{sub-factor(local)} \quad E(3-6)$$

2	Overall priority of SWOT sub-factors				
3	SWOT analysis Factors	Priority of the factors	SWOT analysis Sub- Factors	Priority of the sub-factors	Overall priority of the sub-factors w sub-factors (global) = w factors x w sub-factors (local)
4	Strengths (S)	#DIV/0!	S1	#DIV/0!	#DIV/0!
5			S2	#DIV/0!	#DIV/0!
6			S3	#DIV/0!	#DIV/0!
7			S4	#DIV/0!	#DIV/0!
8	Weaknesses (W)	#DIV/0!	W1	#DIV/0!	#DIV/0!
9			W2	#DIV/0!	#DIV/0!
10			W3	#DIV/0!	#DIV/0!
11			W4	#DIV/0!	#DIV/0!
12	Opportunities (O)	#DIV/0!	O1	#DIV/0!	#DIV/0!
13			O2	#DIV/0!	#DIV/0!
14			O3	#DIV/0!	#DIV/0!
15			O4	#DIV/0!	#DIV/0!
16	Threats (T)	#DIV/0!	T1	#DIV/0!	#DIV/0!
17			T2	#DIV/0!	#DIV/0!
18			T3	#DIV/0!	#DIV/0!
19			T4	#DIV/0!	#DIV/0!

Figure (3-10)
Calculation the Overall Priority of the SWOT Sub-Factors in Microsoft Office Excel

Step 7: Determine the importance degrees of the alternative strategies with respect to each SWOT sub-factor with a 1–9 scale (i.e. calculate W4).

3	Pairwise comparison matrices for priorities of the alternative strategies based on SWOT sub-factors				
4	Strengths (S1)	SO	WO	ST	WT
5	SO	1			
6	WO	#DIV/0!	1		
7	ST	#DIV/0!	#DIV/0!	1	
8	WT	#DIV/0!	#DIV/0!	#DIV/0!	1
9	Total	#DIV/0!	#DIV/0!	#DIV/0!	1.000
10					

Figure (3-11)
Pairwise Comparison Matrices for the Alternative Strategies the SWOT Sub-factor Local Priorities in Microsoft Office Excel

	G	H	I	J	K	L	M	N
								Consistency measure =MMULT()
		SO	WO	ST	WT	Local weight	Weight	
SO		#DIV/0!	#DIV/0!	#DIV/0!	0.000	#DIV/0!		#VALUE!
WO		#DIV/0!	#DIV/0!	#DIV/0!	0.000	#DIV/0!		#DIV/0!
ST		#DIV/0!	#DIV/0!	#DIV/0!	0.000	#DIV/0!		#DIV/0!
WT		#DIV/0!	#DIV/0!	#DIV/0!	1.000	#DIV/0!		#DIV/0!
Total		#DIV/0!	#DIV/0!	#DIV/0!	1.000			
For n= 4	RI=	0.9						
	CI=							
Is CR ≤ 0.1		0	Yes/No					

Figure (3-12)
Normalized Matrices and Calculations of Importance factor for the
Alternative Strategies for SWOT Sub-factors in Microsoft Office Excel

Step 8: Finally, determine the overall priorities of the alternative strategies, reflecting the interrelationships within the SWOT factors (i.e. calculate $w_{\text{alternatives}}$)

$$w_{\text{alternatives}} = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = W_4 \times w_{\text{sub-factor(global)}} \quad E(3-7)$$

The ANP analysis should indicate the best strategy with highest priority value.

Chapter 4

Research Results, Discussion and Conclusion

- 4.1 Research Results
 - 4.1.1 SWOT Analysis Results
 - 4.1.2 Analytic Network Process Results
- 4.2 Research Hypothesis Analysis
- 4.3 Discussion and Conclusion

Chapter 4

Research Results, Discussion and Conclusion

4.1 Research Results

The data collected from the questionnaire and interviews were recorded and analyzed by Microsoft office 2007 according to the methodology explained on the previous chapter. Total number of responds received are 25 responds, which is very small and this will cause a large amount of error (11.62%) more than we can tolerated, therefore 9 interviews were convened to overcome this deficiency and to reduce the margin of error to 5%.

4.1.1 Questionnaire and interviews Results

All responses and the data collected through questionnaire, interviews were recorded and analyzed carefully as follows:

4.1.1.1 Questionnaire

The questionnaire was designed to cover all the information needed to evaluate the wastewater management of facilities in Kingdom of Bahrain. The general information of facilities, business activity and their information related to operations, processes and the basic materials used in these operation was covered in a descriptive manner at the beginning of the questionnaire and in part (A).

Part (B) Covered information related to water sources and consumption, wastewater/sludge generated and types of treatment system used within the facility. There are 15 centralized sanitary treatment plants distributed geography in areas with high population were recognized through questionnaire responses., those plants are treating domestic and partially industrial wastewater in Kingdom of Bahrain, in the other hand, there are only 10 industrial facilities with decentralized wastewater system. Taking into consideration that we had weak responds to the questionnaire and there are maybe other facilities which certain wastewater management ignored the questionnaire.

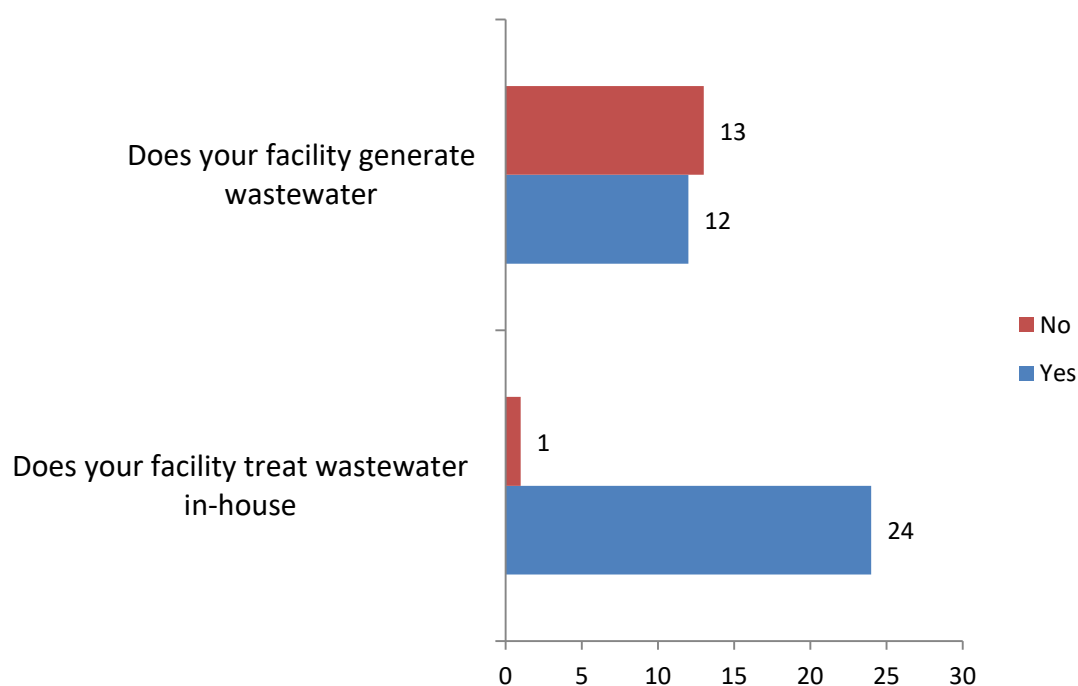


Figure (4-1)
Number of Facilities Generating and Treating Wastewater

The questionnaire demonstrate that, 96% of industrial wastewater are treated in-house by decentralized wastewater treatment systems within the facilities before it was discharge to the sea or wastewater network.

The total amount of wastewater treated by the facilities was calculated to be 365,203 m³/ day with total amount of sludge generated 95 tons per day where all the sludge disposed of by landfill . Wastewater characteristics which indicate the constituents that are or could be present in the wastewater discharge was different from one facility to another depend on the processes and activities carried out within the facility. The main constituents for domestic wastewater treated by Bahrain sanitary plant are: high PH (caustics , etc.), low PH (acids), insoluble substances, hydrogen sulfide, sulfur dioxide ,salt brines, grease or oil , solvents, large particles, surfactants (detergents) and BOD. The wastewater generated from the textiles facilities have yarn, dyes and different chemicals. It have been found that following technologies were used to treat wastewater: bar or bow screen, grit removal, oil/fat removal, flow equalization activated sludge nitrification, denitrification ,disinfection, (direct) filtration, chemical oxidation, biological removal and hyperfiltration.

Part (C) Covered the facility operations, average number of employees and their shifts time. Most of facilities have 2 (12 hours per day) to 3 shifts (8 hours per day) normally worked every day of the week . The average number of employees responsible for wastewater treatment plants are around 3 to 5 employees.

In Part (D) the current national legislations related to wastewater management enforced by Bahrain's Supreme Council for the Environment (SCE) was evaluated. First, the respondents were been asked about their level of knowledge to wastewater management legislation, 80 % found to have a very good to excellent knowledge about

the procedures and the legal actions taken by national environment authority Table (4-1) and Figure (4-2).

Table (4-1) Level of knowledge to wastewater management legislations & procedures

Question No.	Factor	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
D-1	Knowledge to WWM legislations	13	7	4	1	0
D-2	Knowledge to procedures of safe wastewater discharge	16	6	2	1	0

■ Excellent ■ Very Good ■ Good ■ Weak ■ Very Weak

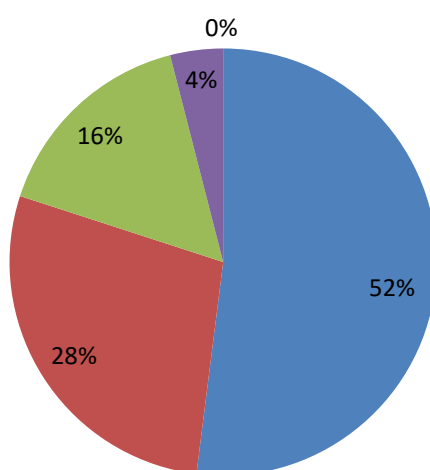


Figure (4-2)
Evaluation of Respondents Knowledge to the Wastewater Management Legislations

A general evaluation to was conducted in order to find out whether the wastewater management legislations are sufficient and to identified the factors influencing the implementation of this legislations as shown in table (4-2) .

Table (4-2) General evaluation to wastewater management legislations

Question No.	Factor	Excellent	Very Good	Good	Weak	Very Weak
D-3	Clear and understandable legal actions taken by Inspectors	2	7	16	0	0
D-4	Inspectors are taking consistent decisions and legal actions	1	5	3	16	0
D-5	Inspectors are taking fair legal actions	3	8	1	0	13
D-6	Set limits to ensure the quality of Discharged water	4	19	1	1	0
D-7	The current legislative framework is appropriate for wastewater management.	1	22	1	1	0
D-8	Well defined implementation measures in legislation	1	6	15	3	0
D-9	Reviewed and updated of national wastewater legislation	3	18	2	2	0
D-10	need to active participation of all stakeholders	18	6	0	1	0

In the questionnaire responses show lack of confidence from facilities to the environment authority inspectors decisions and legal actions for unauthorized wastewater discharge, 82% of the respondents agreed that the national wastewater legislation need to be reviewed and updated through an active participation of all related stakeholders (local government, NGOs and the community) to set and implement new well defined measures in the wastewater legislation.

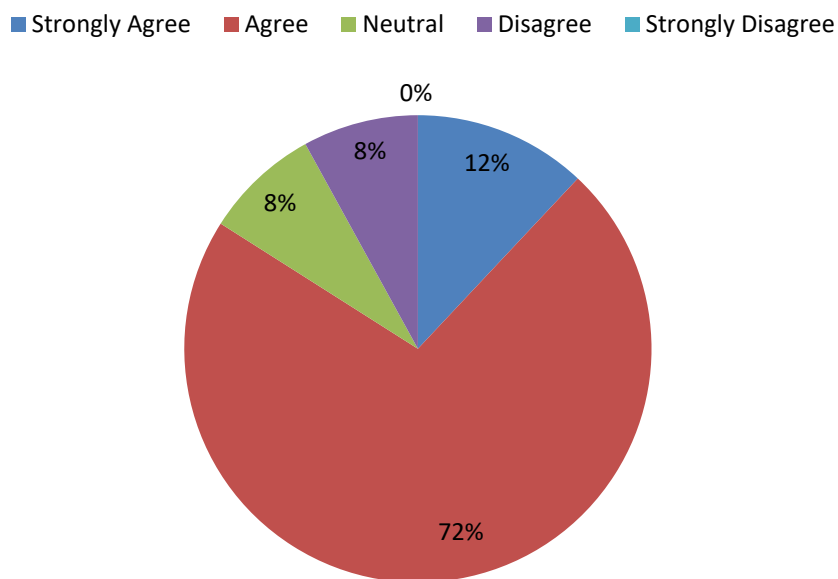


Figure (4-3)
Final evaluation to the national wastewater legislation applied by Bahrain's
Supreme Council for the Environment (SCE)

Legislative decree No. 21 for 1996 on the environment and the Ministerial Order No.10 for 1999: environmental standards for air and water and its amendments No. 2 and 3 for 2001 was evaluated to recognize how much the participants agreed on and aware of stated sentences for each article in the national legislation, as it is shown in Table(4-3). Responses showed that 3 articles needed to be reviewed and updated which are article no. 28 related to inspection procedure, article no. 7 which concerns of the national legislation prevent any unauthorized discharge and article no. 22 that a fair requirement for the discharge area. Respondents choose to have no opinion in 5 articles which shows us lack of awareness programs that educates on the importance of wastewater management to ensure better the implementation of its legislations.

Table (4-3) Evaluation to wastewater management legislations articles

Articles related to wastewater	Very High	High	Middle	Low	No Opinion
	4	3	2	1	0
Legislative decree No. 21					
Article No. 13: The national legislation prevent any unauthorized discharge of wastewater	5	3	3	11	3
Article No. 28: Clear Inspection procedure	4	4	13	1	3
Article No. 29: Fair Sanctions	7	1	3	11	3
MO No.10 for 1999: and its amendments No. 2 an 3 for 2001					
Article No. 7: The national legislation prevent any unauthorized discharge	7	1	14	0	3
Article No. 8: Promote a suitable treatment technology	2	6	4	10	3
Article No. 9: Encourage using a control equipment	2	17	3	0	3
Article No. 20: Demand a quality of the discharged wastewater	5	14	3	1	2
Article No. 22:Treatment & Complying with Standards	14	3	5	1	2
Article No. 22 Repeated: Set a fair requirement for the discharge area	4	4	14	1	2
Article No. 25:demand providing reports and tests	7	14	0	2	2
Article No. 26: Fair Sanctions	4	7	1	11	2
Annex 2 : Table 5: Applicable Industrial Wastewater Limits	4	7	1	11	2

In this research, the focus was on Bahrain's Supreme Council for the Environment (SCE) legislations, but in future further research could be done to harmonize them with other related legislations implemented by other authorities like Ministry of work .

Part (E): Evaluate of the establishment wastewater management system. In part (D) and (E), the questions have a scale of 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree to simplified analysis process. At the beginning of Part E a question has been asked to evaluate respondents knowledge to their company's wastewater management. Figure (4-2) below illustrates that most responders (88%) evaluate their facility to have excellent to a very good managements to wastewater.

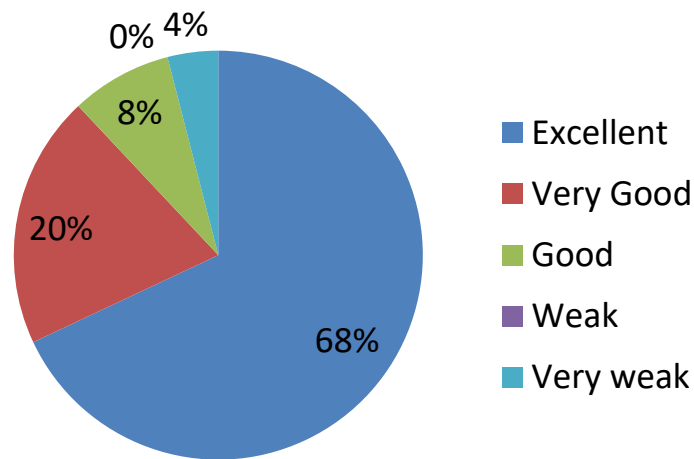


Figure (4-4)
Respondents evaluation to WWM of their facilities

25 questions have been asked to the facilities in order to evaluate their wastewater management, the average was taken to cover certain categories (15 categories) for example E1 and E2 represent competent management and technically qualified Staff are hired to manage and treat wastewater.

Table 1 Responses to the Evaluation Wastewater Management

Question ID	Field	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
E-1	Staff	19	5	1	0	0
E-2	Staff	16	7	2	0	0
E-3	Monitoring	20	4	1	0	0
E-4	Monitoring	20	3	2	0	0
E-5	Comply standards	16	8	1	0	0
E-6	Sludge Reuse	0	2	9	11	3
E-7	Check the validity	21	2	2	0	0
E-8	Maintenance	19	4	2	0	0
E-9	Plans	15	6	3	1	0
E-10	Laboratories	19	5	1	0	0
E-11	Laboratories	10	10	5	0	0
E-12	Safety Requirement	17	7	1	0	0
E-13	Training programs	7	13	5	0	0
E-14	Awareness Programs	4	13	7	1	0
E-15	Safety Requirement	10	12	3	0	0
E-16	Safety Requirement	9	15	1	0	0
E-17	Safety Requirement	11	12	2	0	0
E-18	Documentation	8	14	3	0	0
E-19	Management Awareness	18	5	2	0	0
E-20	External influence	0	4	16	4	1
E-21	R&D	11	4	9	1	0
E-22	Communication	0	4	18	2	1
E-23	Benefit	2	2	4	14	3
E-24	Technology	1	7	13	2	2
E-25	Available Funds	1	1	7	16	0

If we convert the responses received on this part to percentage, we will noticed that most of companies replies agreed on a competent management and technically qualified staff will have a high weight on good WW management system with monitoring by periodic analysis to discharged wastewater will have the highest weight on good WW management system, the overall evaluation result are summarized in Table (4-5).

Table (4-5) Responses Percentage to the Evaluation Wastewater Management

Question ID	Field	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
E-(1+2)	Staff	70%	24%	6%	0%	0%
E-(3+4)	Monitoring	80%	14%	6%	0%	0%
E-5	Comply standards	64%	32%	4%	0%	0%
E-6	Sludge Reuse	0%	8%	36%	44%	12%
E-7	Check the validity	84%	8%	8%	0%	0%
E-8	Maintenance	76%	16%	8%	0%	0%
E-9	Plans	60%	24%	12%	4%	0%
E-(10+11)	Laboratories	58%	30%	4%	0%	0%
E-(12+ 15- 17)	Safety Requirement	39%	48%	7%	1%	0%
E-13	Training programs	32%	56%	12%	0%	0%
E-14	Awareness Programs	72%	20%	8%	0%	0%
E-18	Documentation	0%	16%	64%	16%	4%
E-19	Management Awareness	44%	16%	36%	4%	0%
E-20	External influence	0%	16%	72%	8%	4%
E-21	R&D	8%	8%	16%	56%	12%
E-22	Communication	4%	28%	52%	8%	8%
E-23	Benefit	4%	4%	28%	64%	0%
E-24	Technology	70%	24%	6%	0%	0%
E-25	Available Funds	80%	14%	6%	0%	0%

Illustrated below the results of each questions on part (E):

Question 1: Competent Management and Technically Qualified Staff

E-1 The facility have competent management staff involved in wastewater management

E-2 The facility have technically qualified workforce to deal with wastewater treatment plant

The analysis of the first question, figure (4-5), shows that 70% of the population strongly agree that their facility have competent management and technically qualified staff.

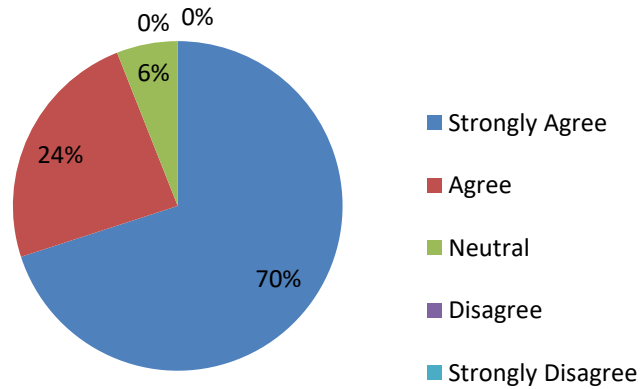


Figure (4-5)
Competent Management and Technically Qualified Staff

Question 2: Monitoring by Periodic Analysis to Discharged WW

E-3 The facility used to work and conduct periodic analysis to check the quality of wastewater discharge

E-4 The facility used to hand over the results of these periodic analysis to the Supreme Council for the Environment

The analysis of the second question, figure(4-5), shows that 80% of the population strongly agree the that their facility conduct periodic analysis and submit it to environment authority.

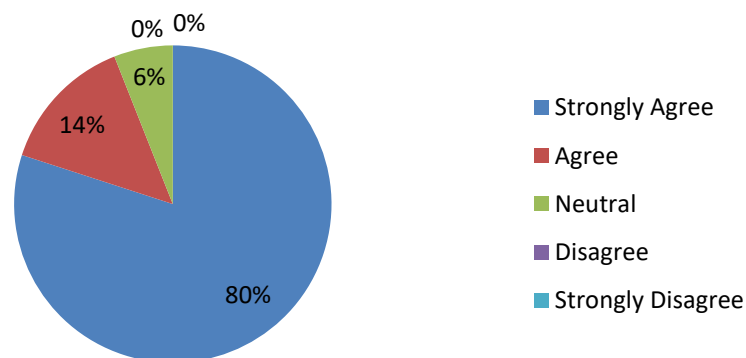


Figure (4-6)
Periodic Analysis to Discharged WW

Question 3: Comply standards

E-5 The quality of wastewater discharge comply with the standards of the Supreme Council for the Environment

The analysis of the third question, figure (4-6), shows that 96% of the population strongly agree the that their facility conduct periodic analysis and submit it to environment authority.

Question 4: Sludge Reuse

E-6 The facility used to reuse generated sludge

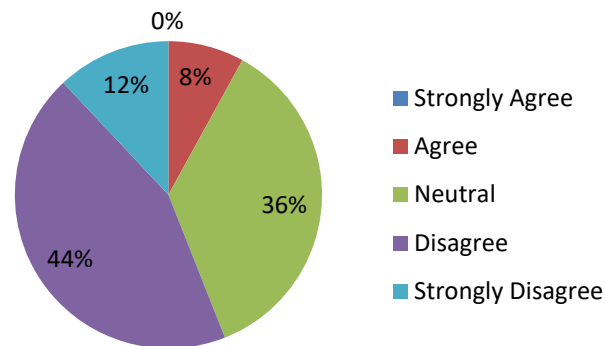


Figure (4-7) Sludge Reuse

The analysis of the fourth question, figure (4-7), shows that 56% of the population disagree the that their facility reuse generated sludge, most of the facilities disposed the sludge by landfill.

Question 5: Check the validity

E-7 The wastewater is treated before its discharge to environment

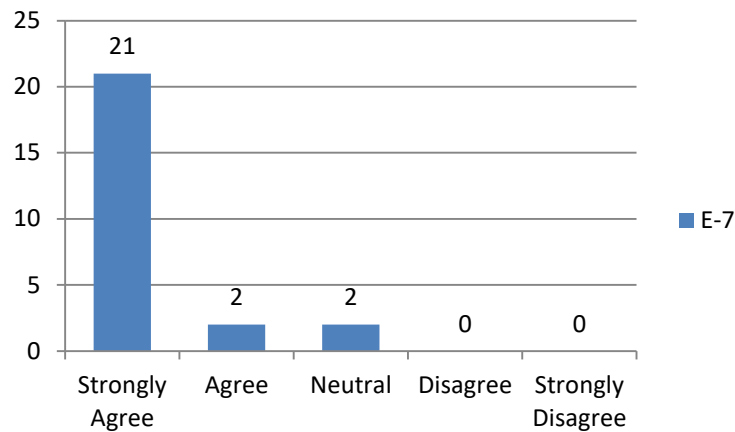


Figure (4-8)
Checking the Validity

The question to check the validity of the responder answers. figure(4-7) , shows that 84% of the population strongly agree which give us confidence on the responses .

Question 6: Maintenance

E-8 The wastewater treatment unit is constantly maintained

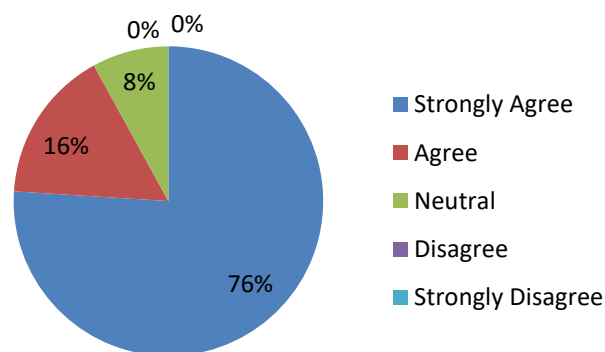


Figure (4-9)
Maintenance of the Wastewater Treatment Plant

The analysis of this question, figure(4-9), shows that 76% of the population strongly agree the that their facility constantly maintained plants.

Question 7: Plans

E-9 The facility sets plans to the development of wastewater treatment systems

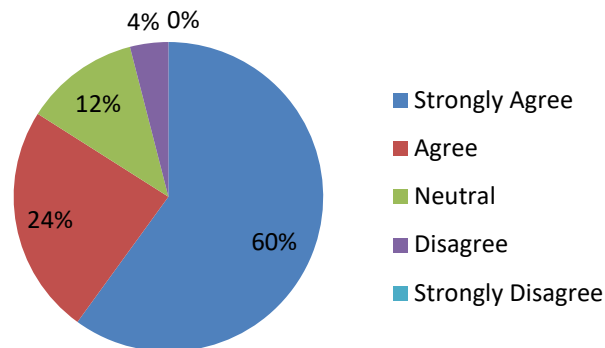


Figure (4-10)
Setting Plans Development of Wastewater Treatment Systems

Figure (4-10) shows that 60% of the population strongly agree that their facility sets plans to the development of wastewater treatment systems.

Question 8: Laboratories E-(10+11)

E-10 The facility has laboratories to analysis wastewater

E-11 The need of accredited laboratories used in the assay results of wastewater analysis

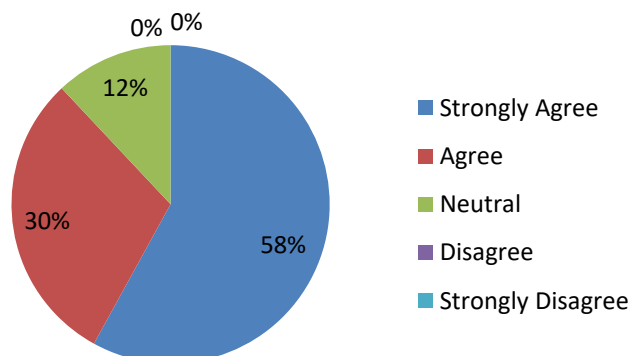


Figure (4-11)
Existence Laboratories

A question have been asked to check the availability of laboratories, figure (4-11), shows that 58% of the population strongly agree the that their facility have it own laboratories.

Question 9: Safety Requirement E-(12 +15 to 17)

E-12 The facility takes into account the safety of workers

E-(15-17) The facility complies with safety requirements during the collection transportation, and treatment of wastewater and sludge

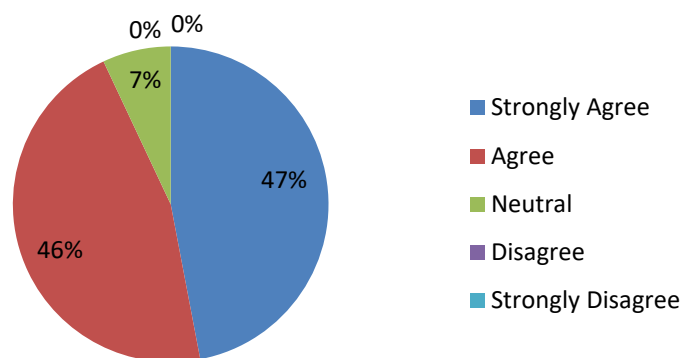


Figure (4-12)
Safety Requirements

In this question, figure (4-12), shows that majority of the population agree and strongly agree that their facility conduct all safety requirement,

Question 10: Training Programs

E-13 The facility develops a training to the importance of wastewater treatment

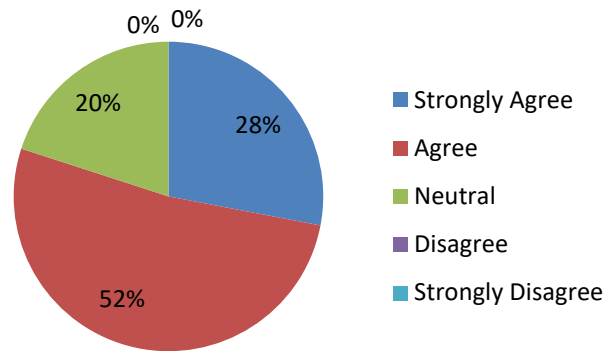


Figure (4-13)
Training Programs

In this question, figure (4-13), shows that training conduct in most of wastewater treatment facility.

Question 11: Awareness Programs

E-14 The facility develops awareness programs to the importance of wastewater treatment

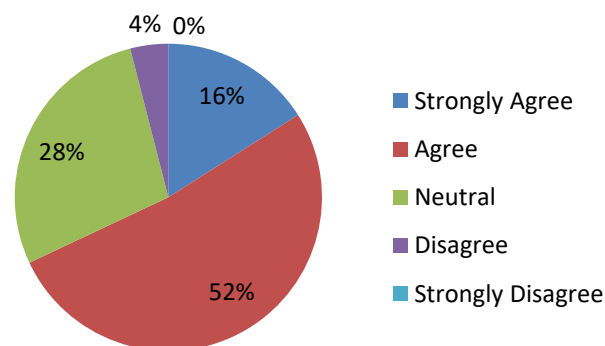


Figure (4-14)
Awareness Programs

The analysis of this question is illustrated in figure(4-14), it shows that 52% of the population agree the that their facility develops facility awareness programs.

Question 12: Documentation

E-18 The facility have proper wastewater management documentation

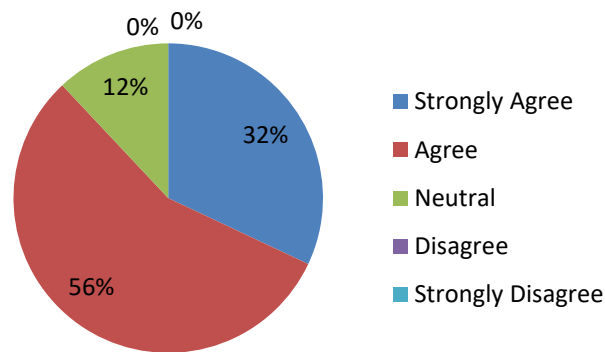


Figure (4-15)
Proper Documentation

The analysis of this question, figure(4-15), shows that 56% of the population agree the that their facility proper wastewater management documentation

Question 13: Management Awareness

E-19 The high top management of the facility are aware of the importance of wastewater management

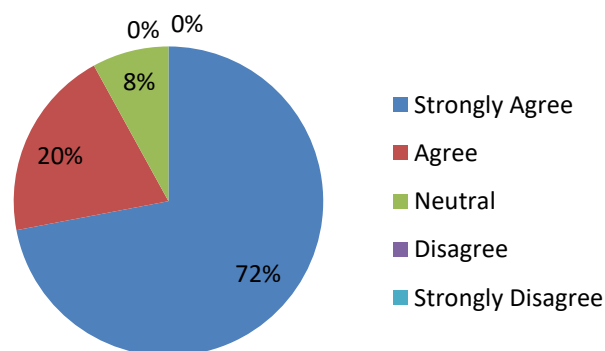


Figure (4-16)
Management Awareness

The analysis of this question, figure(4-16), shows that 72% of the population strongly agree the that their top management of the facility are aware of the importance of wastewater management.

Question 14: External influence

E-20 The Non-governmental organization (NGOs) have influence in the wastewater management

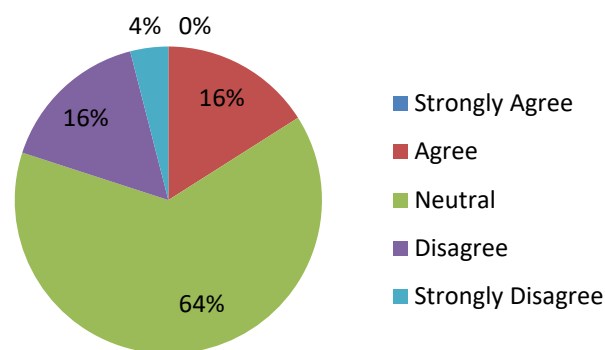


Figure (4-17)
Non-governmental organization (NGOs) have influence

The analysis of this question, figure (4-16), 64% of the population The Non-governmental organization (NGOs) have neutral influence on the wastewater management.

Question 15: R & D

E-21 There are limited economic and financial funds available for research and public investment in wastewater management

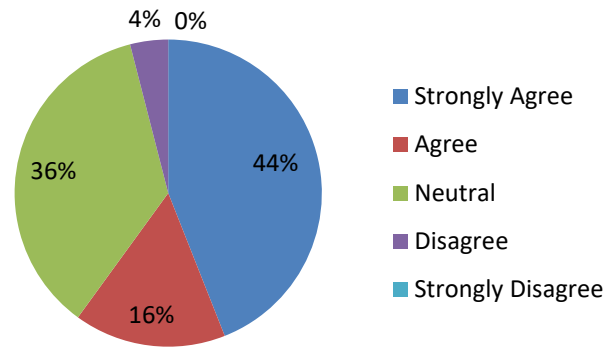


Figure (4-18)
Limited Economic and Financial Funds Available for Research and Public Investment

This question, figure (4-18) , shows that 44% of the population strongly agree that their management doesn't provide enough economic and financial funds for research and public investment in wastewater management.

Question 16: Communication

E-22There are limited share of information between authorities involved in wastewater management

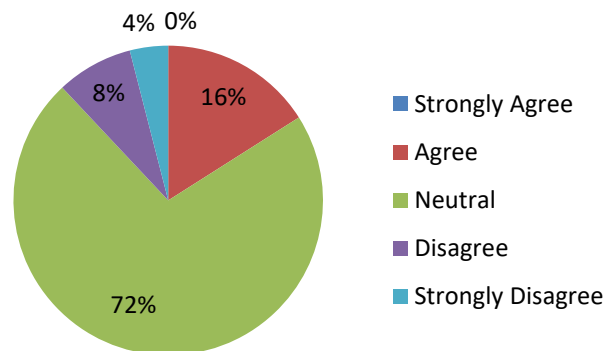


Figure (4-19)
Limited Share of Information

In this question, Figure (4-19), shows that 84%(72+8+4) of the population admit there are missing communication between authorities involved in wastewater management.

Question 17: Benefit

E-23 The treatment of wastewater returns to the facility a revenue.

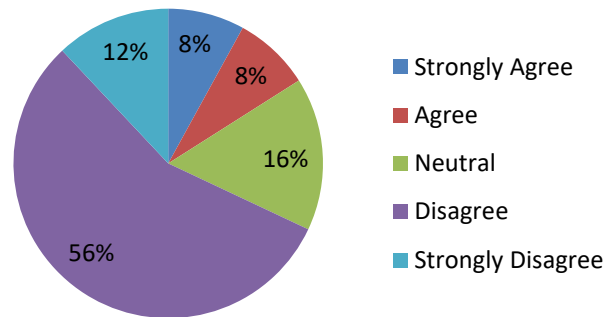


Figure (4-20)
Current Wastewater Treatment Returns Benefit Facility

The analysis of the question, Figure (4-20), shows that more than the half of the population disagree the that treated wastewater is reused to benefit to the facility.

Question 18: Technology

E-24 A new technology is required to replace current technology used to treat wastewater

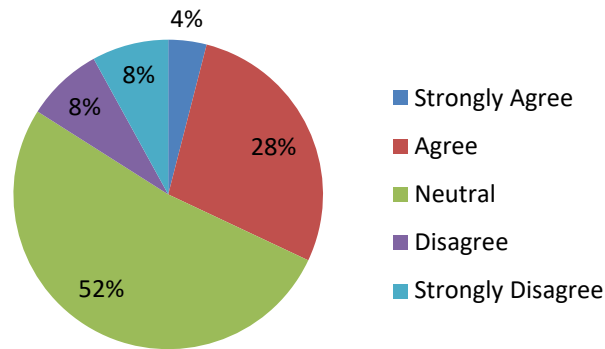


Figure (4-21)
The Need to Replace Current Technology

The analysis of this question, Figure(4-21), shows that 52% of the population was neutral about the need to replace the technology used in the facility, while 28% agree the new technology will improve the quality of treated WW.

Question 19: Available Funds

E-25 The facility spend appropriate funds in research related to wastewater

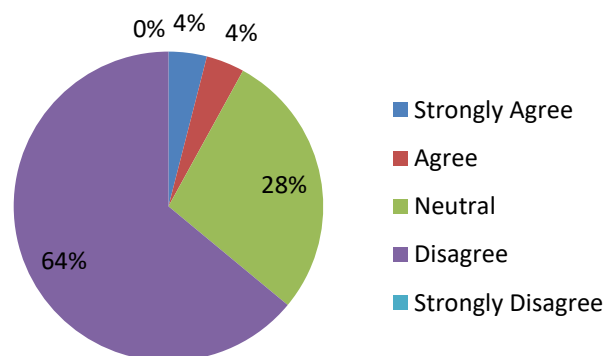


Figure (4-22)
Spend Funds in Research

Figure (4-22), shows that 64% of the population admit that no appropriate funds spend in research to improve the quality of treated wastewater . The evaluation national wastewater management regulations and its

enforcement, another question was been asked to the responders to check their knowledge to the wastewater management legislations as shown in the figure (4-23), 80% of the respondents have an excellent and very good knowledge.

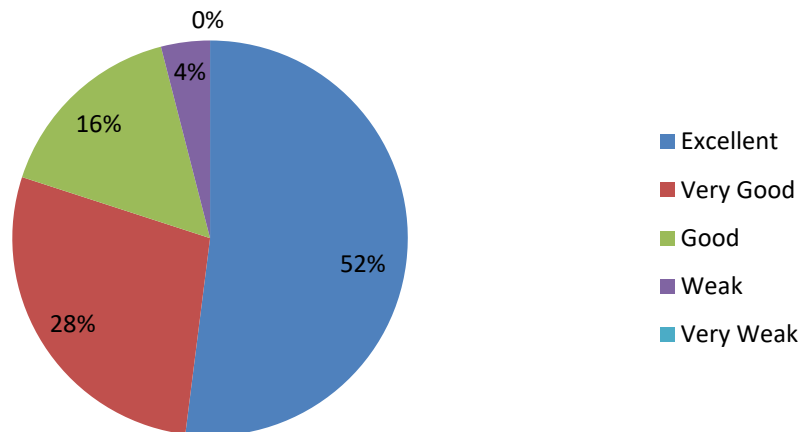


Figure (4-23)
The Responder Knowledge to the Wastewater Management Legislations

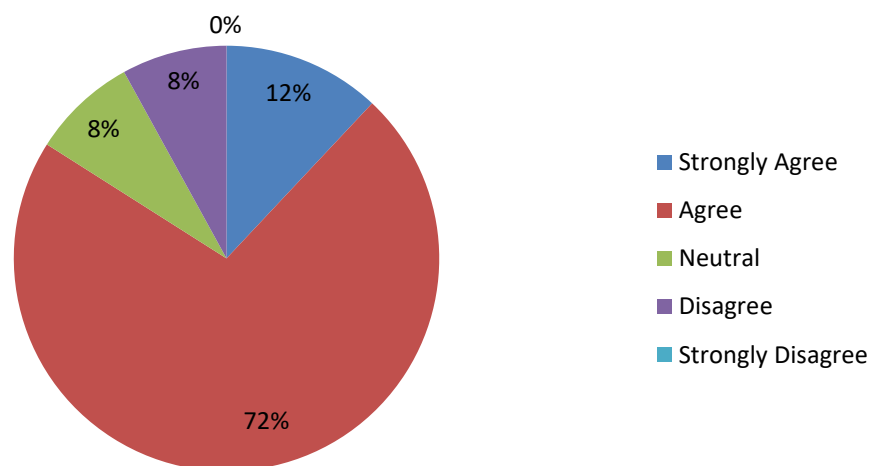


Figure (4-24)
The Need to Reviewed and Updated National Wastewater Legislation

84% of the respondents agree and strong agree the need to reviewed and updated current national wastewater legislation.

As mentioned earlier the questionnaire was design to collect data allow us to evaluate wastewater management systems practiced in Kingdom of Bahrain and the enforcement of the national wastewater management regulations. An intensive analysis was done to identify strengths, weaknesses, opportunities and threats related to wastewater management in the kingdom where the following alternative strategies are developed to enhance wastewater management system and to raise amount of treated wastewater reused.

Table (4-6) Evaluation of wastewater management system applied in the Kingdom of Bahrain

Strengths (S)	Weaknesses (W)
S1: Competent Management staff & Technically qualified workforce to deal with WWTP S2: Periodic analysis conducted to check the quality of wastewater discharge to the kingdom seacoasts S4: Constantly maintained wastewater treatment establishments S6: Availability of laboratories to analysis discharge wastewater S7: Facilities complies with safety requirements during the collection, transportation and treatment of wastewater and sludge S8: Industrial sector are aware of the importance of wastewater management	W1: Limited reuse of treated wastewater W2: No utilization of the generated sludge W3: Weak communication between the relevant wastewater authorities W4: Limited awareness programs in wastewater management W5: Limited funds spend in research and public investment in wastewater management W6: Obsolete national wastewater legislation which need to be reviewed and updated.
Opportunities (O)	Threats (T)
O1: WWT returns to the facility a revenue O2: Exploring new technologies to improve the current wastewater treatment technology	T1: Increase wastewater generated due to the increase in water demand and population T2: Dangerous environment effect of unauthorized wastewater discharge

SO Strategies:

SO1 :Convince the industrial sector of financial benefit gain from reusing treated wastewater (S1, S8 ,O1)

SO2: Upgrading the wastewater treatment establishments using new technologies
(S1, S4, O2).

WO Strategies

WO1:Promoting 100% reuse of treated wastewater in the agriculture (W1,O1)

WO2: Reduce the amount of sludge landfill in Asker and find new technologies alternative way to treat and reused generated sludge
Exploring to improve the current wastewater treatment technology:(W2,O1,O2)

ST Strategies

ST1:Conduct awareness programs to promote the treated wastewater as reusable water (S1,S8,T1)

ST2: Cooperation of industrial sector with governmental authorities to comply with maximum discharge limits of waste water effluent
(S1,S4,S8,T2)

WT Strategies

WT1: Conducting a research to reduce water demand and prevent unauthorized wastewater discharge (W5,T1,T2)

WT2: Conduct systematic review of the national legislations to ensure better enforcement (W6,T1,T2)

One or more of these strategies can be used to enhance and improve the current wastewater management.

4.1.1.2 Interviews

As mention before a semi-structured interviews with partial pre-planning questions were conducted to nine facilities to identify the applied wastewater management system, these following questions have been asked during the interviews .

1. How much the volume of wastewater treated? Is it within the capacity of your plant?
2. What type of wastewater treated?
3. What is the characteristics of the wastewater?
4. How many stages of treatment does your facility use?
5. What type of processes does your facility use?
6. Does your facility reuse the treated water? explain?
7. Does your facility discharge the wastewater in the sea?
8. Does your facility has laboratories to analysis influent wastewater and effluent of treatment processes?
9. How much sludge generated and how is it disposed off?
10. How do you evaluate the management of your facility to wastewater?
11. How do you evaluate legislation applied by national environment authority?

The data collected during the interviews and questionnaire were combined and accurately analyzed.

All interviews were face to face and took place at facility applying centralized and decentralized wastewater treatment systems. General information was collected at the beginning of each interview regarding

the facility operations, processes performed and then went through the mechanism used by facility to treat the wastewater.

An example of interviews to **centralized sanitary treatment plants**, Tubli sewage treatment plant (STP) considered to be the biggest governmental sewage treatment plant in kingdom of Bahrain figure(4-23), it processes 310,000 cubic meters per day, which is above the 200,000 cubic meter capacity of the plant.



Figure (4-25)
Tubli Sewage Treatment Plant (STP)

90% of the treated wastewater is discharged to sea (Tubli Bay) and 10% is used by agriculture for irrigation. The Tubli plant is designed to have a wastewater quality with Total Suspended Solids 10, Biological Oxygen Demand 10, Ammonia 3. Tubli STP is the biggest STP in Bahrain. The existing wastewater treatment facilities at Tubli STP include screening and grit removal for primary treatment; an extended aeration activated sludge process, and settling by clarifiers as secondary biological treatment; and dual-medium filtration, pre-chlorination, disinfection by ozone followed by post-chlorination for tertiary treatment. The ozonation

facility was added to the system in 1987 to ensure high standard treated effluent.(**AI-Noaimi, 2005**)

There are nine other smaller STPs that predominantly discharge treated wastewater to sea. The Ministry of Works has apply its own standards for treated sewage effluent. All MoW STP discharges to sea are sampled for a wide range of parameters. Discharge points are fenced and signed to exclude unauthorized access. Tubli Bay is a restricted area in terms of public usage. The potential for the accumulation of heavy metals in the sediments of Tubli Bay exists. MoW's Tubli STP produces fifty tons of thermally dried sludge per day which is transferred to landfill. Sludge contains heavy metals.

Another interviews was conducted to several decentralized treatment plants, for example Bahrain Petroleum Company (BAPCO) which is the national oil company of Bahrain. BAPCO facilities include crude oil refining, storage, marketing of petroleum products, and a Wharf for product shipment. The nominal capacity of the refinery is 267,000 BPSD, processing Arab Light (85%) and Bahrain (15%) crudes. Currently, crude is supplied to the refinery through dedicated pipelines from Saudi Arabia and the Bahrain fields. BAPCO products (Naphtha, Gasoline, Kerosene, Diesel, Fuel Oil, Asphalt and Lube Base Oil), Wharf facilities are also used to load products from other companies e.g. Banagas (Bahrain National Gas) and GPIC (Gulf Petrochemicals Industries). Oily water streams are normally routed to No. 3 oil separator, there are 4 oil separators in the refinery. The oil separators are open sumps where cooling water return (sea water) streams are collected. The oil is separated from the water and send back to a slop tank. Further processing of oily water from No. 3 separator is carried out in the IAF

(induced Air Flotation) unit, where final treatment of oily water takes place.

BAPCO generates process effluent and sanitary effluent. A Waste Water Treatment Plant (WWTP) and Sewage Treatment Plant (STP) based on membrane bio reactors technology were commissioned in 2013 & 2014, respectively. These projects are part of the environmental compliance plan to be fully compliant with the national environmental regulations as well meet the best International Environmental Standards. Treated wastewater (16350 to 21800 m³ per day) is either re-used for process water, re-used for irrigation purposes, or disposed of to sea. BAPCO operates a landfill which is licensed by SCE. Landfill monitoring data is currently sent to SCE. Some of the interviews were conducted to ensure the validity of the questionnaire replies. A local textile industry facility in the Kingdom of Bahrain was taken as a case study of facilities using decentralized wastewater treatment approach using SWOT analysis and Analytic Network Process (ANP) and compared with centralized wastewater treatment approach (Tubli sewage treatment plant (STP) in order to develop and promote the future wastewater management at the strategic level.

4.1.2 SWOT Analysis Results

The following Model was conducted to find out the SWOT factors and Sub- factors as shown in Figure (4-26). In phase 1 an initial SWOT model was built for each facility taking into consideration industrial characteristic, literature review and information got from the interviews. Next the SWOT model was modified according to the responsible person at each facilities which conform the identified SWOT factors. Finally, the

evaluation model was built by identifying the weight of each factor using analytic network process.

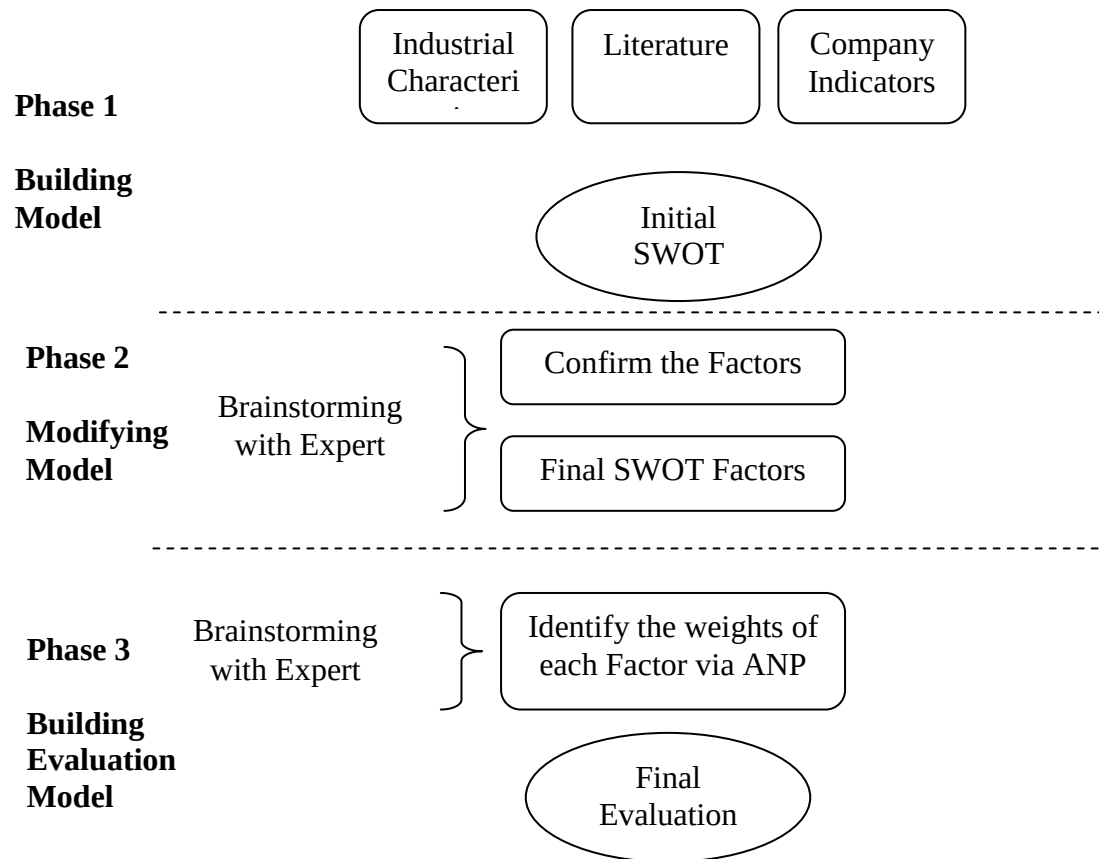


Figure (4-26)
Model of Proposed Methodology (Source:Modified from Yang et al., 2009)

4.1.3 Application of SWOT analysis for a local textile Facility:

In this research, first an external environment analysis is performed by the experts represented by managing director of this local textile company and another employee responsible of wastewater treatment unit operations. By this way, those SWOT sub-factors which affect the wastewater management (WWM) but cannot be controlled by the facility are identified.

Table 2 SWOT Matrix for a Local Textile Facility

Strengths (S)	Weaknesses (W)
S1: Competent Management staff S2: Technically qualified workforce to deal with WWTP S3: Conduct periodic analysis to WW S4: WWT unit is constantly maintained S5: Competent laboratories to analysis WW S6: Taking the safety requirement S7: Proper WW management documentation S8: Cooperative top management S9: Reused treated WW in process S10: Good reputation of the facility which is certified under the Oeko-Tex® Standard and use State-of-the-art equipment S11: Well R&D related to wastewater	W1: Doesn't reuse generated sludge W2: weak communication with environment authority W3: No future plans to the development of WWT systems W4: Ongoing operational costs
Opportunities (O)	Threats (T)
O1: WWT returns to the facility a revenue O2: geo-growth opportunities to expand and improve the existing wastewater treatment plant	T1: Increase in water demand used on the production and its cost . T2: High strict legislative measures apply by environmental authority .

In addition, an internal analysis is performed to determine the sub-factors which affect the WWM but can be controlled by the facility. Based on these analyses, the important strategic sub-factors which have very significant effects on facility management, are determined and listed in table (4-6).

Using the SWOT sub-factors which have been found by analyzing the external environment (threats and opportunities), and internal environment (weaknesses and strengths) for the textile facility, the SWOT matrix and alternative strategies are developed, this technique

help identify the alternatives which can be used to enhance wastewater management system applied within the facility.

The following questions was used with experts to identify the alternative strategies:

- Strengths and Opportunities (SO) – How can facility use their strengths to take advantage of the opportunities?
- Strengths and Threats (ST) – How can facility take advantage of their strengths to avoid real and potential threats?
- Weaknesses and Opportunities (WO) – How can facility use their opportunities to overcome the weaknesses?
- Weaknesses and Threats (WT) – How can facility minimize their weaknesses and avoid threats?

It can be seen from Table(4-8) that the facility has four alternative strategies. As mention before the strategy identified as SO involves making good use of opportunities by using the existing strengths by taking advantage of the top management cooperation to improve the wastewater treatment unit (O2, S8)

While the WO strategy seeks to gain benefit from the available opportunities and contract with a specialized company to study the feasibility of building sludge treatment unit that will help the facility to deal with amount of suspended solid generated during the wastewater treatment (O2,W1).

Table 3 TOWS Matrix and Alternative Strategies for a Local Textile Facility

	Internal Factors	
	Strengths (S)	Weaknesses (W)
External Factors	S1: Competent Management staff S2: Technically qualified workforce to deal with WWTP S3: Conduct periodic analysis to WW S4: WWT unit is constantly maintained S5: Competent laboratories to analysis WW S6: Taking the safety requirement S7: Proper WW management documentation S8: Cooperative top management S9: Reused treated WW in process S10: Good reputation of the facility which is certified under the Oeko-Tex® Standard and use State-of-the-art equipment S11: Well R&D related to wastewater	W1: Doesn't reuse generated sludge W2: weak communication with environment authority W3: No future plans to the development of WWT systems W4: Ongoing operational costs
Opportunities (O)	SO Strategies	WO Strategies
O1: WWT returns to the facility a revenue O2: geo-growth opportunities to expand and improve the existing wastewater treatment plant	Take advantage of the top management cooperation to improve the wastewater treatment unit (O2, S8)	Contract with specialized company to study the feasibility of building sludge treatment unit (O2,W1)
Threats (T)	ST Strategies	WT Strategies
T1: Increase in water demand used on the production and its cost. T2: High strict legislative measures apply by environmental authority .	Reused 100% of the treated wastewater on the production process to reduce the water consumption (T1,S9,S8)	Get involved with related wastewater authorities to study the wastewater effluent characteristic and set the best environmental measures (T2,W2)

Similarly, ST is the strategy associated with using the facility's strengths to remove or reduce the effects of threats. Therefore it has been suggested to reused all the treated wastewater on the production process to reduce the water consumed by providing a new source of water (T1,S9,S8).

The fourth and last strategy is WT, involved enhancing the relation with the related wastewater authorities such as Bahrain's Supreme Council for the Environment (SCE) and Ministry of Work (MoW) to study the wastewater effluent characteristic and set the best environmental measures (T2,W2). After the internal and external environment scanned and the factors have been identified Thomas Wheelen explained sample method summarize factors in his book "strategic management and business ". The VRIO framework (Value, Rareness, Imitability, & Organization) was used to assess the importance of each of the factors that might affect the facility (Wheelen & Hunger, 2012)

1. In Column 1, the most important strengths and weaknesses(Internal Factors) facing the facility was been listed in table 4-9, the most important opportunities and threats (external Factors) facing the facility was been listed in table 4-10.
2. In Column 2 (Weight), weight assigned to each factor from 1.0 (Most Important) to 0 (Not Important) based on that factor's probable impact. The higher the weight, the more important is this factor. where all weights must sum to 1.0 regardless of the number of factors.
3. In Column 3 (Rating), a rating assigned to each factor from 5.0 (Outstanding) to 1.0 (Poor) using Table 4-5 based on management's specific response to that particular factor. Each rating is a judgment regarding how well the facility's management is currently dealing with each specific internal factor.

Table (4-9) : Rating (source :Thomas L Wheelen, 2010)

5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Outstanding	Above Average		Average		Below Average		Poor	

4. In Column 4 (Weighted Score), the weight in Column 2 for each factor was multiplied times its rating in Column 3 to obtain that factor's weighted score.
5. Finally, the weighted scores for all the factors was been added in Column 4 to determine the total weighted score .

Table (4-10) Internal Strategic Factors for a local textile facility

Strengths (S)	Weight	Rating	Weighted Score
S1: Competent management staff	0.05	3	0.15
S2: Technically qualified workforce to deal with WWTP	0.15	5	0.75
S3: Conduct periodic analysis to WW	0.02	4	0.08
S4: WWT unit is constantly maintained	0.1	4.5	0.45
S5: Competent laboratories to analysis WW	0.15	3	0.45
S6: Taking the safety requirement	0.04	2	0.08
S7: Proper WW management documentation	0.01	1	0.01
S8: Cooperative top management	0.05	4	0.2
S9: Reused treated WW in process	0.15	5	0.75
S10: Good reputation of the facility which is certified under the Oeko-Tex® Standard and use State-of-the-art equipment	0.12	4	0.48
S11: Well R&D related to wastewater	0.01	3	0.03
Weaknesses (W)	Weight	Rating	Weighted Score
W1: Doesn't reuse generated sludge	0.04	4	0.16
W2: Weak communication with environment authority	0.03	5	0.15
W3: No future plans to the development of WWT systems	0.04	3	0.12
W4: Ongoing operational costs	0.04	4	0.16
Total of Internal Strategic factors	1		4.02

The total weighted score indicates how well the facility is responding to current and expected factors in its internal and external environment.

Table (4-11) External Strategic Factors for a local textile facility

Opportunities (O)	Weight	Rating	Weighted Score
O1: WWT returns to the facility a revenue	0.2	3	0.6
O2: Geo-growth opportunities to expand and improve the existing wastewater treatment plant	0.6	5	3
Threats (T)			
T1: Increase in water demand used on the production and its cost .	0.1	4.5	0.45
T2: High strict legislative measures applied by environmental authority .	0.1	4	0.4
Total External Strategic factors	1		4.45

We noticed that S2 which refer to using technically qualified workforce and S9 to reuse the treated wastewater in process have the highest weight score of 0.75 within listed strengths.

While the W1 and W4 scored the highest weight of 0.16 which indicate the affect of increasing operational cost on facility management and importance of finding better way to disposal or reused the generated sludge. For the external factors, opportunities have more score value compared to threats .

Note that total weighted score (4.02 and 4.45) can be used later on to compare it with the total weighted score of centralized wastewater management.

4.1.4 Analytic Network Process Results for a local textile Facility

According to the steps mentioned in the methodology chapter the analytic network process as applied to textile facility to evaluate the decentralized wastewater management system as follows:

Step1: SWOT sub-factors was identified and the alternative strategies was determined according to SWOT sub-factors. The schematic structure established is shown in Figure(4-27).

where;

Goal: Evaluate decentralized wastewater management system for a local textile Facility

Criteria: SWOT analysis Factors

Sub-criteria: SWOT analysis Sub- Factors

Alternatives: Four alternative strategies (SO-WO-SW-WT)

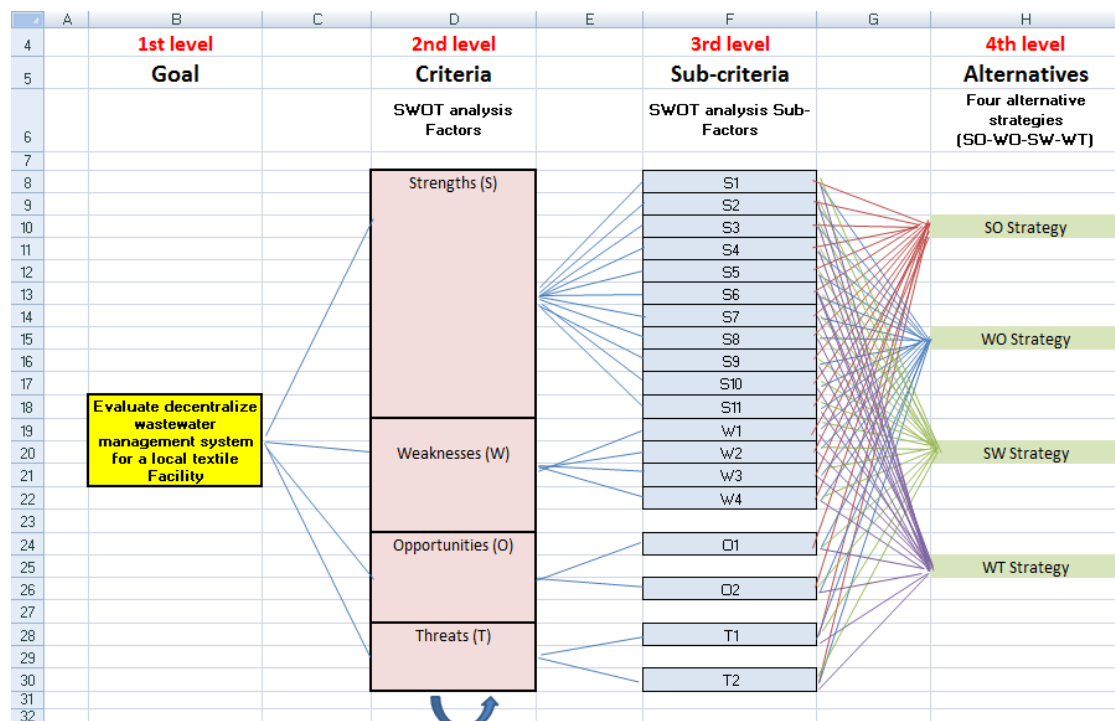


Figure (4-27)
ANP Model for SWOT for a Local Textile Facility

Step2: Assume that there is no dependence among the SWOT factors; the importance degrees of the SWOT factors was determined with a 1–9 scale. The comparison results are shown in Table(4-12). where, SWOT factors are compared considering every SWOT group. All pairwise comparisons are performed during the interview with management of textile facility.

Table (4-12) Pairwise Comparison of SWOT Factors

SWOT Factors	S	W	O	T
Strengths (S)	1	3	3	4
Weaknesses (W)	1/3	1	2	3
Opportunities (O)	1/3	1/2	1	4
Threats (T)	1/4	1/3	1/4	1
Total	1.917	4.833	6.250	12.000

SWOT Factors	Normalized Matrix				Row Average	Importance degrees of SWOT factors
	S	W	O	T		
Strengths (S)	0.522	0.621	0.480	0.333		0.489
Weaknesses (W)	0.174	0.207	0.320	0.250		0.238
Opportunities (O)	0.174	0.103	0.160	0.333		0.193
Threats (T)	0.130	0.069	0.040	0.083		0.081
	1.000	1.000	1.000	1.000		

CR=0.0794

The normalized matrix is calculated for by dividing each element by the sum of its column then the final relative weight equal to the average of each row.

$$w_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.489 \\ 0.238 \\ 0.193 \\ 0.081 \end{bmatrix}$$

It have been noticed that the strengths have 44.5% more importance priorities compare to threats which lowest priority .

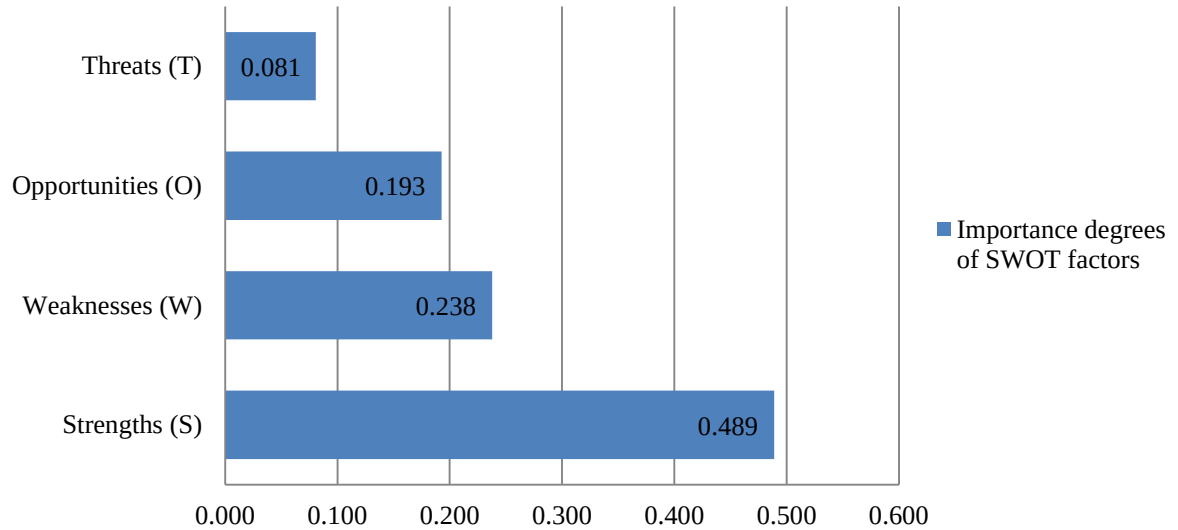


Figure (4-28)
Importance Degrees of SWOT Factors for a Local Textile Facility

The consistency ratio (CR) was used to verify the validity of the pairwise comparison matrices. The CR in the pairwise comparison matrices was calculated using the consistency index and the random index . The consistency index (CI) of a matrix of comparisons is given by the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad E(4-1)$$

where;

λ_{max} is the maximum eigenvalue

n is the size of matrix

The consistency ratio (CR) is obtained by the ratio of the CI and the random index (RI) which is a constant value given for n from 1 to 10 and the value of the CR calculated using ANP must be less than 0.10.

Microsoft Excel is used to compute the eigenvectors from the pairwise comparison matrices and to determine the consistency ratio, As an example it is given the RI index for 4X4 matrix is 0.9, therefore the CI calculated using the $E(4-1)$ will be 0.0714 and the consistency ratio equal 0.0794 (the ratio of 0.0714 over 0.9).

Given : Random Index (Saaty and Vargas, 1991)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

CI	RI
Consistency Index $CI = (\lambda_{\max} - n) / (n - 1)$	Random Index RI for n=4 matrix
0.0715	0.9
CR	
Consistency Ratio $CR = CI / RI$	
$CR = 0.0794 \leq 0.10$	

The consistency ratio (CR) is provided for all the pairwise comparison in the last row of the matrix.

Step 3: The existing dependency among the SWOT factors can be modeled through the ANP approach and find the inner dependences among sub factors .

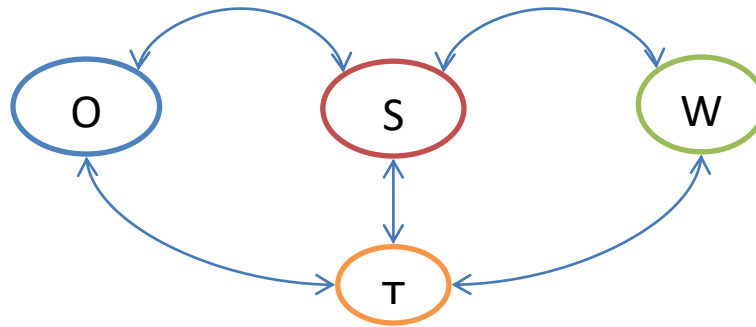


Figure (4-29)
Inner Dependency between SWOT Factors for a Local Textile Facility

As each factor of the SWOT is affected by other factors, therefore; it has been found that strengths factor is affected by W and O factors and threats Factor, Weakness factor is affected by S and T factors, Opportunity factor is affected S and T factors. The inner dependence matrix of each SWOT factor with respect to the other factors was determined, with a 1–9 scale. The relative importance for the inner dependence matrix of SWOT factors is generated as shown in tables from (4-13) to (4-16):

Table 4 Textile Facility Inner Dependence Metrics for SWOT Factors with Respect to "Strengths"

Strengths (S)	W	O	T	Relative importance weight
Weaknesses (W)	1	3	2	0.548
Opportunities (O)	0.333	1	1	0.211
Threats (T)	0.500	1	1	0.241
Total	1.833	5.000	4.000	

CR = 0.0158 ≤ 0.1

Table (4-14) Textile Facility Inner Dependence Metrics for SWOT Factors with Respect to "Weaknesses"

Weaknesses (W)	S	T	Relative importance weight
Strengths (S)	1	6	0.857
Threats (T)	0.167	1	0.143
Total	1.167	7.000	

CR = 0.000

Table 5 Textile Facility Inner Dependence Metrics for SWOT Factors with Respect to "Opportunities "

Opportunities (O)	S	T	Relative importance weight
Strengths (S)	1	9	0.900
Threats (T)	0.111	1	0.100
Total	1.111	10.000	
CR = 0.000			

Table 6 Textile Facility Inner Dependence Metrics for SWOT Factors with Respect to "Threats"

Threats(T)	S	W	O	Relative importance weight
Strengths (S)	1	1/3	1/2	0.156
Weaknesses (W)	3	1	4	0.620
Opportunities (O)	2	1/4	1	0.224
Total	6.000	1.583	5.500	
CR = 0.0942 ≤ 0.1				

$$W_2 = \begin{bmatrix} 1.000 & 0.857 & 0.900 & 0.156 \\ 0.548 & 1.000 & 0.000 & 0.620 \\ 0.211 & 1.000 & 1.000 & 0.224 \\ 0.241 & 0.143 & 0.100 & 1.000 \end{bmatrix}$$

Step 4: the interdependent priorities of the SWOT factors was determined using E (3-5):

$$w_{factors} = W_2 \times w_1 = \begin{bmatrix} 1.000 & 0.857 & 0.900 & 0.156 \\ 0.548 & 1.000 & 0.000 & 0.620 \\ 0.211 & 1.000 & 1.000 & 0.224 \\ 0.241 & 0.143 & 0.100 & 1.000 \end{bmatrix} \times \begin{bmatrix} 0.489 \\ 0.238 \\ 0.193 \\ 0.081 \end{bmatrix}$$

$$= \begin{bmatrix} 0.879 \\ 0.556 \\ 0.314 \\ 0.252 \end{bmatrix}$$

The priority values of factors S, W, O and T will change from 0.489 to 0.879, 0.238 to 0.556, 0.193 to 0.314, and 0.081 to 0.252 respectively.

Step 5: The local importance degrees of the SWOT sub-factors was determined with a 1–9 scale (i.e. calculate $w_{sub-factor(local)}$)

The pairwise comparison matrices are detailed in Appendix D. Priority vectors obtained by analyzing the pairwise comparison matrices provided in Appendix D are shown below.

$$w_{sub-factors(strengths)} = \begin{bmatrix} 0.104 \\ 0.156 \\ 0.074 \\ 0.153 \\ 0.042 \\ 0.031 \\ 0.031 \\ 0.036 \\ 0.268 \\ 0.059 \\ 0.045 \end{bmatrix}$$

$$w_{sub-factors(weaknessess)} = \begin{bmatrix} 0.115 \\ 0.441 \\ 0.268 \\ 0.176 \end{bmatrix}$$

$$w_{sub-factors(oppurtunities)} = \begin{bmatrix} 0.833 \\ 0.167 \end{bmatrix}$$

$$w_{sub-factors(threats)} = \begin{bmatrix} 0.750 \\ 0.250 \end{bmatrix}$$

Step 6: The overall priorities (global) importance degrees of the SWOT sub-factors (i.e. calculate $w_{sub-factor(global)}$) was determined using E (3-6)

$$w_{sub-factor(global)} = w_{factors} \times w_{sub-factor(local)}$$

$$W_{sub-factors(global)} = \begin{bmatrix} 0.879 \\ 0.556 \\ 0.314 \\ 0.252 \end{bmatrix} \times \begin{bmatrix} 0.104 \\ 0.156 \\ 0.074 \\ 0.153 \\ 0.042 \\ 0.031 \\ 0.031 \\ 0.036 \\ 0.268 \\ 0.059 \\ 0.045 \\ 0.115 \\ 0.441 \\ 0.268 \\ 0.176 \\ 0.833 \\ 0.167 \\ 0.750 \\ 0.250 \end{bmatrix} = \begin{bmatrix} 0.095 \\ 0.142 \\ 0.068 \\ 0.139 \\ 0.038 \\ 0.028 \\ 0.028 \\ 0.033 \\ 0.244 \\ 0.054 \\ 0.041 \\ 0.066 \\ 0.255 \\ 0.155 \\ 0.101 \\ 0.241 \\ 0.048 \\ 0.168 \\ 0.056 \end{bmatrix}$$

Step 7: The importance degrees of the alternative strategies was determined with respect to each SWOT sub-factor with a 1–9 scale, the details of the pairwise comparison are provided in appendix E.

$$= \begin{bmatrix} 0.657 & 0.176 & 0.556 & 0.629 & 0.422 & 0.450 & 0.248 & 0.566 & 0.217 & 0.129 & 0.178 & 0.102 & 0.129 & 0.581 & 0.239 & 0.136 & 0.105 & 0.234 & 0.194 \\ 0.069 & 0.061 & 0.178 & 0.059 & 0.085 & 0.142 & 0.070 & 0.134 & 0.061 & 0.067 & 0.059 & 0.744 & 0.186 & 0.068 & 0.050 & 0.066 & 0.735 & 0.076 & 0.060 \\ 0.046 & 0.675 & 0.205 & 0.256 & 0.335 & 0.197 & 0.542 & 0.225 & 0.664 & 0.596 & 0.596 & 0.072 & 0.073 & 0.101 & 0.641 & 0.729 & 0.076 & 0.640 & 0.058 \\ 0.229 & 0.089 & 0.062 & 0.056 & 0.159 & 0.211 & 0.139 & 0.075 & 0.058 & 0.207 & 0.157 & 0.083 & 0.613 & 0.251 & 0.071 & 0.069 & 0.084 & 0.050 & 0.688 \end{bmatrix}$$

Table (4-17) Textile Facility Overall Priority Scores of SWOT Factors with ANP

SWOT analysis Factors	Priority of the factors	SWOT analysis Sub-Factors	Priority of the sub-factors	Overall priority of the sub-factors w sub-factors (global) = w factors x w sub-factors (local)
Strengths (S)	0.879	S1	0.104	0.095
		S2	0.156	0.142
		S3	0.074	0.068
		S4	0.153	0.139
		S5	0.042	0.038
		S6	0.031	0.028
		S7	0.031	0.028
		S8	0.036	0.033
		S9	0.268	0.244
		S10	0.059	0.054
		S11	0.045	0.041
Weaknesses (W)	0.556	W1	0.115	0.066
		W2	0.441	0.255
		W3	0.268	0.155
		W4	0.176	0.101
Opportunities (O)	0.314	O1	0.833	0.241
		O2	0.167	0.048
Threats (T)	0.252	T1	0.750	0.168
		T2	0.250	0.056

Step 8: Finally, the overall priorities of the alternative strategies was determined using E(3-7), which reflects the interrelationships within the SWOT factors .

$$W_{\text{alternatives}} = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = W_4 \times W_{\text{sub-factor(global)}} = \begin{bmatrix} 0.575 \\ 0.249 \\ 0.804 \\ 0.372 \end{bmatrix}$$

The ANP analysis result indicate that reusing 100% of the treated wastewater on the production process to reduce the water consumption is the best strategy (ST) with highest priority value of 0.804, the alternative strategies are ordered as ST-SO-WT-WO.

4.1.5 Application of SWOT analysis for Tubli sewage treatment plant (STP)

The whole method was repeated again for centralized wastewater management system where Tubli sewage treatment plant (STP) was chosen to represent this category.

An in-depth analysis was performed to the internal and external environment to find out the most important strategic sub-factors (strengths, weaknesses, opportunities and threats) which have very significant effects on Tubli sewage treatment plant (STP) management, SWOT sub-factors are listed in table (4-18).

Table 7 SWOT Matrix for Tubli (STP)

Strengths (S)	Weaknesses (W)
S1: Considered to be the largest sewage treatment plant in the kingdom of Bahrain, its connecting the majority of the population to a water network. S2: Good involvement with other related authorities to ensure water resources conservation and better wastewater management . S3:Competent laboratories to analysis WW	W1: Negligible amount of wastewater reused. W2: Poor culture in efficient treated wastewater use in agriculture W3: High maintenance cost W4: Tubli STP working now above capacity of the plant W5: Tubli STP produces fifty tonnes of thermally dried sludge per day which is transferred to landfill, while the existing landfill has only three years capacity.
Opportunities (O)	Threats (T)
O1: Create and Implement new appropriate legislative framework for proper wastewater management O2: Gain the public acceptance and interest for sustainable wastewater management O3: Improved the mechanism of solid waste (sludge) disposal	T1: Increased water demand due to rising temperatures during summer T2: Increasing population served by Tubli sewage Treatment plants. T3: low investment in wastewater infrastructure (STP, network,...etc) due to the limited financial funds

The SWOT matrix and alternative strategies are developed to identify the best alternatives which can be used by Tubli STP to enhance wastewater management system

Table 8 TOWS matrix and alternative strategies for Tubli (STP)

External Factors	Internal Factors	
	Strengths (S)	Weaknesses (W)
	S1: Considered to be the largest sewage treatment plant in the kingdom of Bahrain, its connecting the majority of the population to a water network. S2: Good involvement with other related authorities to ensure water resources conservation and better wastewater management . S3:Competent laboratories to analysis WW	W1: Negligible amount of wastewater reused. W2: Poor culture in efficient treated wastewater use in agriculture W3: High maintenance cost W4: Tubli STP working now above capacity of the plant. W5: Tubli STP produces fifty tonnes of thermally dried sludge per day which is transferred to landfill, while the existing landfill has only three years capacity.
Opportunities (O)	SO Strategies	WO Strategies
O1: Create and Implement new appropriate legislative framework for proper wastewater management O2: Gain the public acceptance and interest for sustainable wastewater management O3: Improved the mechanism of solid waste (sludge) disposal	Corporate with environment authority to amendment of laws and regulations and to set new measures for the wastewater effluent (O1,S2)	Investigate alternative sludge disposal mechanism by building an incinerator to convert the sludge to ash. (O3,W5)
Threats (T)	ST Strategies	WT Strategies
T1: Increased water demand due to rising temperatures during summer T2: Increasing population served by Tubli sewage Treatment plants. T3: low investment in wastewater infrastructure (STP, network ,...etc) due to the limited financial funds	Upgrading of wastewater treatment plants in order to improve the quality and quantity of the effluents and full legislation limit for the disposal in Tubli bay (T1,T2,S1)	Conduct researches to reduce water consumption and its price (T1,T2,W4)

It can be seen from Table(4-19) that the Tubli has four alternative strategies where the SO Strategies show that Tubli should be more corporative with environment authority and try to help amend the existing laws and regulations and to set new measures for the wastewater effluent (O1,S2) . The WO strategy seeks to gain benefit from the opportunities available and investigate to find an alternative mechanism to disposal of the generated sludge (O3,W5). ST strategy used the strengths to remove or reduce the effects of threats that face Tubli management. Therefore it has been suggested wastewater treatment plants need to be upgraded in order to improve the quality and quantity of the effluents discharged to Tubli bay (T1,T2,S1). The last strategy, involved conducting an intensive researches to reduce the water consumed by population which Tubli STP served (T1,T2,W4).

By using the previous VRIO framework (Value, Rareness, Imitability, & Organization) explained earlier to scan the internal and external environment and to assess the importance of each of the factors that might affect the Tubli STP (Wheelen & Hunger, 2012) , as shown in table(4-16). We noticed that Tubli STP the negligible amount of wastewater reused and working above capacity of the plant have the highest weight score of 1.25 and 0.95 respectively within listed weaknesses. while the O1 and O3 scored the highest weight, which indicate that for the external factors, creating and implementing a new appropriate legislative framework and improving the mechanism of solid waste (sludge) disposal are a good opportunities for proper wastewater management.

Table (4-20) Internal Strategic Factors for Tubli (STP)

Strengths (S)	Weight	Rating	Weighted Score
S1: Considered to be the largest sewage treatment plant in the kingdom of Bahrain, its connecting the majority of the population to a water network.	0.15	3	0.45
S2: Good involvement with other related authorities to ensure water resources conservation and better wastewater management	0.15	4	0.6
S3: Competent laboratories to analysis WW	0.02	2	0.04
Weaknesses (W)	Weight	Rating	Weighted Score
W1: Negligible amount of wastewater reused.	0.25	4.5	1.125
W2: Poor culture in efficient treated wastewater use in agriculture	0.04	4	0.16
W3: High maintenance cost	0.05	5	0.25
W4: Tubli STP working now above capacity of the plant.	0.19	5	0.95
W5: Tubli STP produces fifty tonnes of thermally dried sludge per day which is transferred to landfill, while the existing landfill has only three years capacity.	0.15	5	0.75
Total of Internal Strategic factors	1		3.2

Table (4-21) External Strategic Factors for Tubli (STP)

Opportunities (O)	Weight	Rating	Weighted Score
O1: Create and Implement new appropriate legislative framework for proper wastewater management	0.25	5	1.25
O2: Gain the public acceptance and interest for sustainable wastewater management	0.15	3	0.45
O3: Improved the mechanism of solid waste (sludge) disposal	0.3	5	1.5
Threats (T)	Weight	Rating	Weighted Score
T1: Increased water demand due to rising temperatures during summer	0.15	3	0.45
T2: Increasing population served by Tubli sewage Treatment plants.	0.15	3	0.45
T3: low investment in wastewater infrastructure (STP, network ,...etc) due to the limited financial funds	0.15	4	0.6
Total External Strategic factors	1		4.1

If we compared the total weighted scores for the decentralize wastewater management calculated earlier are (4.02 and 4.45) ,we will notice that they are higher than the total weighted scores calculated for the centralized wastewater management (3.2 and 4.1). This will give us clue that decentralized system are more preferable over centralized management system.

4.1.6 Analytic Network Process Results for Tubli sewage treatment plant (STP)

Step1: SWOT sub-factors was identified and the alternative strategies was determined according to SWOT sub-factors. The schematic structure established is shown in Figure(4-27).

where;

Goal: Evaluate centralized wastewater management system for centralized wastewater management system

Criteria: SWOT analysis Factors

Sub-criteria: SWOT analysis Sub- Factors

Alternatives: Four alternative strategies (SO-WO-SW-WT)

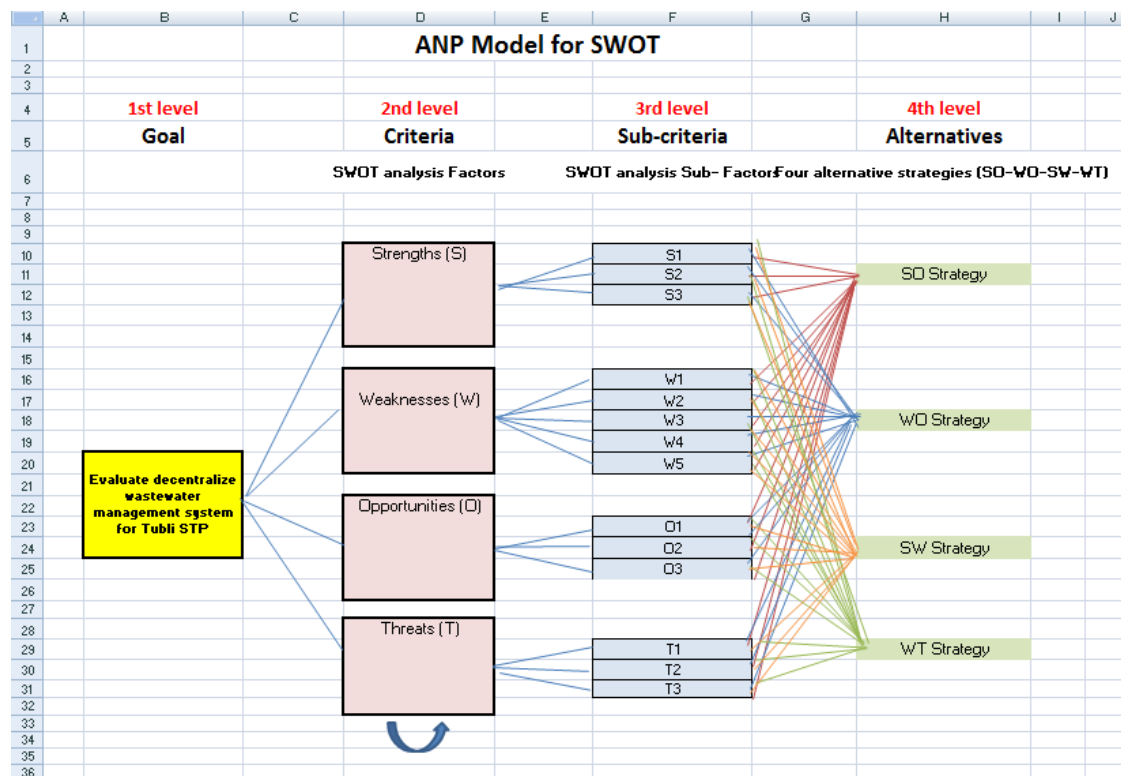


Figure (4-29)
ANP Model for SWOT for Tubli STP

Step2: Assume that there is no dependence among the SWOT factors; the importance degrees of the SWOT factors was determined with a 1–9 scale. The comparison results for Tubli STP are shown in Table(4-21). where, SWOT factors are compared considering every SWOT group. All pairwise comparisons in the application are performed by interview with management of Tubli STP.

Table (4-22) Pairwise Comparison of SWOT Factors for Tubli STP

SWOT Factors	S	W	O	T	Importance degrees of SWOT factors
Strengths (S)	1	1/6	1/3	1/2	0.075
Weaknesses (W)	6	1	3	6	0.569
Opportunities (O)	3	1/3	1	4	0.254
Threats (T)	2	1/6	1/4	1	0.102
Total	12.000	1.667	4.583	11.500	

CR=0.0501

where the weaknesses priorities found to be more important (57%) compared with strengths, opportunities and threats

The eigenvector was obtained E(3-4);

$$w_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.075 \\ 0.569 \\ 0.254 \\ 0.102 \end{bmatrix}$$

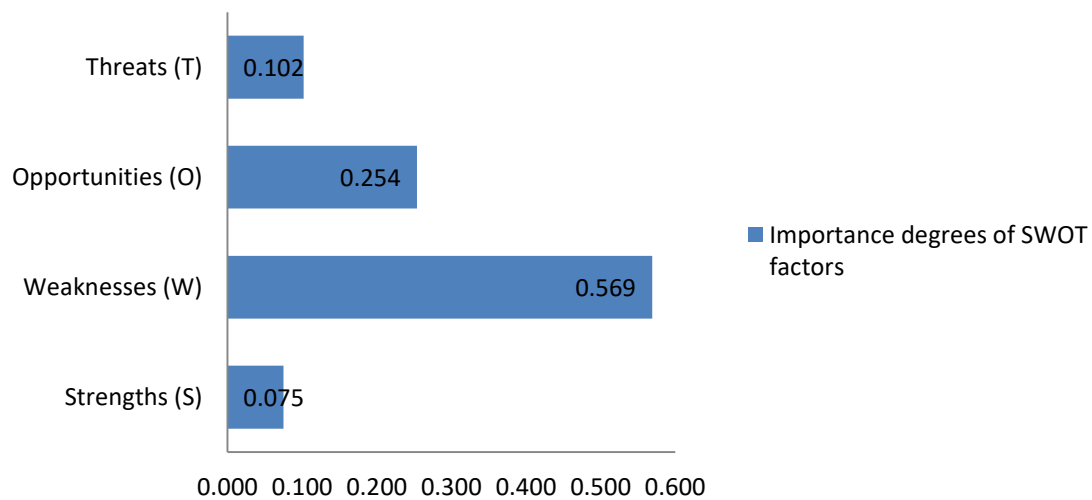


Figure (4-30)
Importance Degrees of SWOT Factors applied for Tubli STP

Step 3: The inner dependence matrix of each SWOT factor with respect to the other factors was determined. The calculated relative importance for the inner dependence matrix of SWOT factors is generated as shown in tables from (4-23) to (4-26):

Table (4-23) Tubli STP Inner dependence matrix for SWOT factors with respect to "Strengths"

Strengths (S)	W	O	T	Relative importance weight
Weaknesses (W)	1	8	7	0.765
Opportunities (O)	1/8	1	1/3	0.074
Threats (T)	1/7	3	1	0.161
Total	1.268	12.000	8.333	

CR= 0.0925

Table(4-24) Tubli STP Inner dependence matrix for SWOT factors with respect to "Weaknesses"

Weaknesses (W)	S	O	T	Relative importance weight
Strengths (S)	1	1/5	1/3	0.104
Opportunities (O)	5	1	4	0.665
Threats (T)	3	1/4	1	0.231
Total	9.000	1.450	5.333	

CR= 0.0749

Table (4-25) Tubli STP Inner dependence matrices for SWOT factors with respect to "Opportunities"

Opportunities (O)	S	W	Relative importance weight
Strengths (S)	1.000	0.125	0.111
Weaknesses (W)	8.000	1.000	0.889
Total	9.000	1.125	

CR= 0.000

Table (4-26) Tubli STP Inner dependence matrices for SWOT factors with respect to "Threats"

Threats (T)	S	W	Relative importance weight
Strengths (S)	1	1/3	0.250
Weaknesses (W)	3	1	0.750
Total	4.000	1.333	

CR= 0.000

The existing dependency among the SWOT factors that affect Tubli STP can be modeled through the ANP approach and find the inner dependences among sub factors.

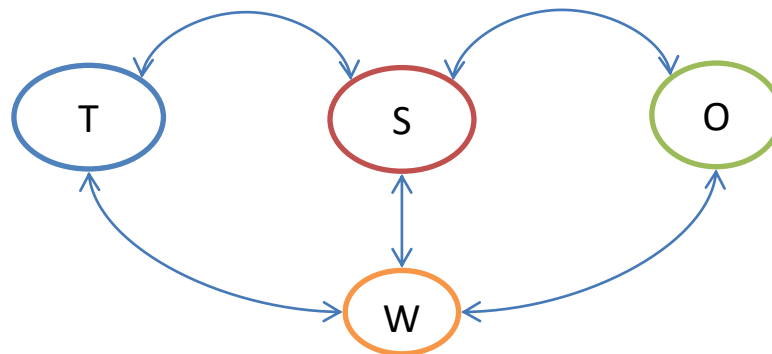


Figure (4-31)
Inner dependency between SWOT Factors for Tubli STP

Each factor of the SWOT are affected by each other, so that; S factor is affected by W, O and T Factor; W factor is affected by S, T and O factor. on the other hand the opportunity factor is affected by only two factors , the strength and the weaknesses.

$$W_2 = \begin{bmatrix} 1.000 & 0.104 & 0.111 & 0.250 \\ 0.765 & 1.000 & 0.889 & 0.750 \\ 0.074 & 0.665 & 1.000 & 0.000 \\ 0.161 & 0.231 & 0.000 & 1.000 \end{bmatrix}$$

Step 4: the interdependent priorities of the SWOT factors was determined using E(3-5):

$$\begin{aligned} w_{factors} = W_2 \times w_1 &= \begin{bmatrix} 1.000 & 0.104 & 0.111 & 0.250 \\ 0.765 & 1.000 & 0.889 & 0.750 \\ 0.074 & 0.665 & 1.000 & 0.000 \\ 0.161 & 0.231 & 0.000 & 1.000 \end{bmatrix} \times \begin{bmatrix} 0.075 \\ 0.569 \\ 0.254 \\ 0.102 \end{bmatrix} \\ &= \begin{bmatrix} 0.188 \\ 0.929 \\ 0.638 \\ 0.246 \end{bmatrix} \end{aligned}$$

The priority values of factors S, W, O and T will change to 0.188, 0.929 ,0.638 and 0.246 respectively.

Step 5: the local importance degrees of the SWOT sub-factors was determined with a 1–9 scale (i.e. calculating $w_{sub-factor(local)}$)

The pairwise comparison matrices are detailed in Appendix F. Priority vectors obtained by analyzing the pairwise comparison matrices provided are summarized below.

$$w_{sub-factors(strengths)} = \begin{bmatrix} 0.512 \\ 0.360 \\ 0.128 \end{bmatrix}$$

$$w_{sub-factors(weaknessess)} = \begin{bmatrix} 0.229 \\ 0.039 \\ 0.122 \\ 0.531 \\ 0.079 \end{bmatrix}$$

$$w_{sub-factors(oppurtunities)} = \begin{bmatrix} 0.571 \\ 0.066 \\ 0.363 \end{bmatrix}$$

$$w_{sub-factors(threats)} = \begin{bmatrix} 0.072 \\ 0.146 \\ 0.782 \end{bmatrix}$$

Step 6: the overall priorities (global) importance degrees of the SWOT sub-factors was determined using E (3-6) (i.e. calculating $w_{sub-factor(global)}$)

$$w_{sub-factor(global)} = w_{factors} \times w_{sub-factor(local)}$$

$$w_{sub-factors(global)} = \begin{bmatrix} 0.188 \\ 0.929 \\ 0.638 \\ 0.246 \end{bmatrix} \times \begin{bmatrix} 0.512 \\ 0.360 \\ 0.128 \\ 0.229 \\ 0.039 \\ 0.122 \\ 0.531 \\ 0.079 \\ 0.571 \\ 0.066 \\ 0.363 \\ 0.072 \\ 0.146 \\ 0.782 \end{bmatrix} = \begin{bmatrix} 0.096 \\ 0.068 \\ 0.024 \\ 0.212 \\ 0.036 \\ 0.113 \\ 0.493 \\ 0.074 \\ 0.364 \\ 0.042 \\ 0.232 \\ 0.018 \\ 0.036 \\ 0.192 \end{bmatrix}$$

Table (4-27) Overall Priority Scores of SWOT Factors for Tubli STP using ANP

SWOT Factors	Priority of the factors	SWOT Sub-factor	Priority of sub-factors	Overall priority of the sub-factors
Strengths	0.188	S1	0.512	0.096
		S2	0.360	0.068
		S3	0.128	0.024
Weaknesses	0.929	W1	0.229	0.212
		W2	0.039	0.036
		W3	0.122	0.113
		W4	0.531	0.493
		W5	0.079	0.074
Opportunities	0.638	O1	0.571	0.364
		O2	0.066	0.042
		O3	0.363	0.232
Threats	0.246	T1	0.072	0.018
		T2	0.146	0.036
		T3	0.782	0.192

Step 7: The importance degrees of the alternative strategies was determined with respect to each SWOT sub-factor with a 1–9 scale, the details of the pairwise comparison are provided in appendix G.

$$= \begin{matrix} & & & & & & W_4 & & & & & & & & \\ \begin{matrix} \\ \\ \\ \end{matrix} & \begin{bmatrix} 0.537 & 0.644 & 0.232 & 0.153 & 0.162 & 0.100 & 0.065 & 0.083 & 0.684 & 0.102 & 0.070 & 0.057 & 0.075 & 0.079 \\ 0.068 & 0.058 & 0.079 & 0.141 & 0.080 & 0.105 & 0.060 & 0.670 & 0.072 & 0.129 & 0.633 & 0.056 & 0.063 & 0.088 \\ 0.348 & 0.203 & 0.590 & 0.577 & 0.111 & 0.097 & 0.531 & 0.193 & 0.168 & 0.488 & 0.228 & 0.362 & 0.680 & 0.206 \\ 0.048 & 0.096 & 0.099 & 0.129 & 0.647 & 0.698 & 0.344 & 0.054 & 0.076 & 0.282 & 0.068 & 0.525 & 0.182 & 0.627 \end{bmatrix} \end{matrix}$$

Step 8: Finally, the overall priorities of the alternative strategies was determined using E(3-7), which reflects the interrelationships within the SWOT factors

$$W_{\text{alternatives}} = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = W_4 \times W_{\text{sub-factor(global)}} = \begin{bmatrix} 0.477 \\ 0.335 \\ 0.680 \\ 0.509 \end{bmatrix}$$

The ANP analysis result indicate that the (ST) is best strategy with highest priority value of 0.680, the alternative strategies are ordered as ST-WT - SO -WO.

4.2 Discussion and Conclusions

Wastewater management legislations need to be reviewed and updated through an active participation of all related stakeholders (local government, NGOs and the community) to set and implement new well defined measures in the wastewater legislation and to ensure better enforcement of this legislations.

The questionnaire was used to collect data to evaluate wastewater management systems strengths, weaknesses, opportunities and threats identified and used to develop several alternative strategies that enhance wastewater management system and to raise the amount of treated wastewater reused. One or more of (SO -WO -ST -WT) strategies can be used combined or separate to enhance and improve the current wastewater management.

SWOT tool was used in this research, to evaluate internal (strengths and weaknesses) and external (opportunities and threats) SWOT factors for both decentralized and centralized wastewater management system applied by the textile facility and Tubli STP. SWOT sub-factors were identified and the alternative strategies (SO-WO-SW-WT) were determined according to SWOT sub-factors. Since SWOT possesses deficiencies in the measurement and evaluation steps, the Analytical Network Process (ANP) approach was used to measure the dependency among strategic factors and sub-factors that will reflect both the weight and change of the strategic priorities.

A network model of four levels was used, where the first level indicates the goal (best strategy), the criteria (SWOT factors) and sub- criteria (SWOT sub-factors) are found in the second and third levels respectively, and the last level is for alternatives (alternative strategies).

For the textile facility the alternative strategies identified as SO involves making good use of opportunities by using the existing strengths by taking advantage of the top management cooperation to improve the wastewater treatment unit. While the WO strategy seeks to gain benefit from the available opportunities and contract with a specialized company to study the feasibility of building sludge treatment unit that will help the facility to deal with amount of suspended solid generated during the wastewater treatment. Similarly, ST is the strategy associated with using the facility's strengths to remove or reduce the effects of threats. Therefore it has been suggested to reuse all the treated wastewater on the production process to reduce the water consumed by providing a new source of water . The fourth and last strategy is WT, which involved enhancing the relation with the related wastewater authorities such as Bahrain's Supreme Council for the Environment (SCE) and Ministry of Work (MoW) to study the wastewater effluent characteristic and set the best environmental measures.

The ANP analysis for the local textile facility indicated that reusing 100% of the treated wastewater on the production process is the best strategy (ST) to reduce the water consumption with highest priority value of 0.804, the alternative strategies are ordered from highest value to lowest as follows ST-SO-WT-WO (0.804, 0.575, 0.372 and 0.249)

The Textile facility should take advantage of top management cooperation and convince them on the importance of wastewater treatment and its benefit to overcome limited economic and financial funds. The reuse of all the treated wastewater on the production process will be the best strategy the facility can use to improve their management and to reduce their water consumption .

The same mechanism was repeated again for a centralized wastewater management system (Tubli STP) where four alternative strategies were identified, the SO Strategy showed that Tubli should be more corporative with environment authority and try to help amend the existing laws and regulations and to set new measures for the wastewater effluent. The WO strategy seeks to gain benefit from the opportunities available and investigate to find an alternative mechanism to disposal of the generated sludge. ST strategy used the strengths to remove or reduce the effects of threats that face Tubli management. Therefore it has been suggested that the wastewater treatment plants need to be upgraded in order to improve the quality and quantity of the effluents discharged to Tubli bay .The last strategy, involved conducting an intensive researches to reduce the water consumed by population which Tubli STP served. The ANP analysis for Tubli STP indicate that the (ST) is the best strategy with highest priority value, the alternative strategies were ordered as ST-WT- SO -WO with the following values 0.680, 0.509 , 0.335 and 0.477 respectively. It was found that, Tubli needs to upgrade its wastewater treatment plants in order to improve the quality and quantity of the effluents and full legislation limit for the disposal in Tubli bay . Based on this research, it can be concluded that for both the centralized and decentralized management system which were evaluated, ST is the best alternative strategy that should be used to improve the existing management system through using the facility's strengths to remove or reduce the effects of threats.

CHAPTER 5

Research Recommendations

Chapter 5

Recommendations

The recommendations that should be taken for safe and sustainable wastewater management in the Kingdom of Bahrain are as follows:

First, the existing standards for treated wastewater discharges to environment should be reviewed and this review process should be conducted through consultation with all governmental and industrial stakeholders, to find out realistic standards and regulations and promote appropriate monitoring and evaluation mechanisms that minimize wastewater risks to public health and the environment.

Second, Bahraini industrial companies should be encouraged to reduce the environmental pollution caused by its industrial activities and use the best technologies to treat the wastewater. In addition to that, medium and small factories should be engaged in awareness programs and activities that contribute to the protection the environment.

Third, There are lack of monitoring programs covering the areas which have mixtures of multiple non-residential wastewater discharging in the governmental STP network like Sitra STP, therefore the responsibilities should be distributed properly between the related wastewater management authorities in Bahrain to have an effective monitoring system and to prevent illegal discharge to environment.

Fourth, The industrial companies should explore, adapt and adopt efficient and appropriate technologies to reuse treated effluent, ensure environmental sustainability, suitable to the local conditions, and affordability.

Fifth, since only 10% of the treated wastewater is reused and landfill is the only way used to dispose the sludge with no plans to reuse it, therefore plans should be set to increase the amount of wastewater reuse in agriculture and utilize the treated sludge in construction work as cement ingredient or in agriculture as fertilizers.

Sixth, the responsibilities of the various organizations involved in wastewater collection, treatment and reuse must be considered and reconciled to achieve general acceptance of wastewater re-use. public awareness should be enhanced, participation and dissemination of best practices encourage demand-driven planning of water reuse. It is of fundamental important to have active public involvement in the planning phase until the full implementation process.

Based on this research, the centralized and decentralized management systems were evaluated individually using SWOT analysis with ANP , both systems are effective in achieving the quality measures of treated wastewater discharged to the environment. with respect to the cost needed to maintain or upgrade the system, centralized management system will need more financial funds to be continuously maintained compared to decentralized.

Decentralized wastewater system, is more preferable to treat the wastewater close to where it is generated.

Generally there are some factors that limited the findings of this research, the most critical one is the lack of suitable and reliable resources. The relevant governmental authorities don't have reliable list of the industrial companies which have an in-house wastewater treatment.

Many facilities are discharging industrial wastewater directly to the environment or on the municipal sewage without previous permit, which had a negative impact on my research and effect the exact amount of wastewater produce in the Kingdom and the amount treated.

In this research, the focus was on Bahrain's Supreme Council for the Environment (SCE) legislations. In future a further research could be done to harmonize them with other related legislations implemented by other authorities like Ministry of work .

Using SWOT analysis supported with AND is very useful evaluation tool which is recommended for both the centralized and decentralized management system to find the best alternative strategy to improve their existing management system.

Since ANP method is subjected to human judgment each time, it will have different evaluation for the factors. Therefore, more future research should be used to improve ANP the and make it more effective to analyze the factors.

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APPENDICES

Appendix A	Supported Information
Appendix B	Wastewater Management Questionnaire
Appendix C	Tables related to waste water generated from Textile Industry
Appendix D	Pairwise comparison metrics for SWOT sub-factors local priorities applied for local textile Facility
Appendix E	Alternative Strategies Priorities based on SWOT sub-Factors Applied for Local Textile Facility
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Appendix G	Alternative Strategies Priorities based on SWOT sub-Factors Applied for Tubli STP

Appendix A

Supported Information

Table A-1: Bahrain Fact sheet generated from FAO

LAND AND POPULATION	Year	Value	Unit
Area			
Country total area	2013	77	1000 ha
Cultivated area (arable land + permanent crops)	2013	4.6	1000 ha
Population			
Total population	2015	1377	1000
Population density	2015	1788	inhab/km ²
Rural population	2015	170	1000
Economically active population in agriculture	2014	3	1000
As % of total economically active population	2014	0.4525	%
RENEWABLE WATER RESOURCES (RWR)	Year	Value	Unit
Long-term average annual precipitation			
Depth		83	mm/year
Volume		0.0639	km ³ /year
Long-term average annual RWR			
Internal (IRWR)		0.004	km ³ /year
External (ERWR)		0.112	km ³ /year
Total Actual (TRWR)		0.116	km ³ /year
Dependency ratio		96.55	%
TRWR per capita	2014	84.24	m ³ /year
Total dam capacity	1995	0	km ³
WATER WITHDRAWAL	Year	Value	Unit
By sector			
Agricultural	2003	0.1592	km ³
Municipal	2003	0.1779	km ³
Industrial	2003	0.0203	km ³
Total	2003	0.3574	km ³
Total water withdrawal per capita	2003	348	m ³
By source			
Surface water withdrawal	2003	0	km ³
Groundwater withdrawal	2003	0.2387	km ³
Total freshwater withdrawal	2003	0.2387	km ³
Desalinated water produced	2003	0.1024	km ³
Direct use of treated municipal wastewater	2012	0.016	km ³
Direct use of agricultural drainage water		-	km ³
Pressure on water resources			
Total freshwater withdrawal as % of TRWR	2003	205.8	%
Agricultural water withdrawal as % of TRWR	2003	137.2	%

IRRIGATION AREAS	Year	Value	Unit
Area equipped for irrigation			
Full control irrigation	2000	4.015	1000 ha
- surface irrigation	2000	3.39	1000 ha
- sprinkler irrigation	2000	0.16	1000 ha
- localized irrigation	2000	0.465	1000 ha
Equipped lowland areas		-	1000 ha
Spate irrigation		-	1000 ha
Total area equipped for irrigation	2001	4.06	1000 ha
As % of cultivated area	2001	78.08	%
Area actually irrigated	2001	4.06	1000 ha
As % of area equipped for irrigation	2001	100	%

Source: FAO AQUASTAT Database, 2016

Table A-2: EPA's Priority(Toxic) Pollutant List

1. Antimony	43. Trichloroethylene	87. Fluorene
2. Arsenic	44. Vinyl chloride	88. Hexachlorobenzene
3. Beryllium	45. 2-Chlorophenol	89. Hexachlorobutadiene
4. Cadmium	46. 2,4-Dichlorophenol	90. Hexachlorocyclopentadiene
5a. Chromium (III)	47. 2,4-Dimethylphenol	91. Hexachloroethane
5b. Chromium (VI)	48. 2-Methyl-4-chlorophenol	92. Indeno(1,2,3-cd)pyrene
6. Copper	49. 2,4-Dinitrophenol	93. Isophorone
7. Lead	50. 2-Nitrophenol	94. Naphthalene
8. Mercury	51. 4-Nitrophenol	95. Nitrobenzene
9. Nickel	52. 3-Methyl-4-chlorophenol	96. N-Nitrosodimethylamine
10. Selenium	53. Pentachlorophenol	97. N-Nitrosodi-n-propylamine
11. Silver	54. Phenol	98. N-Nitrosodiphenylamine
12. Thallium	55. 2,4,6-Trichlorophenol	99. Phenanthrene
13. Zinc	56. Acenaphthene	100. Pyrene
14. Cyanide	57. Acenaphthylene	101. 1,2,4-Trichlorobenzene
15. Asbestos	58. Anthracene	102. Aldrin
16. 2,3,7,8-TCDD (Dioxin)	59. Benzidine	103. alpha-BHC
17. Acrolein	60. Benzo(a)anthracene	104. beta-BHC
18. Acrylonitrile	61. Benzo(a)pyrene	105. gamma-BHC
19. Benzene	62. Benzo(a)fluoranthene	106. delta-BHC
20. Bromoform	63. Benzo(ghi)perylene	107. Chlordane
21. Carbon tetrachloride	64. Benzo(k)fluoranthene	108. 4,4'-DDT
22. Chlorobenzene	65. bis(2-Chloroethoxy)methane	109. 4,4'-DDE
23. Chlorodibromomethane	67. bis(2-Chloroisopropyl)ether	110. 4,4'-DDD
24. Chloroethane	68. bis(2-Ethylhexyl)phthalate	111. Dieldrin
25. 2-Chloroethylvinyl ether	69. 4-Bromophenyl phenyl ether	112. alpha-Endosulfan
26. Chloroform	70. Butylbenzyl phthalate	113. beta-Endosulfan
27. Dichlorobromomethane	71. 2-Chloronaphthalene	114. Endosulfan sulfate
28. 1,1-Dichloroethane	72. 4-Chlorophenyl phenyl ether	115. Endrin
29. 1,2-Dichloroethane	73. Chrysene	116. Endrin aldehyde
30. 1,1-Dichloroethylene	74. Dibenzo(a,h)anthracene	117. Heptachlor
31. 1,2-Dichloropropane	75. 1,2-Dichlorobenzene	118. Heptachlor epoxide
32. 1,3-Dichloropropylene	76. 1,3-Dichlorobenzene	119. PCB-1242
33. Ethylbenzene	77. 1,4-Dichlorobenzene	120. PCB-1254
34. Methyl bromide	78. 3,3-Dichlorobenzidine	121. PCB-1221
35. Methyl chloride	79. Diethyl phthalate	122. PCB-1232
36. Methylene chloride	80. Dimethyl phthalate	123. PCB-1248
37. 1,2,2,2-Tetrachloroethane	81. Di-n-butyl phthalate	124. PCB-1260
38. Tetrachloroethylene	82. 2,4-Dinitrotoluene	125. PCB-1016
39. Toluene	83. 2,6-Dinitrotoluene	126. Toxaphene
40. 1,2-trans-dichloroethylene	84. Di-n-octyl phthalate	
41. 1,1,1-Trichloroethane	85. 1,2-Diphenylhydrazine	
42. 2,4 Dichlorophenol	86. Fluoranthene	

Source: Code of Federal Regulations, 40 CFR 131.36, July 1, 1993.

Appendix B

Wastewater Management Questionnaire

The objective of this Questionnaire is:

- To evaluate both the wastewater management systems practiced in Kingdom of Bahrain and the enforcement of the national wastewater management regulations.
- To analyze the data in order to develop and promote the future wastewater management at the strategic level.

General Information

Facility Name:	Contact Name (Optional):
Facility Address:	Contact Number (Optional):
Facility Type:	
Check your facility category or business activity:	
☐ Textile industry, apparel and leather	☐ Basic Metal Industries
☐ Paper, paper products, printing & publishing	☐ Industry and non-metallic products, except petroleum products
☐ Chemical industry, chemical products, petroleum products, coal, rubber and plastic	☐ Manufacture of metal products, machinery & equipment
☐ Food industry, beverages and tobacco	☐ Other.....
☐ Timber industry and wood products	☐

Part (A): Product /Service Information

A-1) Briefly describe the operations, processes and services performed and the products produced at your facility:

A-2) List basic materials used in the operation at your facility:

Part (B): Water/Wastewater Information

B-1) List water sources and approximate range of water usage:

- | | | |
|--|--------------|------------------------|
| - Electricity & Water Authority source | to..... | m ³ per day |
| - Private source: | | |
| Desalinated water | to..... | m ³ per day |
| - Other (specify)..... | to..... | m ³ per day |

B-2) List the approximate range of water consumption leaving your facility

- | | | |
|----------------------------|--------------|------------------------|
| - Sanitary sewer | to..... | m ³ per day |
| - Contained in the product | to..... | m ³ per day |
| - Storm drain | to..... | m ³ per day |
| - Waste and sludge | to..... | m ³ per day |
| - Other (specify)..... | to..... | m ³ per day |

B-3) Does your facility generate wastewater ☐ Yes ☐ No

B-4) Does your facility treat wastewater in-house ☐ Yes ☐ No

B-5) How much the approximate range of wastewater generated that will be discharged into the main sewage network to..... m³ per day

B-6) How much the volume of wastewater treated to..... m³ per day

B-7) Type of wastewater treated

☐ Domestic (restrooms, employee showers, etc.)

☐ Industrial (cooling water, process ,etc)

☐ Both

B-8) How many stages of treatment does your facility use:

☐ Primary

☐ Secondary

☐ Tertiary

☐ Advanced Tertiary

☐ Other

B-9) Indicate type of processes that will be used for treating wastewater or sludge (check all that apply) :

Types of treatments to select from

Primary Treatment Processes	Secondary Treatment Processes	Advanced Treatment Processes	Advanced Treatment Processes
Bar or bow screen Grit removal Primary Sedimentation: Comminution Oil / fat removal Flow equalization pH neutralization Imhoff tank	Activated sludge Extended aeration Aerated lagoon Trickling filter Rotating bio-discs Anaerobic treatment/UASB Anaerobic filter Stabilization ponds Constructed wetlands Aquaculture	Nitrification Denitrification Chemical precipitation Disinfection (Direct) filtration Chemical oxidation Biological removal Constructed wetlands Aquaculture	Chemical treatment Reverse osmosis Electrodialysis Carbon adsorption Selective ion exchange Hyperfiltration Oxidation Detoxification

B-8) How is the sludge disposed off?

☐ Landfill ☐ Fertilizer ☐ Other:-----

B-9) Where does the treated wastewater go after it leaves the plant?

☐ Sea ☐ Reuse ☐ Other:-----

B-10) Wastewater Characteristics: Indicate the constituents that are or could be present in the wastewater discharge:

- | | |
|--|--|
| ☐ High pH (caustics , etc.) | ☐ Toxic Gases |
| ☐ Insoluble Substances | ☐ Phenols |
| ☐ Low pH (acids) | ☐ Toxic or Irritating Substances |
| ☐ Hydrogen Sulfide | ☐ Pesticides |
| ☐ Sulfur Dioxide | ☐ polychlorinated biphenyl (PCB 's) |
| ☐ Nitrous Oxide | ☐ Radioactive Substances |
| ☐ Chlorine | ☐ Salt Brines |
| ☐ Bromine | ☐ High Temperature Wastes |
| ☐ Iodine | ☐ Grease or Oil |
| ☐ Other Disinfectants | ☐ Solvents |
| ☐ Explosive Substances | ☐ Dissolved Metals such as Arsenic ,
Beryllium , Cadmium, Chromium ,
Copper , Iron , Lead , Manganese ,
Mercury, Nickel , Selenium , Silver, and
Zinc . |
| ☐ Flammable Substances | ☐ Cyanide |
| ☐ Large Particles | ☐ Others:----- |
| ☐ Surfactants (detergents) | ----- |

B-11) How much sludge is hauled off site on a monthly basis? to.....
Ton per day

B-12) Desired Results/Benefits from treating wastewater:

- Reduce organic compound (s) Specify types and target level
(s):.....
- Improve effluent quality:
 - ☐ BOD ☐ TSS ☐ FOG ☐ Sludge ☐ Phosphorous
 - ☐ H2S ☐ NH3 ☐ Metal ☐ Odor ☐ Oil/Grease

Part (C): Facility Operation

Indicate shifts normally worked each day:

Shift	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
1 st							
2 nd							
3 rd							
	1 st Shift		2 ^{na} Shift		3 ^{ra} Shift		
Start Time:							
End Time:							
Average No. Of Employees (range)	to.....		to.....		to.....		

Part (D): National Wastewater Legislation

This part of the questionnaire is about the current national legislations related to wastewater management (WWM).

Please mark the answer that reflects your opinion:

		Excellent	Very Good	Good	Weak	Very Weak
D-1)	How do you evaluate your level of knowledge to the wastewater management legislations	☐	☐	☐	☐	☐
D-2)	How do you evaluate your level of knowledge to the procedures in term of safe discharge of wastewater	☐	☐	☐	☐	☐

To what extent do you agree with the following statements:

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
D-3)	The procedures and the policy for legal actions taken by National Environment Authority Inspectors are clear and understandable	☐	☐	☐	☐	☐
D-4)	Environment authority inspectors are taking consistent decisions and	☐	☐	☐	☐	☐

	legal actions for unauthorized wastewater discharge					
D-5)	Environment authority inspectors are taking fair legal actions	☐	☐	☐	☐	☐
D-6)	A set of indicator and limits are considered on the national legislation to ensure the quality of Discharged water	☐	☐	☐	☐	☐
D-7)	The current legislative framework is appropriate for wastewater management.	☐	☐	☐	☐	☐
D-8)	All implementation measures are well defined in the wastewater legislation	☐	☐	☐	☐	☐
D-9)	The national wastewater legislation need to be reviewed and updated	☐	☐	☐	☐	☐
D-10)	An active participation of all stakeholders(local government, NGOs and the community) is necessary in the implementation wastewater legislation	☐	☐	☐	☐	☐

Please indicate how much do you agree about the following stated sentences for each article:

D-11	Legislative Decree No. 21 for 1996 on the environment	Very High	High	Mode	Low	No Opinion
1	Article No. 13: The national legislation prevent any unauthorized discharge of wastewater	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
2	Article No. 28: Clear Inspection procedure	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
3	Article No. 29: Fair Sanctions	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
D-12	The Ministerial Order No.10 For 1999:Environmental Standards for Air And Water and Amendment No. 2 an 3 for 2001	Very High	High	Mode	Low	No Opinion
	Part 3: Conformity Requirement for Air And Water Standards					
1	Article No. 7: The national legislation prevent any unauthorized discharge	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
2	Article No. 8: Promote a suitable treatment technology	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
3	Article No. 9: Encourage using a control equipment	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
	Part 6:Standards & measurement related to the Sources of water pollution					
4	Article No. 20: Demand a quality of the discharged wastewater	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
5	Article No. 22:Treatment & Complying with Standards	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
6	Article No. 22 Repeated: Set a fair requirement for the discharge area	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
7	Part 7:General Requirements					

8	Article No. 25:demand providing reports and tests	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
9	Article No. 26: Fair Sanctions	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
10	Annex 2 : Table 5: Applicable Industrial Wastewater Limits	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐

Part (E): Establishment Wastewater Management System

	Excellent	Very Good	Good	Weak	Very Weak
How do you evaluate the management of your facility to wastewater?	☐	☐	☐	☐	☐

To what extent do you agree to the following statements:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
E-1 The facility have competent Management staff involved in wastewater management	☐	☐	☐	☐	☐
E-2 The facility have Technically qualified workforce to deal with wastewater treatment plant	☐	☐	☐	☐	☐
E-3 The facility used to work and conduct periodic analysis to check the quality of wastewater discharge	☐	☐	☐	☐	☐
E-4 The facility used to hand over the results of these periodic analysis to the Supreme Council for the Environment	☐	☐	☐	☐	☐
E-5 The Quality of wastewater discharge comply with the standards of the Supreme Council for the Environment	☐	☐	☐	☐	☐
E-6 The facility used to reuse generated sludge	☐	☐	☐	☐	☐
E-7 The wastewater is treated before its discharge to environment	☐	☐	☐	☐	☐
E-8 The wastewater treatment unit is constantly maintained	☐	☐	☐	☐	☐
E-9 The facility sets plans to the development of wastewater treatment systems	☐	☐	☐	☐	☐
E-10 The facility has laboratories to analysis wastewater	☐	☐	☐	☐	☐
E-11 The need of accredited laboratories used in the assay results of wastewater analysis	☐	☐	☐	☐	☐
E-12 The facility takes into account the safety of workers	☐	☐	☐	☐	☐
E-13 The facility develops a training to the importance of wastewater treatment	☐	☐	☐	☐	☐
E-14 The facility develops awareness programs to the importance of wastewater treatment	☐	☐	☐	☐	☐
E-15 The facility complies with safety requirements during the collection of wastewater and sludge	☐	☐	☐	☐	☐
E-16 The facility complies with safety requirements during transportation of	☐	☐	☐	☐	☐

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	wastewater and sludge in the centralized system					
E-17	The facility complies with safety requirements during treatment of wastewater and sludge	☐	☐	☐	☐	☐
E-18	The facility have proper wastewater management documentation	☐	☐	☐	☐	☐
E-19	The high top management of the facility are aware of the importance of wastewater management	☐	☐	☐	☐	☐
E-20	The Non-governmental organization (NGOs) have influence in the wastewater management	☐	☐	☐	☐	☐
E-21	There are limited economic and financial funds available for research and public investment in wastewater management	☐	☐	☐	☐	☐
E-22	There are limited share of information between authorities involved in wastewater management	☐	☐	☐	☐	☐
E-23	The treatment of wastewater returns to the facility a revenue.	☐	☐	☐	☐	☐
E-24	A new technology is required to replace current technology used to treat wastewater	☐	☐	☐	☐	☐
E-25	The facility spend appropriate funds in research related to wastewater	☐	☐	☐	☐	☐

For any questions please do not hesitate to call me at any time on Mobile no. +973 39185121 - Fatima Ahmed or by email: fif_2121@hotmail.com

You may resend the questionnaire to mentioned email or by fax to 17530730
This questionnaire is in 6 pages.

The End of Questionnaire
Thanks very much for your participation

Appendix C

Tables related to wastewater generated from Textile Industry

Table C-1: Discharge limits of various countries

Parameter	CCME	China	BIS	Hong Kong	FEPA	Mexico	Thailand	Philippines	Indonesia	Bangladesh	SL
pH	6.5-8.5	6-9	5.5-9	6-10	6-9	6-8.5	5-9	6-9	6-9	6.5-9	6-8.5
Temperature (°C)	30	-	50	43	40	-	-	40	-	40-45	40
Colour (Pt-Co)	100	80	None	1(Lovibond)	7(Lovibond)	-	-	100-200	-	-	30
TDS mg/L	2000	-	2100	-	2000	-	2000-5000	1200	-	2100	2100
TSS mg/L	40	150	100	800	30	-	30-150	90	60	100	500
Sulphide µg/L	200	1000	2000	1000	200	-	-	-	-	1000	2000
Free Chlorine µg/L	1000	-	1000	-	1000	-	-	1000	-	-	-
COD mg/L	80	200	250	2000	80	< 125	120-400	200-300	250	200	600
BOD mg/L	50	60	30	800	50	< 30	20-60	30-200	85	150	200
Oil & Grease mg/L	-	-	10	20	10	-	300	5-15	5	10	30
Dissolved Oxygen µg/L	6000	-	-	≥ 4000	-	-	-	1000-2000	-	4500-8000	-
Nitrate µg/L	13000	-	10000	-	20000	10000	-	-	-	10000	45000
Ammonia µg/L	0.1	-	-	500	0.2	-	-	-	-	5000	60
Phosphate µg/L	<4000	1000	5000	5000	5000	-	-	-	2000	-	2000
Calcium µg/L	-	-	-	-	200000	-	-	200000	-	-	240000
Magnesium µg/L	200000	-	-	-	200000	-	-	-	-	-	150000
Chromium µg/L	1	-	100	100	<100	50	500	50-500	500	2000	50
Aluminium µg/L	5	-	-	-	<1000	5000	-	-	-	-	-
Copper µg/L	<1000	1000	3000	1000	<1000	1000	1000	1000	2000	500	3000
Manganese µg/L	5	2000	2000	500	5.0	200	5000	1000-5000	-	5000	500
Iron µg/L	300	-	3000	1500	20000	1000	-	1000-20000	5000	2000	1000
Zinc µg/L	30	5000	5000	600	<10000	10000	-	5000-10000	5000	5000	10000
Mercury µg/L	0.026	-	0.01	1	0.05	-	5	5	-	10	1

Source: Ghaly, 2014

CCME - Canadian Council of Ministers of the Environment

BIS - Bureau of Indian Standards

FEPA - Federal Environmental Protection Agency (United States)

SL - Sri Lanka

Table C-2: Typical pollution loads from the processing of 100% cotton

Process	pH	SEV (l/kg)	BOD	COD	TSS	TDS	Oil&Gas	pH
			kg per 1000 kg of product					
Desizing								
Enzyme starch	6-8	2.5-9	45.5	91	89	5	5	6-8
Acid starch	6-8		45.5	91	89.5	7.5	5	6-8
Polyvinyl alcohol (PVA)	6-8		2.5	5	5	48	2.5	6-8
Carboxymethyl cellulose (CMC)	6-8		4	8	5	45	9.5	6-8
Scouring								
Unmercerised greige fabric	12.5	2.5-43	21.5	64.5	5	50	40	12.5
Merцерised greige fabric	12.5		16.5	49.5	5	50	30	12.5
Merцерising								
Greige fabric	12	231-306	13	39	5	148	10	12
Scoured fabric	12		4	12	5	148	-	12
Bleached fabric	12		2	6	5	148	-	12
Bleaching								
Hydrogen peroxide	9-12	2.5-124	0.5	2	4	22	-	9-12
Sodium hypochlorite	9-12		1	4	4	5	-	9-12
Dyeing								
Fibre reactive HE dyes (woven)	12		6	24	-	180		12
Basic	6-7.5	149-300						6-7.5
Direct	6.5-7.6	14-53						6.5-7.6
Vats	5-10	8.3-166						5-10
Sulphur	8-10	24-212						8-10

Source: Ghaly, 2014

Table C-3: Pollution load from the processing of 50/50 cotton-polyester blend

Source	Effluent (l/kg)	pH	COD	BOD	TS	SS	TDS
		kg per 1000 kg of product					
Desizing							
Starch	12.5	6-8		38.5	97	77	20
PVA	12.5	6-8		2.5	55.4	5	50.4
CMC	12.5	6-8		3.93	59.5	5	54.5
Mixture	4.2		74		78		
Scouring							
Unmercerised	25	12		10.8	14.8	5	9.8
Merцерised	25	12		8.34	14.7	5	9.7
Bleaching							
Peroxide	16.7			1.3	24	4	20
Oxidative-desize-bleach	5.1		23		184		
Merцерising							
Poly/cotton	16.7			3.2	82	5	77
Dyeing							
Disperse-vat	42	12	68	22.8	122		122
Vat	100				150		
Disperse	80				20		
Direct-disperse		6-8	32	10.7			114
Sulphur-disperse		11	68	22.8			69.7
Reactive-disperse		12	41	13.8			192
Printing							
Pigment (woven)		6-8	5	1.26		0.13	2.5
Pigment (knit)		6-8	5	1.26		0.13	2.5
Vat (woven)		10	86	21.5		25	34
Vat (knit)		10	86	21.5		25	35
Machine wash	100						
Screen wash	7						
Hose vessels	30						
Pigment wash	12.5			1	3	0	3
Finishing							
Resin finishing		6-8					22
Resin finishing flat curling		6-8		25	6.32		17.3

Source: Ghaly, 2014

Table C-4: Pollution load from the processing of wool

Process	pH	BOD	TS
Scouring	9-10.4	30,000-40,000	1,129-64,448
Dyeing	4.8-8	380-3,000	2,000-10,000
Washing	7.3-10.3	4,000-11,455	4,830-19,267
Neutralising	1.9-9	28	1,241-4,830
Bleaching	6	390	908

Source: Ghaly, 2014

Table C-5: Pollution load from the processing of synthetic fibres

Fabric	BOD	COD	SS	TDS
	Kg per 1000 kg product			
Rayon	30	52	55	100
Acetate	45	78	40	100
Nylon	45	78	30	100
Acrylic	125	216	87	100
Polyester	185	320	95	150

Source: Ghaly, 2014

Appendix D

Pairwise comparison metrics for SWOT sub-factors local priorities applied for local textile Facility

Table D-1: Pairwise comparison matrix for strengths priorities

Strengths (S)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Local weight
S1: Competent Management staff	1	3	2	1/2	1/2	4	2	5	1/4	3	2	0.104
S2: Technically qualified workforce to deal with WWTP	1/3	1	2	1	3	4	1	7	3	8	4	0.156
S3: Conduct periodic analysis to WW	1/2	1/2	1	1/8	2	4	2	3	1/7	3	6	0.074
S4: WWT unit is constantly maintained	2	1	8	1	7	3	3	7	1/6	8	2	0.153
S5: Competent laboratories to analysis WW	2	1/3	1/2	1/7	1	2	2	1/3	1/7	1/6	1/3	0.042
S6: Taking the safety requirement	1/4	1/4	1/4	1/3	1/2	1	3	2	1/9	1/4	1/3	0.031
S7: Proper WW management documentation	1/2	1	1/2	1/3	1/2	1/3	1	1/4	1/7	1/3	1/2	0.031
S8: Cooperative top management	1/5	1/7	1/3	1/7	3	1/2	4	1	1/8	1	1/2	0.036
S9: Reused treated WW in process	4	1/3	7	6	7	9	7	8	1	9	8	0.268
S10: Good reputation of the facility which is certified under the Oeko-Tex® Standard and use State-of-the-art equipment	1/3	1/8	1/3	1/8	6	4	3	1	1/9	1	3	0.059
S11: Well R&D related to wastewater	1/2	1/4	1/6	1/2	3	3	2	2	1/8	1/3	1	0.045
Total	11.617	7.935	22.083	10.202	33.500	34.833	30.000	36.583	5.317	34.083	27.667	

Table D-2: Pairwise comparison matrix for weaknesses priorities

weakness (W)	W1	W2	W3	W4	Local weight
W1: Doesn't reuse generated sludge	1	1/3	1/2	1/2	0.115
W2: weak communication with environment authority	3	1	3	2	0.441
W3: No future plans to the development of WWT systems	2	1/3	1	3	0.268
W4: Ongoing operational costs	2	1/2	1/3	1	0.176
Total	8.000	2.167	4.833	6.500	

CR=0.0978

Table D-3: Pairwise comparison matrix for opportunities priorities

Opportunities (O)	O1	O2	Local weight
O1: WWT returns to the facility a revenue	1	5	0.833
O2: geo-growth opportunities to expand and improve the existing wastewater treatment plant	0.200	1	0.167
Total	1.200	6.000	

Table D-4: Pairwise comparison matrix for threats priorities

Threats (T)	T1	T2	Local weight
T1: Increase in water demand used on the production and its cost .	1	3	0.750
T2: High strict legislative measures apply by environmental authority .	0.333	1	0.250
Total	1.333	4.000	

Appendix E

Alternative Strategies Priorities based on SWOT sub-Factors Applied for Local Textile Facility

Table E-1 Pairwise comparison matrix for alternative strategies priorities based on Strength (S1) " Competent Management staff "

Strengths (S1)	SO	WO	ST	WT	Local weight
SO	1	8	9	7	0.657
WO	1/8	1	2	1/7	0.069
ST	1/9	1/2	1	1/7	0.046
WT	1/7	7	7	1/7	0.229
Total	1.379	16.500	19.000	7.429	

CR=0.095

Table E-2 Pairwise comparison matrix for alternative strategies priorities based on Strength (S2) "Technically qualified workforce to deal with WWTP"

Strengths (S2)	SO	WO	ST	WT	Local weight
SO	1	3	1/6	3	0.176
WO	1/3	1	1/8	1/2	0.061
ST	6	8	1	8	0.675
WT	1/3	2	1/8	1	0.089
Total	7.667	14.000	1.417	12.500	

CR=0.055

Table E-3 Pairwise comparison matrix for alternative strategies priorities based on Strength (S3) Conduct periodic analysis to WW

Strengths (S3)	SO	WO	ST	WT	Local weight
SO	1	3	5	6	0.556
WO	1/3	1	1	3	0.178
ST	1/5	1	1	6	0.205
WT	1/6	1/3	1/6	1	0.062
Total	1.700	5.333	7.167	16.000	

CR=0.087

Table E-4 Pairwise comparison matrix for alternative strategies priorities based on Strength (S4) "WWT unit is constantly maintained"

Strengths (S4)	SO	WO	ST	WT	Local weight
SO	1	8	5	9	0.629
WO	1/8	1	1/6	1	0.059
ST	1/5	6	1	6	0.256
WT	1/9	1	1/6	1	0.056
Total	1.436	16.000	6.333	17.000	

CR=0.078

Table E-5 Pairwise comparison matrix for alternative strategies priorities based on Strength (S5) "Competent laboratories to analysis WW"

Strengths (S5)	SO	WO	ST	WT	Local weight
SO	1	3	2	3	0.422
WO	1/3	1	1/5	1/3	0.085
ST	1/2	5	1	3	0.335
WT	1/3	3	1/3	1	0.159
Total	2.167	12.000	3.533	7.333	

CR= 0.083

Table E-6 Pairwise comparison matrix for alternative strategies priorities based on Strength (S6) "Taking the safety requirement"

Strengths (S6)	SO	WO	ST	WT	Local weight
SO	1	3	2	3	0.450
WO	1/3	1	1/2	1	0.142
ST	1/2	2	1	1/2	0.197
WT	1/3	1	2	1	0.211
Total	2.167	7.000	5.500	5.500	

CR=0.077

Table E-7 Pairwise comparison matrix for alternative strategies priorities based on Strength (S7) "Proper WW management documentation"

Strengths (S7)	SO	WO	ST	WT	Local weight
SO	1	4	1/4	3	0.248
WO	1/4	1	1/5	1/3	0.070
ST	4	5	1	4	0.542
WT	1/3	3	1/4	1	0.139
Total	5.583	13.000	1.700	8.333	

CR= 0.096

Table E-8 Pairwise comparison matrix for alternative strategies priorities based on Strength (S8)"Cooperative top management"

Strengths (S8)	SO	WO	ST	WT	Local weight
SO	1	5	4	5	0.566
WO	1/5	1	1/3	3	0.134
ST	1/4	3	1	3	0.225
WT	1/5	1/3	1/3	1	0.075
Total	1.650	9.333	5.667	12.000	

CR= 0.096

Table E-9 Pairwise comparison matrix for alternative strategies priorities based on Strength (S9) "Reused treated WW in process"

Strengths (S9)	SO	WO	ST	WT	Local weight
SO	1	5	1/7	5	0.217
WO	1/5	1	1/8	1	0.061
ST	7	8	1	9	0.664
WT	1/5	1	1/9	1	0.058
Total	8.400	15.000	1.379	16.000	

CR= 0.100

Table E-10 Pairwise comparison matrix for alternative strategies priorities based on Strength (S10) "Good reputation of the facility "

Strengths (S10)	SO	WO	ST	WT	Local weight
SO	1	3	1/5	1/3	0.129
WO	1/3	1	1/6	1/3	0.067
ST	5	6	1	5	0.596
WT	3	3	1/5	1	0.207
Total	9.333	13.000	1.567	6.667	

CR= 0.100

Table E-11 Pairwise comparison metrics for alternative strategies priorities based on Strength (S11)"Well R&D related to wastewater"

Strengths (S11)	SO	WO	ST	WT	Local weight
SO	1	3	1/6	2	0.178
WO	1/3	1	1/7	1/4	0.059
ST	6	7	1	4	0.606
WT	1/2	4	1/4	1	0.157
Total	7.833	15.000	1.560	7.250	

CR= 0.091

Table E-12 Pairwise comparison metrics for alternative strategies priorities based on Weakness (W₁) "Doesn't reuse generated sludge"

Weaknesses (W ₁)	SO	WO	ST	WT	Local weight
SO	1	1/9	2	1	0.102
WO	9	1	9	9	0.744
ST	1/2	1/9	1	1	0.072
WT	1	1/9	1	1	0.083
Total	11.500	1.333	13.000	12.000	

CR =0.023

Table E-12 Pairwise comparison metrics for alternative strategies priorities based on (W₂) "weak communication with environment authority"

Weaknesses (W ₂)	SO	WO	ST	WT	Local weight
SO	1	1	2	1/9	0.129
WO	1	1	2	1/2	0.186
ST	1/2	1/2	1	1/9	0.073
WT	9	2	9	1	0.613
Total	11.500	4.500	14.000	1.722	

CR =0.083

Table E-13 Pairwise comparison metrics for alternative strategies priorities based on (W₃) "No future plans to the development of WWT systems"

Weaknesses (W ₃)	SO	WO	ST	WT	Local weight
SO	1	7	5	4	0.581
WO	1/7	1	1/2	1/3	0.068
ST	1/5	2	1	1/5	0.101
WT	1/4	3	5	1	0.251
Total	1.593	13.000	11.500	5.533	

CR =0.093

Table E-14 Pairwise comparison metrics for alternative strategies priorities based on (W4) "Ongoing operational costs"

Weaknesses (W4)	SO	WO	ST	WT	Local weight
SO	1	5	1/5	6	0.239
WO	1/5	1	1/9	1/2	0.050
ST	5	9	1	9	0.641
WT	1/6	2	1/9	1	0.071
Total	6.367	17.000	1.422	16.500	

CR =0.092

Table E-15 Pairwise comparison metrics for alternative strategies priorities based on (O₁) "WWT returns to the facility a revenue"

Opportunities (O1)	SO	WO	ST	WT	Local weight
SO	1	3	1/9	2	0.136
WO	1/3	1	1/9	1	0.066
ST	9	9	1	9	0.729
WT	1/2	1	1/9	1	0.069
Total	10 5/6	14	1 1/3	13	

CR =0.045

Table E-16 Pairwise comparison metrics for alternative strategies priorities based on (O₂) "geo-growth opportunities to expand and improve the existing wastewater treatment plant"

Opportunities (O2)	SO	WO	ST	WT	Local weight
SO	1	1/9	2	1	0.105
WO	9	1	8	9	0.735
ST	1/2	1/8	1	1	0.076
WT	1	1/9	1	1	0.084
Total	11 1/2	1 1/3	12	12	

CR =0.028

Table E-17 Pairwise comparison metrics for alternative strategies priorities based on (T₁) 'Increase in water demand used on the production and its cost'

Threats (T ₁)	SO	WO	ST	WT	Local weight
SO	1	5	1/5	5	0.234
WO	1/5	1	1/8	2	0.076
ST	5	8	1	9	0.640
WT	1/5	1/2	1/9	1	0.050
Total	6.400	14.500	1.436	17.000	

CR =0.076

Table E-18 Pairwise comparison metrics for alternative strategies priorities based on (T₂) "High strict legislative measures apply by environmental authority"

Threats (T ₂)	SO	WO	ST	WT	Local weight
SO	1	4	5	1/8	0.194
WO	1/4	1	1	1/9	0.060
ST	1/5	1	1	1/9	0.058
WT	8	9	9	1	0.688
Total	9.450	15.000	16.000	1.347	

CR =0.097

Appendix F

Pairwise comparison metrics for SWOT sub-factors local priorities applied for Tubli STP

Table F-1: Pairwise comparison matrix for strengths priorities

Strengths (S)	S1	S2	S3	Local weight
S1: Considered to be the largest sewage treatment plant in the kingdom of Bahrain, its connecting the majority of the population to a water network.	1	2	3	0.512
S2: Good involvement with other related authorities to ensure water resources conservation and better wastewater management .	1/2	1	4	0.360
S3:Competent laboratories to analysis WW	1/3	1/4	1	0.128
Total	1.833	3.250	8.000	

CR= 0.0937

Table F-2: Pairwise comparison matrix for weaknesses priorities

	W1	W2	W3	W4	W5	Local weight
W1: Negligible amount of wastewater reused.	1	6	4	1/3	2	0.229
W2: Poor culture in efficient treated wastewater use in agriculture	1/6	1	1/4	1/8	1/3	0.039
W3: High maintenance cost	1/4	4	1	1/6	3	0.122
W4: Tubli STP working now above capacity of the plant.	3	8	6	1	9	0.531
W5: Tubli STP produces fifty tonnes of thermally dried sludge per day which is transferred to landfill, while the existing landfill has only three years capacity.	1/2	3	1/3	1/9	1	0.079
Total	4.917	22.000	11.583	1.736	15.333	

CR= 0.0996

Table F-3: Pairwise comparison matrix for opportunities priorities

Opportunities (O)	O1	O2	O3	Local weight
O1: Create and Implement new appropriate legislative framework for proper wastewater management	1	7	2	0.571
O2: Gain the public acceptance and interest for sustainable wastewater management	1/7	1	1/7	0.066
O3: Improved the mechanism of solid waste (sludge) disposal	1/2	7	1	0.363
Total	1.643	15.000	3.143	

CR= 0.0465

Table F-4: Pairwise comparison matrix for threats priorities

Threats (T)	T1	T2	T3	Local weight
T1: Increased water demand due to rising temperatures during summer	1	1/3	1/8	0.072
T2: Increasing population served by Tubli sewage Treatment plants.	3	1	1/9	0.146
T3: low investment in wastewater infrastructure (STP, network ,...etc) due to the limited financial funds	8	9	1	0.782
Total	12.000	10.333	1.236	

CR= 0.0781

Appendix G

Alternative Strategies Priorities based on SWOT sub-factors Applied for Tubli STP

Table G-1 Pairwise comparison matrix for alternative strategies priorities based on Strength (S1)

Strengths (S1)	SO	WO	ST	WT	Local weight
SO	1	6	3	7	0.537
WO	1/6	1	1/6	1	0.068
ST	1/3	6	1	9	0.348
WT	1/7	1	1/9	1/7	0.048
Total	1.643	14.000	4.278	17.143	

CR =0.008

Table G-2 Pairwise comparison matrix for alternative strategies priorities based on Strength (S2)

Strengths (S2)	SO	WO	ST	WT	Local weight
SO	1	7	6	7	0.644
WO	1/7	1	1/6	1/2	0.058
ST	1/6	6	1	2	0.203
WT	1/7	2	1/2	1	0.096
Total	1.452	16.000	7.667	10.500	

CR =0.090

Table G-3 Pairwise comparison matrix for alternative strategies priorities based on Strength (S3)

Strengths (S3)	SO	WO	ST	WT	Local weight
SO	1	3	1/4	4	0.232
WO	1/3	1	1/5	1/2	0.079
ST	4	5	1	7	0.590
WT	1/4	2	1/7	1	0.099
Total	5.583	11.000	1.593	12.500	

CR =0.085

Table G-4 Pairwise comparison matrix for alternative strategies priorities based on weakness (W1)

Weaknesses (W1)	SO	WO	ST	WT	Local weight
SO	1	1	1/3	1	0.153
WO	1	1	1/4	1	0.141
ST	3	4	1	6	0.577
WT	1	1	1/6	1	0.129
Total	6.000	7.000	1.750	9.000	

CR =0.017

Table G-5 Pairwise comparison matrix for alternative strategies priorities based on weakness (W2)

Weaknesses (W2)	SO	WO	ST	WT	Local weight
SO	1	2	2	1/5	0.162
WO	1/2	1	1/2	1/6	0.080
ST	1/2	2	1	1/7	0.111
WT	5	6	7	1	0.647
Total	7.000	11.000	10.500	1.510	

CR = 0.038

Table G-6 Pairwise comparison matrix for alternative strategies priorities based on weakness (W3)

Weaknesses (W3)	SO	WO	ST	WT	Local weight
SO	1	1	1	1/7	0.100
WO	1	1	1	1/6	0.105
ST	1	1	1	1/8	0.097
WT	7	6	8	1	0.698
Total	10.000	9.000	11.000	1.435	

CR =0.003

Table G-7 Pairwise comparison matrix for alternative strategies priorities based on weakness (W4)

Weaknesses (W4)	SO	WO	ST	WT	Local weight
SO	1	1	1/6	1/7	0.065
WO	1	1	1/7	1/8	0.060
ST	6	7	1	3	0.531
WT	7	8	1/3	1	0.344
Total	15.000	17.000	1.643	4.268	

CR =0.075

Table G-8 Pairwise comparison matrix for alternative strategies priorities based on weakness (W5)

Weaknesses (W5)	SO	WO	ST	WT	Local weight
SO	1	1/8	1/3	2	0.083
WO	8	1	7	8	0.670
ST	3	1/7	1	5	0.193
WT	1/2	1/8	1/5	1	0.054
Total	12.500	1.393	8.533	16.000	

CR =0.089

Table G-9 Pairwise comparison matrix for alternative strategies priorities based on Opportunity (O1)

Opportunities (O1)	SO	WO	ST	WT	Local weight
SO	1	8	5	9	0.684
WO	1/8	1	1/3	1	0.072
ST	1/5	3	1	2	0.168
WT	1/9	1	1/2	1	0.076
Total	1.436	13.000	6.833	13.000	

CR =0.014

Table G-10 Pairwise comparison matrix for alternative strategies priorities based on Opportunity (O2)

Opportunities (O2)	SO	WO	ST	WT	Local weight
SO	1	1	1/4	1/5	0.102
WO	1	1	1/3	1/2	0.129
ST	4	3	1	3	0.488
WT	5	2	1/3	1	0.282
Total	11.000	7.000	1.917	4.700	

CR =0.076

Table G-11 Pairwise comparison matrix for alternative strategies priorities based on Opportunity (O3)

Opportunities (O3)	SO	WO	ST	WT	Local weight
SO	1	1/7	1/4	1	0.070
WO	7	1	6	7	0.633
ST	4	1/6	1	5	0.228
WT	1	1/7	1/5	1	0.068
Total	13.000	1.452	7.450	14.000	

CR =0.091

Table G-12 Pairwise comparison matrix for alternative strategies priorities based on threat (T1)

Threats (T1)	SO	WO	ST	WT	Local weight
SO	1	1	1/7	1/8	0.057
WO	1	1	1/8	1/8	0.056
ST	7	8	1	1/2	0.362
WT	8	8	2	1	0.525
Total	17.000	18.000	3.268	1.750	

CR =0.019

Table G-13 Pairwise comparison matrix for alternative strategies priorities based on threat (T2)

Threats (T2)	SO	WO	ST	WT	Local weight
SO	1	1	1/8	1/2	0.075
WO	1	1	1/9	1/5	0.063
ST	8	9	1	6	0.680
WT	2	5	1/6	1	0.182
Total	12.000	16.000	1.403	7.700	

CR =0.060

Table G-14 Pairwise comparison matrix for alternative strategies priorities based on threat (T3)

Threats (T3)	SO	WO	ST	WT	Local weight
SO	1	1	1/5	1/6	0.079
WO	1	1	1/2	1/6	0.088
ST	5	2	1	1/6	0.206
WT	6	6	6	1	0.627
Total	13.000	10.000	7.700	1.500	

CR =0.098

ملخص الأطروحة

أن حجم مياه الصرف الناتجة عن المرافق المنزلية والصناعية والتجارية ازداد بزيادة الكثافة السكانية، والتحضر، والتنمية الصناعية. ولذلك سيتم في هذا البحث قياس فعالية نظام الصرف المركزي ولا مركزي لإدارة مياه الصرف وتحليل النظام المتبع لفهم الإدارة المتبعة الحالية في مملكة البحرين، وقد تمت الاستعانة في هذا البحث بنظام التحليل الرباعي (القوة - الضعف - الفرص - التحديات) مع عملية التحليل الشبكية كأدوات تحليلية من أجل تطوير وتعزيز إدارة مياه الصرف في المستقبل وعلى المستوى الاستراتيجي وذلك بقياس العلاقة بين العوامل الاستراتيجية. وقد تمت الاستعانة بجهات متعددة للحصول على البيانات اللازمة والداعمة لهذا البحث مثل التقارير الحكومية واللوائح المتعلقة بإدارة مياه الصرف الصحية والمنشورة لدى هيئة التشريع والافتاء ، كما تم اعداد استبيان مفصل وكانت الإستجابة 38/25 وأجراء مقابلات شخصية مع خبراء في 9 من المنشآت التي تقوم بمعالجة مياه الصرف الصحي في مملكة البحرين وكذلك الجهات الرقابية ذات العلاقة. في هذا البحث، تم قياس فعالية نظام الصرف المركزي ولا مركزي لإدارة مياه الصرف و تحليل النظام المتبع في منشأة في قطاع الغزل والنسيج و محطة توبلي للصرف الصحي ، بالاستعانة بنظام التحليل الرباعي مع عملية التحليل الشبكية فقد تم التعرف على العوامل الفرعية والأستراتيجيات البديلة وهي كالتالي استراتيجية استعمال نقاط القوة إلى تحقيق أقصى قدر من الفرص، استراتيجية تقليل نقاط الضعف من خلال الاستفادة من الفرص واستراتيجية استخدام القوة للحد من التحديات. أما الاستراتيجية الأخيرة هي استراتيجية التقليل من نقاط الضعف وتجنب التحديات. ونظراً لكون نظام التحليل الرباعي لا يمكننا من قياس الأوزان المترتبة لهذه العوامل، فقد تم استخدام عملية التحليل الشبكية لقياس الترابط بين العوامل الاستراتيجية والعوامل الفرعية التي من شأنها أن تنعكس علي كل وزن وتغيير من الأولويات. وأشار التحليل لمنشأة الغزل والنسيج المحلية أن إعادة استخدام 100% من مياه الصرف الصحي المعالجة في عملية الإنتاج للحد من استهلاك المياه هو أفضل استراتيجية (استخدام القوة للحد من التحديات) وقد حصلت علي أعلى قيمة أولوية من بين الأستراتيجيات الأخرى بقيمة قدرها 0.804 بحيث يمكن استخدامها لتحسين إدارتها لمياه الصرف والحد من استهلاك المياه. وتم إعادة طريقة التقييم مرة أخرى لنظام إدارة مياه الصرف الصحي المركزية لمحطة توبلي لمعالجة مياه الصرف حيث أشارت النتائج إلى أن أفضل استراتيجية هي (استخدام القوة للحد من التحديات) مع أعلى قيمة أولوية 0.680 وقد وجد أن على محطة توبلي تحديث محطة معالجة الصرف الصحي لتحسين نوعية وكمية مياه الصرف التي يتم تصريفها في خليج توبلي. وبناء على هذا البحث، نستنتج أن كل من نظام الإدارة المركزية واللامركزية فعال وملائم وأن الاستراتيجية الأفضل لتطويرهما هي الاستعانة بنقاط القوة للمنشأة لمواجهة التحديات والتي من شأنها تعزيز وتحسين الإدارة وضمان إعادة استخدام المياه الصرف المعالجة.

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