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Classification Model for Selecting Appropriate Wastewater Treatment Technology Compatible with the Community Capacity

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Declaration

I certify that this thesis submitted for the degree of Master in environmental science is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not be submitted for a higher degree to any other university or institution.

Ibrahim Mohammad Tomizeh

Signature: Date: 25/07 / 2023

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Classification Model for Selecting Appropriate Wastewater Treatment Technology Compatible with the Community Capacity

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Abstract

Wastewater treatment and sanitation is a major issue in protected environment and health in many countries in the world especially in the developing arid and semi-arid countries where water sources in all countries are rare and a source of conflict. Sustainable wastewater treatment systems may provide sustainable none conventional water source if operated and managed properly. There are national and local organizations work on monitoring water services regularly, assignee indicators to measure the effectiveness of the service, other organizations follow up the service after implementation "post-implementation monitoring". As there is no clear process for evaluating and selecting the appropriate technology commensurate with the community's capacity and needs. As such, the limited knowledge of decision makers has led to choosing unsustainable solutions as 65% of projects in developing countries fail in their early stages. However, many studies and research indicated that focusing and studying the community increases the community ownership of these projects by including the community capabilities and needs in the stage of choosing the technologies. Thesis aims to develop classification model for wastewater treatment plants to be compatible with community capacity to reduce the failure in sanitation systems. With this model, the decision makers will have the ability to examine and scale the problem according to their requirement.in this research (Bouabid and Louis) methodology will be use based on analysis eight main capacity factors to evaluate and asses the community and wastewater treatment technologies and chose the most appropriate technology that compatible with the community. Most of sanitation technologies failed after a short period because of the bad monitoring after implementation of the project finalized because of not tacking inconsideration the community characteristics, and capacity factor. Several researchers try to find the best fit of choosing a propriety technology but after selecting the technologies, many options appear and with the same level leading to a selection of many none specific technologies, leading to none sustainable treatment system, in this

research some parameters will be added to reduce options depends on the needs of the treated water and the its source. The geographical extension and the sparse population of the Palestinian territories lead to an exhausting challenge for governments to establish centralized wastewater treatment plants for its communities; in addition, 65% of Palestinian territories are area C where it forbidden to establish centralized WWTPs. Moreover, the lack of sewage networks and the economic crises lead to consider the WWTPs with low operating and maintenance costs, as well as the least consuming land and energy, are the most appropriate options so that these communities have the ability to manage and operate these stations.

أداة اختيار أفضل تكنولوجيا لمعالجة المياه العادمة بما يتناسب مع قدرات المجتمع

اعداد: إبراهيم محمد طميزة
اشراف: د. جواد شقير

الملخص:

تعتبر معالجة مياه الصرف الصحي قضية بيئية رئيسية لحماية صحة الإنسان في العديد من البلدان في العالم وخاصة في البلدان النامية القاحلة وشبه القاحلة حيث مصادر المياه تعد نادرة ومصدر للصراع بين الأنظمة والتيارات السياسية. قد توفر أنظمة معالجة مياه الصرف الصحي المستدامة مصدرًا مستداما للمياه إذا تمت مراقبتها وإدارتها بشكل صحيح ووجود منظمات وطنية ومحلية تعمل على مراقبة خدمات المياه بانتظام وأن يكون لديها مؤشرات مخصصة لقياس فعالية الخدمة، وتتابع منظمات أخرى الخدمة بعد التنفيذ "مراقبة ما بعد التنفيذ". إلا انه لا توجد عملية واضحة لتقييم واختيار التكنولوجيا المناسبة بما يتناسب مع قدرة المجتمع واحتياجاته. على هذا النحو، أدت المعرفة المحدودة لصانعي القرار إلى اختيار حلول غير مستدامة حيث أن 65٪ من المشاريع في البلدان النامية تفشل في مراحلها الأولى. ومع ذلك، تشير العديد من الدراسات والبحوث إلى أن التركيز ودراسة المجتمع يزيد من ملكية المجتمع لهذه المشاريع.

تهدف الرسالة إلى تطوير نموذج تصنيف لمحطات معالجة مياه الصرف الصحي ليكون متوافقًا مع قدرة المجتمع لتقليل الفشل في أنظمة الصرف الصحي. في هذا البحث، سيتم استخدام منهجية (بوعبيد ولويس) بناءً على تحليل ثمانية عوامل قدرة رئيسية لتقييم وتقدير المجتمع ومعالجة مياه الصرف الصحي التقنيات واختيار أنسب التقنيات التي تتوافق مع المجتمع. مع هذا النموذج، سيكون لدى صانعي القرار القدرة على دراسة المشكلة وقياسها وفقًا لمتطلباتهم. فشلت معظم تقنيات الصرف الصحي بعد فترة وجيزة بسبب المراقبة السيئة بعد الانتهاء من تنفيذ المشروع بسبب عدم معالجة اللامبالاة في خصائص المجتمع وعامل القدرة. يحاول العديد من الباحثين العثور على أفضل ما يناسب اختيار تقنية الملاءمة، ولكن بعد اختيار التقنيات، تظهر العديد من الخيارات وبنفس المستوى تؤدي إلى اختيار العديد من التقنيات غير المحددة، مما يؤدي إلى عدم وجود نظام معالجة مستدام، في هذا البحث، ستؤدي بعض المعلمات إلى تضاف لتقليل الخيارات حسب احتياجات المياه المعالجة ومصدرها.

يؤدي الامتداد الجغرافي وقلة عدد السكان في الأراضي الفلسطينية إلى تحدي مرهق أمام الحكومات لإنشاء محطات معالجة مركزية لمياه الصرف الصحي في مجتمعاتها، بالإضافة إلى أن 65٪ من الأراضي الفلسطينية هي منطقة ج حيث يُحظر إنشاء محطات معالجة مياه الصرف الصحي المركزية. علاوة على ذلك، فإن الافتقار إلى شبكات الصرف الصحي والأزمات الاقتصادية تؤدي إلى اعتبار محطات معالجة مياه الصرف الصحي ذات تكاليف التشغيلية والصيانة المنخفضة، فضلاً عن الأراضي والطاقة الأقل استهلاكًا مثل عملية الحمأة المُنشطة، هي الخيارات الأنسب حتى تتمكن هذه المجتمعات بالقدرة على إدارة وتشغيل هذه المحطات.

List of Abbreviations

ABR	Anaerobic Baffled Reactor	MSW	Management of solid waste
AGF	Anaerobic Gravel Filters	NGOs	Nongovernmental organizations
AnP	Anaerobic Pond	O&M	Operations and Maintenance
ARIJ	Applied Research Institute - Jerusalem	PCBS	Palestinian Central Bureau of Statistics
AT	Aeration tank	PP	Polishing Pond
ATF	Aerobic Trickling Filter	PSF	Polishing Sand Filter
AUFGF	Anaerobic Up-flow Gravel Filter	PT	Palestinian Territories
BF	Bio-filter	PVC	Polyvinyl Chloride
BOD	Biochemical oxygen demand	PWA	Palestinian Water Authority
CCL	Community capacity level	RBC	Rtating biological contactor
CD	Chlorine Disinfection	SBR	Sequencing Batch Reactors
CF	Capacity factor	SDGs	Sustainable Development Goals
CFA	Capacity Factor Analysis	SDT	Subsurface Drainage technique
CO_2	Carbon dioxide	SF	Sand Filtration
COD	Chemical oxygen demand	SS	Suspended solids
CSP	Contact Stabilization Pond	ST	Septic Tank
CW	Constructed Wetland	TDS	Total dissolved solid
DO	Dissolved oxygen	TF	Trickling Filter
DUPC2	IHE Delft Programmatic Cooperation	TLA	Technology level assessment
DWPS	Duckweed-based pond system	TN	Total Nitrogen
DWS	Drinking water supply	TP	Total phosphorus
E.g.	for example	TSS	Toxic shock syndrome
EAP	Extended Aeration Process	UASB	Up-flow anaerobic sludge blanket
FP	Facultative Pond	UN	United Nations
HFCW	Horizontal Flow Constructed Wetlands	UvD	Ultraviolet Disinfection
HP	Horse power	VFCW	Vertical Flow Constructed wetlands
kWh	kilowatt hour	WASH	Water, Sanitation and Hygiene
l/p/d	Litter per person per day	WHO	World Health Organization
MBR	Membrane bio reactor	WSPs	Waste Stabilization Ponds
MCM	million cubic meter	WSS	Wastewater and sewage services
MGF	Multimedia Granule Filtration	WWTP	Wastewater treatment plant

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Chapter One:

1. General Background

Palestinian territories (PT) divide into two geographical entities - West Bank and the Gaza Strip. The population in 2022 was approximately 5.35 million (Figure 1). About 52% of the West Bank population lives in 11 urban areas, 41% lives in more than 500 villages and about 6% lives in 19 refugee camps. In the Gaza Strip, about 64% of the population lives in the five main urban areas, 5% in rural areas and the remaining 32%, lives in eight refugee camps (PCBS, 2022).

Figure 1 : Governorates of Palestine

Compared to other countries in the Middle East and surrounded countries, water supply and sanitation in the (PT) have serious challenges due to the Israeli occupation. According to the Water and Sanitation Monitoring Program (WaSH), Israelis control and use over 82% of the water in the coastal aquifer in Gaza, and 85% of the water in the mountainous aquifer in the West Bank, (PCBS, 2022).

People who lives in Palestinian communities suffering from real water crisis. The daily water consumption for Palestinian is 84.2 liters per day, and this average reached 82.4 liters per day in the West Bank, and 86.6 liters in the Gaza Strip. In addition, this less the world health organization limits which consider 100 litter/day is the minimum limit (PCBS, 2022).

PT is among the Middle Eastern countries that intensively experience water problems. The current water crisis in Palestine is take place due to the Israeli occupation and their control over the Palestinian aquifers that prevent Palestinians from having sufficient access to clean water (Jayyousi and Srouji, 2009). According to Palestinian Water Authority (2012), the lack of access to safe, sufficient, and adequate drinking water is a major problem for Palestinians, whose standard of living has decreased to the minimum, depriving them from the basic human rights to health, food security and water.

Wastewater could be one of the most important water sources for Palestinians. Its contribution to daily household total wastewater (Grey and Black) production is about 80%.

Wastewater reuse has importance from different points of view:

1. Wastewater harm the environment because it include toxic pollutants.
2. Treated wastewater can be a source for agricultural irrigation causing reduces the pressure on the freshwater.
3. The cost of the treated wastewater can be less than other options that used for irrigation such as desalination. In addition, treated wastewater conserve the nutrients and reduce the need for fertilizer.

1.1. Wastewater situation in Palestine:

Palestine suffers from the lack of proper sanitary infrastructure, the sanitary services are limited only to collect and transfer the sewage form sewage network and cesspit tanks, which emptied by vacuum tanks, where usually disposed the influent in valleys, open areas, sewage networks, or in dumping sites, (Palestinian Hydrology Group. 2006).

53.9% of the households in Palestine disposed of their wastewater through the sewage network during the year 2015 (38.4% in the West Bank and 83.5% in the Gaza Strip); 31.8% of households in Palestine use cesspits, 13.5% Of households use deaf drill and 0.8% of households use other means of disposal of wastewater. (Palestinian Central Bureau of Statistics, (PCBS, 2017).

1.2. Existing wastewater treatment plants technologies in Palestine (Centralized Systems)

About 67% of wastewater collected in the sewage networks are discharge in the wastewater treatment facilities. In West Bank, 15 MCM/year is the annual wastewater collected by the sewage networks and about 10 MCM/year treated in 6 centralized WWTPs and 19 collective WWTPs. Existing centralized wastewater treatment plants that are operating at a good efficiency rate are: West Nablus, Jenin, Jericho and the Tulkarm pre-treatment plant. The Ramallah and Al Bireh WWTPs are overloaded and functioning at low-moderate efficiencies (ARIJ, 2015)

Table1 : Existing centralized wastewater treatment plants in Palestine (West Bank).

Name of Wastewater Treatment plant	Actual and Design Flow (m3/day)	Status of WWTP
Al-Bireh WWTP	Actual Flow = 6,000 Design Flow = 5,000	Operational year 2000; overloaded, currently under rehabilitation and upgrade
Ramallah WWTP	Actual Flow = 2,400	Operational year 1975 and rehabilitated in 2002/2003; not operating well (overloaded) and does not meet the requirements for effluent discharge
Tulkarm Wastewater Pre- Treatment Plant	Actual Flow = 7,120	Operational year 1972 and rehabilitated in 2004. Operating well with high efficiency
Jenin WWTP	Actual Flow = 9,000	Operating after being rehabilitated
West Nablus WWTP	Actual Flow =10,000 Design Flow =12,000	Operational year 2013. Operating under monitoring after start up
Jericho WWTP	Actual Flow =300 Design Flow = 9,600	Operational year 2013. Treating only 300 m3/d due to the lack of sewage collection network

Source: (ARIJ, 2015)

According to **(Arafeh, G., 2012)** the following existing technologies are used in urban areas of West Bank and Gaza strip.

- Facultative Pond
- Aerated Lagoon
- Polishing Pond
- Stabilization Pond
- Anaerobic Pond
- Extended Aeration System

1.3. Existing onsite wastewater treatment plants technologies (collective system)

Collective wastewater treatment systems established in several localities that lacked sewage collection networks and that depended on cesspits for wastewater disposal. Such wastewater treatment systems are composed of a vacuum truck collection system plus a collective WWTP. As shown in Table 2 below.

Table 2 : Collective wastewater treatment plants in West Bank.

WWTP Name	Governorate	Wastewater Treatment Process	WWTP related information
Kharas WWTP	Hebron	Upflow Anaerobic Sludge Blanket (UASB) -Horizontal Flow Constructed Wetlands	O =2003 and was rehabilitated in 2016, D=120, A=100
Nuba WWTP			O=2002 and was rehabilitated in 2016, D=120, A=200
Deir Samit WWTP		Septic Tank - Anaerobic Upflow Gravel Filter	O=2001, D=13.5, A=na
Sair WWTP		Activated Sludge	O=Under Construction, D=1,200, A=na
Al-Quds University WWTP	Jerusalem	Extended Aeration Process –Chlorine Disinfection and Sand Filtration	O=2007, D=50, A=na
Bani Zeid (Al-Gharbiyeh) WWTP	Ramallah &Al-Bireh	Upflow Anaerobic Sludge Blanket (UASB) -Vertical Flow Constructed Wetlands	O=2004, D=100, A=20
Al-Tireh WWTP		Activated Sludge- Membrane Bioreactor (MBR)	O=2013, D=na, A=2000

WWTP Name	Governorate	Wastewater Treatment Process	WWTP related information
'Ein Siniya WWTP		Anaerobic Baffled Reactor -Activated Sludge Process–Multimedia Granule Filtration – Ultraviolet Disinfection	O=2007, D=10, A=na
Rammun - El Taibeh WWTP		Rotating Biological Contactor (RBC)	O=2014, D=na, A=450
Sarra WWTP	Nablus	Constructed Wetlands	O=2004, D=na, A=130
Bait Hassan WWTP		Constructed Wetlands	O=2013, D=na, A=80
Bait Dajan WWTP		Activated Sludge	O=2014, D= na, A=100
Biddya WWTP	Salfit	Septic Tank – Horizontal Flow ConstructedWetlands	O=2007 and was rehabilitated in 2014, D=35, A=20
‘Anza WWTP	Jenin	Activated Sludge	O=2015, D=na, A=80
Zeita WWTP	Tulkarm	Septic Tank – Constructed Wetland	O=2004, D=na, A=na
Note: * O=Operational Year, D=Design Flow (m^3/d), A=Actual Flow (m^3/d), na: not available			

Source: (ARIJ, 2015)

1.4. Problem statement

Access to clean and safe sanitation remains a challenge in much of developing countries. Safe sanitation systems are essential for any community and it effected directly to human health and economic growth.

In 2017, 4.5 billion people are suffering from lack of safety managing of sanitary service all around the world; 2.3 billion among them still do not have requisite sanitation services (Osseiran, N., 2017). As a result, thousands of people are dying every year due to diarrhea and other diseases such as typhoid, hepatitis A, and cholera. Therefore, the needs to improve the waters and sanitation services are clear and necessary. Most sanitation failures happened because of there is no clear process for decision maker to evaluate the community's capacity to manage and operate the sanitation technologies. The limited of experience and knowledge led decision makers and stakeholders to choose random type of WWTP depend on primary data (generally, high cost and high compact). Wherefore, the first action to be take is to meet the need for basic sanitation. This need must fit with the community capacity to build and operate the most appropriate wastewater treatment technology.

1.5. Research question:

What is the most appropriate wastewater treatment technology that fit with the community needs and capacity?

This question can be answer by following the following objectives.

1.6. Objectives of the Study:

The general objective of this study is to develop classification model for wastewater treatment technologies that asset the decision maker to choose the most appropriate WWTP that compatible with community needs and capacity to reduce the failure in sanitation systems.

Specific objectives of this research include:

- Develop a mathematical method that combined between the target community capacity and the wastewater treatment technologies levels.
    1. To evaluate the community that has the need for the sanitation services and convert its capacity into a value.
    2. To collect all possible wastewater treatment technologies in Palestine and regional countries.
    3. To convert the WWT technologies into a levels.
    4. Matching process between the target communities levels with the WWT technologies levels.
    5. Build and test the software model.
    6. Model calibration.

Chapter Two:

2. Lectures review

2.1. Introduction

Selecting the most appropriate and sustainable WWT technology among many alternatives is a very complicated process because the selecting choice must have combined between technical, economic, environmental, and social criteria. The United Nations (UN) and several local and international organizations have highlighted the importance of this issue to deal with the negative effects of lack of access to sanitation on human health in its adoption of Sustainable Development Goals (SDGs) (Arroyo, P. , 2018).

Health risk related to sanitation found mostly in urban area in developing countries. These risks arise from lack effective waste management along the sanitation chain (collection, transfer, treatment and disposal) and poor sanitation practices and behaviors (Maggie A., 2007).

At present, globally around 360,000 children under five year die annually from diarrhea and other sanitation diseases. This happened because there are 4.5 billion people around the world are suffering from lack of sanitation services (Osseiran, N. , 2017).

An example of the relationship between disease prevalence and inadequate sanitation occurred during1854-1858 in Lisbon. With 200,000 inhabitants living in one of biggest cities in Europe. The challenges facing the Portuguese capital in sanitation, urban circulation, food supply and housing. The 1856 cholera epidemic doubled the mortality level, and in 1857, Yellow fever doubled the number of deaths in Lisbon. In January 1858, the French engineer, P. J. Pézerat, employed in the municipal administration, was asked to submit a project to improve sewage disposal and identify the most urgent urban renewal problems (Silva, A., 2007).

Sanitation sustainability needs to find effective and efficient systems. Appropriate sanitation systems are able to produce high rate of effluent with minimal environmental impact (De Feo, G., 2016).

(Balkema, A. J., 2002) develop a methodology for assessing the sustainability of water technologies including wastewater treatment. He used four dimensions of sustainability: environmental, economic, social-cultural and technical requirements issues have been studied. Each sustainable dimension has its own criteria, often the high number of indicators makes the comparison between two different technologies complicated. So that, he used a scoring system for weighting the indicators against each other to come to a distinct result.

(Bergh, J., 1994) found that sustainability is an interaction between human resources, social and economic dimensions, with the aim to improve these systems by taking into consideration the trade-offs.

(Balkema, A. J., 2003) suggest that sustainability is depend on three dimensions, economical, well-being and environment and these dimensions cannot be separated. There are many definitions for the concept of sustainability. The World Commission on Environment and Development (WCED, 1987) define it as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". The definition mean that all generation have the equal rights to live now or in the future. Another definition for the World Conservation Strategy (IUCN, 1991) says that: "Improving the quality of human life while living in the carrying capacity of supporting ecosystems".

(Ahmed, Y. at al, 2017) by her research in the literature. She develops a methodology by test the essential dimensions of sustainability. Economic, social and environment for WWT systems in Egypt. This had been done by assume number of factor for each sustainability dimension. Finally, he arranged these factors in ascending order starting with economic factors such as capital and running costs, then environmental factors such as removal efficiency and energy consumption. In addition, social factors such as job opportunities.

(Sperling, M., 1996) made analysis to organize wastewater treatment technologies selection criteria by comparison between developing and developed countries. For developed countries, the items organized in decreasing order. The critical items were efficiency, reliability, sludge disposal factors and land requirements. Where, for developing countries, the order was construction costs, sustainability, simplicity and operational costs because financial ability may be the main factor that determines the sustainability of the sanitary service or not in developing countries.

The decision on the wastewater treatment process should chose by balancing between economic and technical aspects, with taken in consideration the quantitative and qualitative factors of each alternative (Sperling, M., 1996). (Popovic, T., 2018) sustainability is defined as the appropriate combination of environmental accuracy, economic richness and social justice. The idea of sustainability insures that the inseparable integration of the economy, social and environment

Selection process for most appropriate wastewater treatment options is the first step before designing and implementing the sanitation services.(Bouabid, A. et all, 2015) were developed a model to choose the most appropriate sanitation technology by determine eight capacity factors that evaluate the community level to manage and operate the municipal sanitation services to reduce the failure in WWTP . In a study, (Pailla, S. and Louis, G., 2011) use Louis approach which use model to develop a modified model for selection of the best appropriate domestic water infrastructure system in Nalgonda District, India.

In Palestine, the majority of Palestinian who live in Area C of the West Bank are not connected to the sewage network, Forcing people to use vacuum tanks to empty their cesspits. Insufficient water for domestic consumption and for livestock, is affecting the ability of these communities to live in flexible life. The destruction of essential WASH infrastructure lacking building permits generates a coercive environment, and can lead to displacement, poverty and increased risk of disease and illness (OCHA, 2019). In this research, Louis and Bouabid model will be used to develop modified model that help to choose the most sustainable sanitation system that fit the small community's capacity in Palestine. With this model, the decision makers will have the ability to examine and scale the problem according to their requirements.

2.2. Failures of sanitation systems

High population density, lack to proper financial and institutional arrangements, and geographical location of rural areas are often weakening the possibility to improve waste management (Mazeau, A., 2010). With 4.5 billion people globally are suffering from lack of safety managing of sanitary service. There is much to do. Identifying where to invest and how to develop services, strategies and policies that are very important. Moreover, it requires data, analysis and the common reflection of different stakeholders (Ssozi, D., 2012).

The only way to improve human health, livelihood conditions and save lives is providing safe drinking water and sanitation. While was huge revolution in the field of sanitation in the past decade in developed countries. Developing countries unfortunately are still suffering from lack of water supply and sanitation services. There are many factors impact the sustainability of water and sanitation services such as: no detailed analysis for the problem. In addition, there is no clear objectives, ignoring stakeholders, no selection model to choose technologies and no follow up after implementation.

In Africa, there are about 50,000 sanitary systems are not working. As a result, 215- 360 $ millions of investments wasted because of bad planning and follow up after implementation (Breslin, E., 2010).in Mali, about 80% of water points in Menaca region are broken or not working well. Moreover, in the north of Ghana, 58% of water points need to be fixed. The IRC Holland makes the cast of "in the last 20 years 600,000 to 800,000 water hand pump were installed in Sub-Saharan Africa of which some 30% are known to fail prematurely, where in failed investment cost of between $1.2-$1.5 billion" (Breslin, E., 2010).

There are some national and local organizations works on monitoring for water services regularly. The organizations that work on monitoring sanitation services, they put indicators to measure the effectiveness of the service. Other organizations who work to follow up the service after implementation, which call ""post-implementation monitoring". However, most of sanitation technologies failed after a short period because of the bad operation after implementation.

2.3. Sustainability of sanitation systems

Sustainability examines the most important criteria for sanitation technology when choosing a community sustainability technology, that means not only reducing the current cost of the scheme and collapses, but also to increase the positive social impact and reduce the negative impact of the environment.

Sanitation system considers sustainable, when the system achieves economically viable, socially acceptable, technically and institutionally appropriate, and protects the environment and natural resources (Susanna, 2008). The following sustainability criteria have to be taken into account in the design or upgrade phase.

1. **Health and hygiene:** this dimension looking for protect human health from all pathogens and hazardous substance that come from sanitation systems including collection, transfer, treatment and disposal options.
2. **Environment and natural resources:** this dimension interested in all natural resources that used in sanitation systems such as energy and water and other natural resources that used to implement and operate the systems. Moreover, the emissions that release to the environment such as CO_2 recycle all the effluent and excreta to reduce the negative impact on the environment.
3. **Technology and operation**: include the technical knowledge by the local community to operate and management all the sanitation option units (collection, transfer, treatment and disposal). Also, the relation between the flexibility and adaptability of the technical components with the existing infrastructure.
4. **Financial and economic**: this factor includes the ability of the local community to pay for construction, operation and maintenance the sanitation system. In addition, this dimension includes the direct benefits that come from sanitation systems. For example, the income from selling the treated water and fertilizers.
5. **Socio-cultural and institutional aspects:** this dimension looking in social acceptance. This mean to examine people's desire to use wastewater and their needs. In addition, what is most appropriate technology for them?

2.4. The process of selecting appropriate sanitation system nowadays

According to **(Kalbermatten, J., 1982)** at his research "appropriate sanitation alternatives, a technical and economic appraisal ". The process for selecting appropriate technology for sanitation system done by the following steps.

The first step, consist a list of all alternatives that provide the sanitation service. Within the alternatives, there are some appropriate technologies can be excluded for healthy, social or technical reasons. For example, septic tank needs large drainage fields. So that, this system will be not fit in area with high population density. After that, all the rest alternative technologies will provide full health and social benefits remains. Then, economical study for these technologies. Then excluding the alternatives that exceed the ability of consumers. The final step in the selection of appropriate sanitation technology should be with the final beneficiaries. By displaying all the alternatives that have passed the technical, health, social and economic tests. This will be more easily when the final beneficiaries determine the level of service they are willing to pay for.

2.5. Wastewater treatment technologies and processes

In planning and design stage for implementation the wastewater treatment system, the following points should be take into account to achieve the greatest benefit.

- Environmental impact study
- The aim of the wastewater treatment
- The level of treatment and removal efficiency.

The efficiency of removing pollutants from wastewater to reach required quality depends on the level of treatment and efficiency. Wastewater treatment classified into four levels as follows:

- Preliminary
- Primary
- Secondary
- Tertiary

In the preliminary stage, coarse solid will be removal. While in the primary, stage aims to remove settleable solids parts and organic matter. Physical process used usually in these two stages of treatment. The objective of secondary treatment is to remove the organic matter and nutrients by using biological process. Finally, in tertiary treatment the aims at removing specific pollutants like toxic or non-biodegradable components and nutrients.

2.6. List of wastewater treatment technologies in Palestine:

Wastewater may become usable for agricultural and industrial usage by using wastewater treatment technologies, which remove the pollutants and chemicals. Three processes of wastewater treatment include:

- **Physical processes:** treatment methods where physical procedures used to treat the wastewater (e.g. screening, mixing, flocculation, sedimentation, flotation, filtration).
- **Chemical processes:** treatment methods where chemical materials and reactions used to remove the contaminants from the wastewater (E.g. precipitation, adsorption, disinfection).
- **Biological processes:** treatment methods where biological process used to break down the organic matters to remove the contaminants from the wastewater. (E.g. carbonaceous organic matter removal, nitrification, denitrification).

There are three levels of on-site wastewater treatment plants in Palestine, which are at community, collective, and household distributed. Each of these levels contains different type of technologies arranged in several systems. The below points summarize the implemented systems and technologies of onsite wastewater treatment plants in rural areas in Palestine (Arafeh, G., 2012).

At Community Level:

- Up-flow anaerobic sludge blanket (UASB) - Septic Tank (ST)
- Contact Stabilization Pond (CSP)

- Up-flow Anaerobic Sludge Blanket (UASB)-Horizontal Flow Constructed Wetlands (HFCW)
- Extended Aeration Process (EAP) - Chlorine Disinfection (CD) and Sand Filtration (SF)
- Anaerobic Pond (AnP) - Facultative Pond (FP) - Polishing Pond (PP)
- Waste Stabilization Ponds (WSPs)

At Collective Level:

- Septic Tank (ST) - Anaerobic Up-flow Gravel Filter (AUFGF) - Aerobic Trickling Filter (ATF) followed by Polishing Sand Filter (PSF)
- Anaerobic Gravel Filters (AGFs) followed by Polishing Sand Filters (PSFs)
- Small Scale Activated Sludge (Extended Aeration Process (EAP) - Chlorine Disinfection (CD) and Sand Filtration (SF))
- Septic Tank (ST) - Constructed Wetland (CW)
- Septic Tank (ST) - Horizontal Flow Constructed wetlands (HFCW)
- Up-flow Anaerobic Sludge Blanket (UASB) - Vertical Flow Constructed wetlands (VFCW)
- Anaerobic Baffled Reactor (ABR) – Activated Sludge process (AS) – Multimedia Granule Filtration (MGF) – Ultraviolet Disinfection (UvD)
- Septic tank (ST) and Bio-filter (BF) Anaerobic Up-flow Gravel Filter (AUFGF)
- Septic Tank (ST) followed by Trickling Filter (TF)
- Septic Tank (ST) - Multilayer Trickling Filter (TF) - Polishing Pond (PP)
- Duckweed-based pond system (DWBP) - Small-scale biochemical system (BS) - Aeration tank (AT)
- Duckweed and Algae based ponds (DW & ABPs)

- Sequencing Batch Reactors (SBRs)

At Household Level:

- Septic tank (ST) - Up-Flow Gravel filter (UFGF) – Sand Filtration (SF)
- Activated Sludge (AS)
- Constructed Wetland (CW)
- Subsurface Drainage technique (SDT)
- Septic Tank (ST) – Trickling Filter (TF) – Sand Filter (SF)

Table 3 presents the main secondary level domestic sewage treatment systems. The technology of wastewater treatment has various other processes and variants, but this research addresses only the most frequently used systems in warm-climate countries such as Palestine and surrounded countries.

Table 3 : Summary description of the main biological wastewater treatment systems

Constructed wetlands	While the former systems are land-based systems, these are aquatic-based systems. Shallow basins or channels in which aquatic plants grow compose the systems. The system can be of free-water surface (water level above ground level) or subsurface flow (water level below ground level). Biological, chemical and physical mechanisms act on the root–soil system.
Rotating biological contactor (bio-disc)	The biomass grows adhered to a support medium, which usually composed by a series of discs. The discs, partially immersed in the liquid, rotate, exposing their surface alternately to liquid and air.
Conventional activated sludge	The biological stage comprises two units: aeration tank (reactor) and secondary sedimentation tank. The biomass concentration in the reactor is very high, due to the recirculation of the settled solids (bacteria) from the bottom of the secondary sedimentation tank. The biomass remains in the system longer than the liquid, which guarantees a high BOD removal efficiency. It is necessary to remove a quantity of the sludge (biomass) that is equivalent to what produced. This excess sludge removed needs to be stabilized in the sludge treatment stage. The oxygen supply done by mechanical aerators or by diffused air. Upstream of the reactor there is a primary sedimentation tank to remove the settle able solids from the raw sewage.

Up-flow anaerobic sludge blanket reactor (UASB)	BOD is converted an aerobically by bacteria dispersed in the reactor. The liquid flow is upwards. The upper part of the reactor divided into settling and gas collection zones. The settling zone allows the exit of the clarified effluent in the upper part and the return of the solids (biomass) by gravity to the system, increasing its concentration in the reactor. Amongst the gases formed is methane. The system has no primary sedimentation tank. The sludge production is low, and the excess sludge wasted already thickened and stabilized.
Facultative aerated lagoon	Oxygen supplied by mechanical aerators instead of through photosynthesis. The aeration is not enough to keep the solids in suspension, and a large part of the sewage solids and biomass settles, being decomposed an aerobically at the bottom.
Waste Stabilization Ponds	large, man-made water bodies in which Backwater, greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment.
Facultative pond	Wastewater flows continuously through a pond especially constructed for wastewater treatment. The wastewater remains in the ponds for many days. The soluble and fine particulate BOD is aerobically stabilized by bacteria which grow dispersed in the liquid medium, while the BOD in suspension tends to settle, being converted an aerobically by bacteria at the bottom of the pond. Algae through photosynthesis supply the oxygen required by the aerobic bacteria. The land requirements are high.
trickling filter	Bacteria that grow attached to a support medium (commonly stones or plastic material) stabilize BOD aerobically. The sewage applied on the surface of the tank through rotating distributors.
Anaerobic pond – facultative pond	Around 50 to 65% of the BOD is converted in the anaerobic pond (deeper and with a smaller volume), while the remaining BOD is removed in the facultative pond. The system occupies an area smaller than that of a single facultative pond.
Anaerobic Baffled Reactor (ABR)	Considered as an upgraded septic tank. The ABR consists of an initial settler compartment and a second section of a series of baffled reactors. The baffles used to direct the wastewater flow in an up-flow mode through a series of sludge blanket reactors. This configuration provides a closer contact between anaerobic biomass and wastewater, which improves treatment performance.

2.7. Palestinian Standards for wastewater:

For a long time, Palestine did not have any specific wastewater regulations, references usually made to the WHO recommendations or to the neighbored country's standard (ex. Egypt, Jordan). The Environment Quality Authority with coordination of Palestinian ministries and universities has established specific wastewater reuse regulations. The draft of Palestinian legislation for reuse of treated wastewater is still under study in the Palestinian Standard institute. On the other hand, PWA recognizes the importance of establishing proper Environmental Limit Values (standards and guidelines) for effluent from domestic wastewater treatment plants as well as the industrial standards for wastewater to discharge on the sewage systems. (Arafeh, G., 2012).

Despite meeting the regulation and guidelines, the reuse of wastewater is not entirely a risk-free. Continued research will result in developing new technologies or improving the existent methodologies used for assessment of health risk associated with trace contaminants, evaluation of microbial quality, treatment systems, and evaluation of the fate of microbial, chemical and organic contaminants (Hong, P., 2018).

Table 4: Reclaimed wastewater classification (Arafeh, G., 2012).

Class		BOD_5	TSS	Fecal coliforms
class A	High quality	20 mg/l	30 mg/l	200 MPN/100 ml
class B	good quality	20 mg/l	30 mg/l	1000 MPN/100 ml
class C	Medium quality	40 mg/l	50 mg/l	1000 MPN/100 ml
class D	Low quality	60 mg/l	90 mg/l	1000 MPN/100 ml

The regulations and standards of treated water and effluent requirements differ from one county to another. In Table 5, the Palestinian standards for treated wastewater characteristics according to different applications.

Table 5: Recommended guidelines by the Palestinian standards institute for treated wastewater characteristics according to different applications

Quality Parameter mg/l	Fodder irrigation		Gardens play	Ground water recharge infiltration	Drainage to sea 500m far	Wood land and forests	Fruits
	Dry	Green					
BOD5	60	45	40	60	40	60	45
COD	200	150	150	200	150	200	150
DO	> 0.5	> 0.5	> 0.5	> 0.5	> 1	> 0.5	> 0.5
TDS	1500	1500	1200	1500	1500	1500	1500
TSS	50	40	30	50	50	50	40
pH	6-90	6-9	6-9	6-9	6.0-9.0	6-9	6-9

2.8. Comparison between the wastewater treatment systems:

Presented below a comparative analysis between the main wastewater treatments systems applied to domestic sewage. Table 6 shows the average effluent concentrations of the main pollutants of interest in domestic sewage.

Table 6: The average effluent concentrations of the main pollutants of interest in domestic sewage (Ortage, S., 2021)

system	BOD5 (mg/L)	COD (mg/L)	SS (mg/L)	Ammonia (mg/L)	Total N (mg/L)
Primary treatment (septic tanks)	200–250	400–450	100–150	>20	>30
Facultative pond	50–80	120–200	60–90	>15	>20
Anaerobic pond + facultative pond	50–80	120–200	60–90	>15	>20
Facultative aerated lagoon	50–80	120–200	60–90	>20	>30
Anaerobic pond + facultative pond + high rate pond	40–70	100–180	50–80	5–10	10–15
Slow rate treatment	<20	<80	<20	<5	<10
Rapid infiltration	<20	<80	<20	<10	<15
Overland flow	30–70	100–150	20–60	10–20	>15
Constructed wetlands	30–70	100–150	20–40	>15	>20
Septic tank + anaerobic filter	40–80	100–200	30–60	>15	>20
Septic tank + infiltration	<20	<80	<20	<10	<15

system	BOD5 (mg/L)	COD (mg/L)	SS (mg/L)	Ammonia (mg/L)	Total N (mg/L)
UASB reactor	70–100	180–270	60–100	>15	>20
UASB + activated sludge	20–50	60–150	20–40	5–15	>20
UASB + anaerobic filter	40–80	100–200	30–60	>15	>20
UASB + high rate trickling filter	20–60	70–180	20–40	>15	>20
UASB + facultative aerated pond	50–80	120–200	60–90	>20	>30
UASB + overland flow	30–70	90–180	20–60	10–20	>15
Conventional activated sludge	15–40	45–120	20–40	<5	>20
Activated sludge – extended aeration	10–35	30–100	20–40	<5	>20
Convent. Activated sludge with biological N removal	15–40	45–120	20–40	<5	<10
Convent. activated	15–40	45–120	20–40	<5	<10
Conventional activated sludge + tertiary	10–20	30–60	10–20	<5	>20
Rotating biological contactor	15–35	30–100	20–40	5–10	>20
Low rate trickling filter	15–40	30–120	20–40	5–10	>20
High rate trickling filter	30–60	80–180	20–40	>15	>20

Chapter Three:

3. Methodology

For local decision makers, selecting the most appropriate sanitation technology that suitable for surrounding environments complex. Wastewater treatment systems are linked to many factors (politics, technical, land used and others) and depend on different criteria such as (topography, water consumption, population density and so on.).

(Louis and Bouabid) develop a method that helping users to decide wastewater treatment options, it depends on the available capacities and community requirements. (Ahmad, T., 2004) Developed evaluation model that classify the sanitation technologies into deferent levels depend on four criteria, in this research, these models used to develop comprehensive modified model to connect between both models that fit Palestinian Communities Characteristics. The components of classification model shown in (Figure 2):

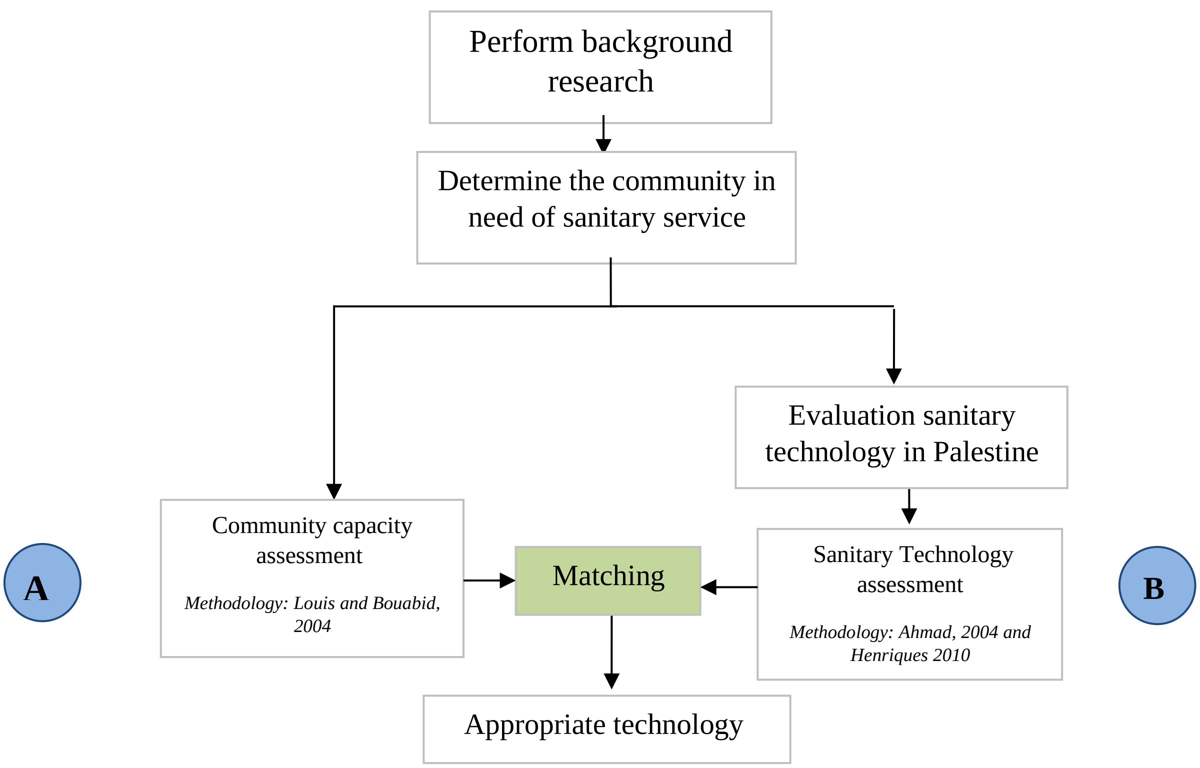

Figure 2 : components of classification system

The research connects between the community capacities (A) with the sanitary technologies (B) to achieve the greatest possible benefit.

After select the most appropriate technologies, some options may have the same level so many technologies will selected. To avoid this obstacle and to reduce the options, other parameters will added that reduce these possibilities. Each community needs for the treated wastewater differently for other communities, some of them used it for irrigations and others need it for industrial activities. Wherefore, the treated wastewater's quality will be the judge to differentiate the options. For example, if we have a community with level three of development, and we have two technologies have the same level. The logic says that both options are valid for this community, but, every technology has different uses depend on the treated wastewater quality, so BOD, COD, TP, TN, SS and TDS will have used to reduce the number of option depend on the community needs.

3.1. Community capacity level (CCL)

(Bouabid, A. & Louis, Garrick. 2015) suggest a tool for lower income counties to be a decision making in which the stakeholders can assess community's ability to manage and sustain their water and sanitation services.

Louis and his colleagues from the University of Virginia (Ahmad, T., 2004);(Bouabid, A. 2004); (Bouabid, A. & Louis, Garrick. 2015) have developed a methodology to determine the level of community development that relates to water and sanitation projects. (Bouabid, A. 2004) noted that services may include:

• **Drinking water supply (DWS),** its includes “the construction, operation and maintenance of public water systems, including production, acquisition and distribution of water to the general public for residential, commercial and industrial use”;

• **Wastewater and sewage services (WSS),** defined as “the provision, operation and maintenance of sanitary and storm sewer systems, sewage disposal and treatment facilities”;

• **Management of solid waste (MSW),** which defined as the process of collecting, removing and disposing of hazardous wastes and other wastes in a manner that preserves human health and reduce the negative environment impacts.

Community capacity level (CCL) analysis methodology defined as the properties that determine the community capacity to manage and operate its municipal sanitary services MSS “the community maybe consider single house, residential building, factory or whole city depends on the needs". This approach based on analysis eight main capacity factors that affect the community ability to manage and operate MSS: Institutional, Human Resources, Technical, Economic and Financial, Environmental and Natural Resources, Energy, and Social and Cultural as shown in figure 3. The CCL methodology relies on a set weight for each CFs; each CF has its own requirements and this requirement different for each service option. All the requirements for that same CF has the same weight. To calculate the capacity factor (CF) for each category all requirements for this category are collected. Thus, calculate a Community Capacity Level (CCL).

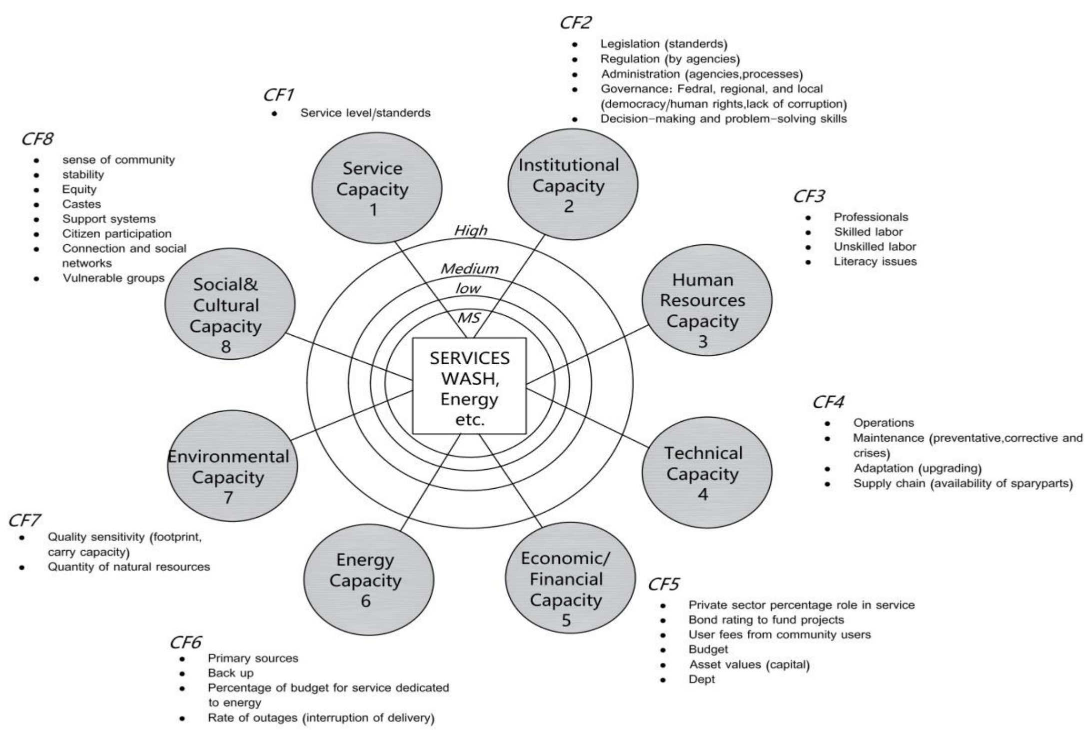

Figure 3 : Categories of Community Capacity (Louis and Bouabid, 2004)

For example, suppose we have technical categories for DWS, and it consists of four requirements, operation, maintenance, adaption and supply chain. Each requirement divided into five groups from scale 1-100, and each group has 20 points. Each group has its description as shown it (Table 7).

Table 7: Breakdown of Technical Capacity Factor into Four Components for Drinking Water Supply

`	Score	1-20	21-40	41-60	61-80	81-100
4	Technical Capacity					
C41	Operations	Manual collection and untreated water use	Pumping water	Pumping water Control water quality	Monitor water system Control water quality Control pipes	Monitor water system Control water quality Control pipes network Monitor treatment
C42	Maintenance	None	Disinfection Minor repair	Check water systems major repair	Check/maintain water systems Major repair Maintain pipes	Check/maintain water system Check/maintain network Check/maintain water meter
C43	Adaptation	None	Rarely	Occasionally	Usually	Frequently
C44	Supply Chain	None	National supplier	Regional supplier	National manufacturer Regional supplier	National manufacturer Local supplier

Source: Bouabid, A.& Louis, Garrick. (2015)

The capacity factor CF4 calculated by weighted average of its requirement ratings C4j, by using the following formula;

$$CF_4 = \Sigma C_{4j}\ wj\ (j=1, 4)$$

Where w_j is a weighting factor associated with requirement rating C_{4j}.

In general, for each one of the eight factors (i=1-8) represented in figure 3 have to calculate its score by using the following formula;

$$CF_i = \Sigma\ C_{ij}w_j\ (i=1\text{-}8 \text{ and } j=1, ni)$$

Where $n_i$is the number of requirements for each capacity factor CF_i.

Finally, the community development level is determining by taking the lowest score of the capacity factor for eight categories.

$$CCL = \min(f_i)\ .\ i=2,..,8$$

According (Bouabid, A.& Louis, Garrick. 2015), community development level classified into five level regarding the municipal sanitation service. The overall score for the community capacity converts into 1-5 development stage using (Table 8).

Table 8: Conversion and Community Stages of Development

Score CA	CCL	Stage/Interpretation	Community profile description
0-20	1	High Entropy	Initial stage where there is no formal public service provided
21-40	2	Pre-Community	Limited local service provided with no regulatory or administrative control
41-60	3	Community-Based	A mix of public and informal private service is provided with minimal controls
61-80	4	Centralized	Regional public service is provided with adequate controls
81-100	5	Diversified	Regional public and selective private service is provided with improved controls

Source: Bouabid, A. & Louis, Garrick. (2015)

3.1.1. Community's development stages:

Each community has its properties and needs, there are communities vary in their lifestyles, some of them depend on agriculture practice for their life and some of them working in raising cattle and others depend on industrial sector…etc. in this research, communities were classified into five stages. The following stages represent the level of support needed to properly implement and maintain the wastewater treatment technologies. The community assessment below evaluated from Ali Bouabid's research (Capacity Factor Analysis for evaluating Water and Sanitation Infrastructure choices for Developing Communities, 2015).

1. **Stage 1 (initial community)**: the community don't recognize the issue as a problem and there is no organization at any level.
2. **Stage 2 (pre-community)**: There is a general feeling among some in the community that there is a local problem and that something ought to done about it.
3. **Stage 3** (**Community- Based**): This stage occurs when a distinct group of people who follow some regulations and forms.
4. **Stage 4 (centralize community)**: occur when the community follow a leadership. This leadership governs many community groups.
5. **Stage 5 (decentralize community)**: occur when the activities of an organization, particularly those regarding planning and decision making, are distributed or delegated away from a central but to a few different groups.

3.1.2. Requirements for the Modified-CFA for developing communities.

In this part, the requirement for the modified CFA (Capacity Factor Analysis) will discuss. The mod-CFA content the same original capacity factors (eight CFs). However, the requirement under each CF are slightly different, may added or deleted some requirement depend on community properties.

1. Service capacity factor

This factor refers to the service that the community receive. In addition, shows the gap between the actual level of service provided and the imposed level. According to (Bouabid, A., 2004), he recommended that the wastewater treatment technology should be treat 80-90% of received water (e.g., 32–45 L/person/day). Also, according to (Henriques, J., 2008). The service capacity factor is dividing into five levels as follows;

Table 9: Service Capacity Factor requirement

1	**service capacity**						wj
C11	**effective service level**	<20 l/p/d	20-40 l/p/d	40-60 l/p/d	60-80 l/p/d	80-100 l/p/d	1
f1	**score**					$\sum C_{1j}w_j$	1

2. Institutional capacity factor

This factor identifies the components of the institutional structure that must exist to provide the services. In case of sanitation system failures, many causes fall under the responsibility of an overseeing set of institutional bodies. The institutional factor discusses the possible area where the institution can fail and affect the whole system. As such, the following requirements where identified under the Institutional CF.

Table 10: Institutional Capacity Factor requirement

2	**Institutional Capacity**						w_j
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	0.20
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	0.20
C_{23}	**Administrative agencies**	None	Nation	Regional	State	Village, city , town	0.20
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	0.20
C_{25}	**Partnership with NGOs**	None	Low	Medium	High	Very High	0.20
f_2	**Score Institutional Capacity**					$\sum C_{2j}w_j$	***1***

The Body of Legislation refers to the existing recognized Palestinian standards for wastewater in the area of interest from collection, transfer, treatment and disposal in area study. ***Associated regulations*** is laws that control the dealing with sanitation in the study area for sustain, clean and safe environment. ***Administrative agencies*** refer to efficiency of the administrative is to meet the sanitation's safety, quality, and management needs. ***Administrative processes*** are reflecting the efficiency of the authorities in performing their duties and implementing the enforces the regulations of treatment process in study area. ***Partnership with NGOs*** is a borrowed requirement from (Pailla, S. and Louis, G., 2011).and is reflects the communications and cooperation between the NGOs and the institute who run the sanitation services.

3. Human resources capacity factor

This factor relates to the quality of work and workers that is available to provide services as well as the level of training. The proposed modified requirements for the Human resources CF presented in (Table 11).

Table 11: Human resources Capacity Factor requirement

3	**Human Resources Capacity (service provider)**						w_j
C31	**Professionals**	None	Accountant	Administrative supervisor Health Scientist Accountant	Administrative manager Health Scientist Engineer Accountant	Administrative manager Health Scientist Engineer Lawyer Public relations manager Accountant	0.20

<table>
<tr><th>3</th><th colspan="6">Human Resources Capacity (service provider)</th><th>w_j</th></tr>
<tr><td>C_{32}</td><td>Skilled Laborers</td><td>None</td><td>Mechanic</td><td>Maintenance technician
Laboratory technician
Plant Operator</td><td>Maintenance technician
Laboratory technician
Plant Operator
Health inspector
Administrative assistant</td><td>Maintenance technician
Laboratory technician
Plant Operator
Health inspector
Administrative assistant</td><td>0.20</td></tr>
<tr><td>C_{33}</td><td>Unskilled Laborers</td><td>Guard</td><td>Guard
Mechanic assistant</td><td>Guard
Mechanic assistant
Driver</td><td>Guard
Mechanic assistant
Driver</td><td>Guard
Mechanic assistant
Driver</td><td>0.20</td></tr>
<tr><td>C_{34}</td><td>Access Higher Education</td><td>None</td><td>State</td><td>Regional</td><td>District</td><td>Town, village, city</td><td>0.20</td></tr>
<tr><td>C_{35}</td><td>* Training</td><td>None</td><td>Low</td><td>Medium</td><td>High</td><td>Very High</td><td>0.20</td></tr>
<tr><td>f_3</td><td colspan="5">Score Human Resources Capacity</td><td>$\sum C_{3j}w_j$</td><td>1</td></tr>
</table>

** added by Author*

Almost all the above requirements taken from (Henriques, J., 2008). ***Professionals*** who are the most directing involved in sanitation processes such as engineering, management. ***Skilled laborers*** are who responsible for operate and maintain the treatment processes such as, electrician, and technician. ***Unskilled laborers***, who have basic knowledge about the maintenance such as cleaners, plumbers. ***Access higher education*** is a borrowed requirement form (Pailla, S. and Louis, G., 2011) and it is reflect the importance to access the schools, universities to spread the awareness about sanitations. ***Training*** is added requirement that looking at the continuous training for the staff.

4. Technical resources capacity factor:

This factor related to the logistical issues needed to address the components of the sanitation system that are in the implementation phase. The proposed modified technical requirements are shown in (Table 12), and all requirements taken from (Henriques, J., 2008).

Table 12: Technical capacity factor requirement

4	**Technical Capacity**						***w_j***
C_{41}	**Operations**	Water Use	Pumping Water	Pumping Water Control Water Quality	Monitor treatment systems Control influent Quality	Monitor treatment systems Control influent Quality Monitor pipes network	0.25
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Check treatment systems Major repair Maintain pipes	Check treatment systems Check/maintain network Check/maintain meter Maintain IT systems	0.255
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	0.25
C_{44}	**Spare parts**	None	Low	Medium	High	Very High	0.25
f_4	***Score Technical Capacity***					**$\sum C_{4j} w_j$**	1

Operations in sanitation system, the main operation are collection, transfer, treatment and disposal, where the treatment is the most important phase. ***Maintenance***, each treatment technology has its own characteristics of maintenance. Some of it need simple maintenance, and some of it need complex maintenance. ***Adaptation*** it refers to the capability of the system to upgrade to meet the community needs in the future. Also to keep pace with technology development. ***Spare parts*** it refers to the availability of spare part of the treatment technologies in local or regional markets.

5. Economic and financial capacity factor:

It refers to the economic capability for the community to financial the sanitation technology and sustaining its own water infrastructural system. In most rural communities, the financial capability is low.

Table 13: Economic and Financial Capacity factor requirement

5	**Economic and Financial Capacity**						w_j
C_{51}	**Private sector investment**	None	Low	Medium	High	Very high	0.143
C_{52}	**Bonds Rating**	None	Low	Medium	High	Very high	0.143
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Increasing block rate	0.143
C_{54}	**Budget**	None	Basic	Annual	quarterly	Monthly	0.143
C_{55}	**Asset values**	None	Real estate	Real estate	Real estate	Real estate	0.143
C_{56}	**Debt**	Very High	High	Medium	Low	None	1.423
C_{57}	***Willing to use and pay**	None	Low	Medium	High	Very High	0.143
f_5	***Score Economic and Financial Capacity***					$\sum C_{5j}w_j$	***1***

** added by Author*

Private sector investment, the percentage of private sector contribution in wastewater treatment processes in case they allow providing this services to the community. ***Bonds Rating*** is referring to the economical capacity for the municipality to invest in wastewater treatment processes. ***User fees*** it refers to the monthly fees that collect from the users in the community to pay for the services. ***Budge*** the tool that used in accounting to manage the budget of the service. ***Asset values*** is referring to the monetary value that the community have. This may support the sustainability the life of the service. Such as; money, real estate and equipment. ***Debt*** The ratio of debt of the community in relation to its Asset values. ***Willing to use and pay*** is an added requirement form author and it is reflect the desire and ability of the community to use sanitation system and pay fees for it.

6. Energy capacity factor:

This factor is one of the most important factors to evaluate the community's capacity to adapt to higher-level technological solutions energy capacity deals with existing energy, its availability, costs, and reliability to provide sanitation services. Electricity needed in most of sanitation service unit options to operate the pumps and generators. However, most of rural community do not have the ability to offer this service without power outage. So that, energy factor considers a challenge for rural communities. The requirements chosen for evaluation are as follows in (Table 14). All of these requirements were taken from **(Henriques, J., 2008)**.

Table 14: Energy capacity factor requirement

6	**Energy Capacity**						***w_j***
C_{61}	**Primary source**	None	Non-conventional	Conventional electricity	Electricity mid-voltage	Electricity high voltage	0.25
C_{62}	**(Back up) Alternative source**	None	Generator > 10 HP	Generator < 10 HP	Generator < 50 HP	Generator > 50 HP	0.25
C_{63}	**Percentage of energy budget**	Very High	High	Medium	Low	Very low	0.25
C_{64}	**Outage power rate**	Very High	High	Medium	Low	Very low	0.25
f_6	**Score Energy Capacity**					$\sum C_{6j} w_j$	**1**

Primary source is referring to the availability of primary energy source to operate the treatment process such as electricity. ***Back up*** is referring to the availability of alternative power source in case the primary source turned off. ***Percentage of energy budget*** is referring to the share of energy from the total cost of the treatment process. ***Outage power rate*** refers to threat of outage in the power source in study area.

7. **Environmental and ecological capacity factor:**

The Environmental and ecological CF show significant change from the original CFA, including from its original name "Environmental and Natural Resources" (Henriques, J., 2008). As such, the mod-CFA recognized this need and expanded the Environmental and Ecological CF to include multiple requirements, such as the stakeholder's general awareness of their ecological system, the size of the natural resource system itself, and the predictability of those resources over the future. Refers to the availability of natural resources to implement sanitation technology, the capacity of the environment, the level of pressure it can hold, and ensure that services do not significantly affect or deplete natural resources. As such, the following requirements in (Table15) must be evaluate.

Table 15: Environmental and Ecological Capacity factor requirement

7	**Environmental and Ecological Capacity**						w_j
C_{71}	**Environment quality/Sensitivity**	Very low	Low	Medium	High	Very high	0.5
C_{72}	**Quantity**	Very low	Low	Medium	High	Very high	0.5
f_7	**Score Environmental Capacity**					$\sum C_{7j}w_j$	***1***

Environment quality/Sensitivity is referring to the ability of the environment to hold out the pressure from the wastewater generated by the community. ***Quantity*** is referring to the availability of sites to construct the wastewater treatment plants in the study area without any damages of the environment

8. **Social-Cultural capacity factor:**

The Social-Cultural CF is incredibly relevant in assessing a community's capacity for a technology solution. Its deals with the community components and structure, the social networks, its capacity of organization, the households and their interactions, and gender and equity issues. Following (Table 16) shows the requirements for this CF.

Table 16: Social and Cultural capacity factor requirement

8	**Social and Cultural Capacity**						***w_j***
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	0.25
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	0.25
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	0.25
C_{84}	**Leadership/entrepreneurship**	Very low	Low	Intermediate	High	Very high	0.25
f_8	**Score Social-Cultural Capacity**					**$\sum C_{8j} w_j$**	**1**

Communities refers when the community in study area connected and organized. ***Stability*** it refers to existing a system of buildings in the community, also to stability of the residents inside the community. ***Equity***, when all members of the community have the same right of using the wastewater treatment facilities within the community. ***Leadership/entrepreneurship*** when the community support the entrepreneurs.

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3.2. Technology level assessment (TLA)

The decision regarding the wastewater treatment process to be consider should be come from a balance between the eight factors. Taking into account quantitative and qualitative aspects of each alternative (Sperling, M., 1996).

In this chapter, two rules will have used to evaluate the technologies, the first one is by using modified-CFA, because it's not enough to evaluate the technology by assess the community capability to run this technology, the community must met have the minimum requirement for the technology to reduce the failure. The technology must be evaluate according each requirement to determine the level that have to meet in order the option work appropriately. The rule is as following:

$$\mathbf{CCL \geq TLA}$$

$$\mathbf{TLA = max\ (}\boldsymbol{f_i}\mathbf{)}$$

The second rule is by using five criteria to evaluate the technology as shown in the methodology:

Once after measuring the community development stages by using community capacity analysis methodology CCL. The next step is check whether the proposed technology or solution match the level of the community. This can be done by following the steps in the figure 4.

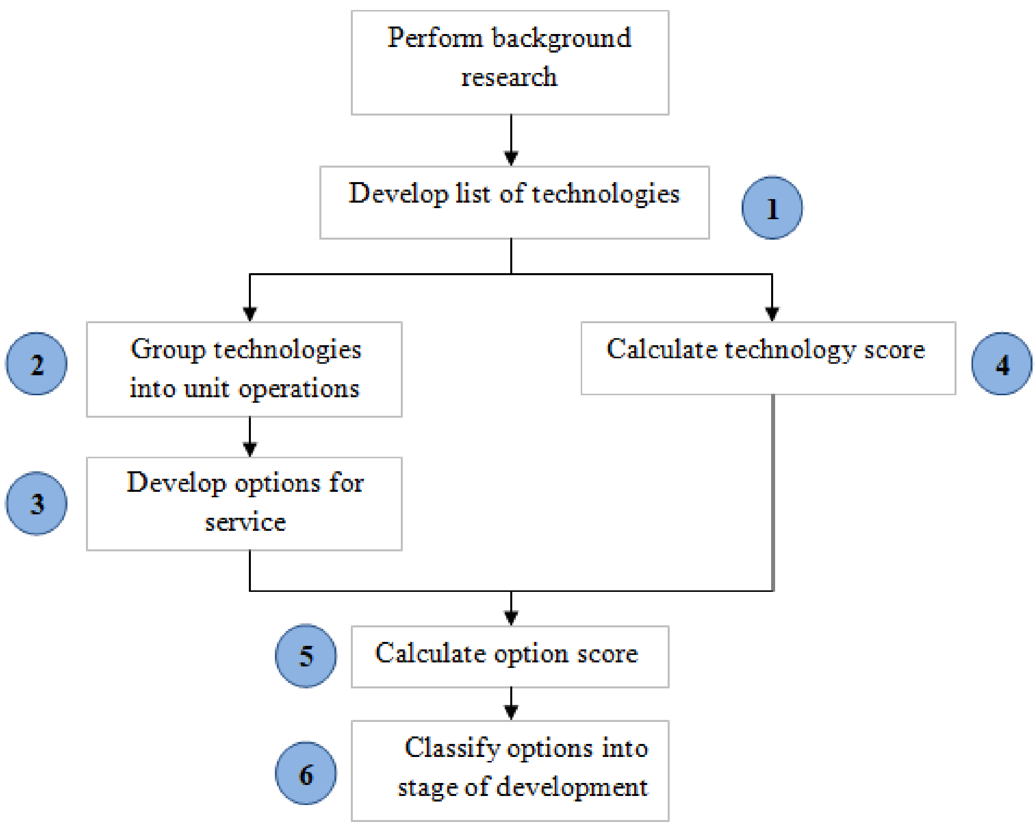

Figure 4 : Six Steps in Technology Assessment.

Source: (Ahmad, T., 2004)

In the first step is to develop a list for all possible technologies that may use for the service option. In step 2, all technologies consist of unit operations or process that contribute to the provision of that service. For wastewater and sanitary service WSS, there are four-unit operations: collection, transfer, treatment, and disposal. However, in this, the treatment option will be evaluate and other options will be ignoring because the treatment phase is more important and the critical step in wastewater treatment. (Table 17) shows operations for WSS.

Table 17: unit operations for WSS.

Collection	Transfer	Treatment	Disposal
None Bucket Vault/Cartage Septic/Tank	None Small bore/settled sewerage Conventional sewerage Drainage field	None Constructed wetlands Soil aquifer treatment Oxidation ditch Rotating biological contractor Trickling filters Up-flow anaerobic sludge blanket Activated sludge process Stabilization ponds	Burial Composting Pit privy Ventilated improved pit latrine Double vault compost latrine Aqua privy Pour flush toilet Cistern flush toilet Drainage field

Source: Ahmad 2004

In step 3, each operation consists of many technologies or service options that may use for the same need. A service option is defined as “a series of technologies that when used together, lead to the provision of a municipal sanitation service” (Ahmad, T., 2004). The number of service options is large. They include 1,296 WSS service options, but not all of it can be use and should be minimize. As shown in table 3 above.

In step 4, based on (Ahmad, T., 2004) each technology in service option can be rated and evaluated based on four criteria. Cost, energy, institutional capacity, technical requirements factors. However, in this research land requirement will added to the evaluation criteria because the land in Palestine is limited and has its very important in planning phase. Finally, each criterion has three levels. Low, Medium and High (Ahmad, T., 2004).

1. Cost:

This criterion takes in account the initial cost, operation and maintenance cost. The price it will be in Israeli shekel.

- Level 1- Low cost
- Level 2 - Moderate cost
- Level 3 – High cost

2. Energy consumption

This criterion accounts the energy requirement of the technology, its measure the amount of electricity power we need to operate the system.

- Level 1- Low energy requirement
- Level 2 - Moderate energy requirement
- Level 3 – High energy requirement

3. Technical requirement

Technical requirement defines as the minimal functional indicators of the solution. For instance, for wastewater treatment this may be the minimal required effluent quality (Balkema, A.J. et al, 2002). In addition, it can be defining as measuring the mount of knowledge that is needs to install, operate and maintenance a given system.

- Level 1- Low technical requirement
- Level 2 - Moderate technical requirement
- Level 3 – High technical requirement

4. Institutional capacity

Each wastewater treatment systems will require different regulations and control mechanisms. These requirements should be compatible with the existing institutional infrastructure of the community (Balkema, A.J. et al, 2002). Determine by the type of the organization that will be manage and operate the technology.

- Level 1 – No formal organization needed/Low level of organization (e.g. water committee)
- Level 2 – Moderate level of organization (e.g. community level organization, community representatives)
- Level 3 – High level of organization (e.g. governing board)

5. Land requirement:

This criterion added because of the importance of land in Palestine. The reason for a limited land space requirement is that land issues are always a problem and must be handle carefully. In a village, many families each may own land claiming their own piece. This family ownership does not only include the immediate family, but encompasses the extended family as well, resulting in many people owning a piece of land. Land secured for waste treatment would be difficult to obtain. This is also place high on the list because often there is limited land available and this needs to be take into account when choosing a technology. Although this would restrict our options, limited land availability most often cannot overcome. Moreover, most than 65% of Palestine state classify as C area, where under Israeli Control.

- Level 1- Small land requirements
- Level 2 - Moderate land requirements
- Level 3 – High land requirements

Once we have value for all of the technologies, we assign points. The criteria are summarize on the (Table 18). This table shows the mapping of the criteria to the various levels.

Table 18: the evaluation criteria and deferent level

Level	Level 1	Level 2	Level 3
Cost	Low cost	Moderate cost	High cost
Energy	No or minimal energy requirement	Medium energy requirement	High energy requirement
Technical	Low level of technical knowledge	Medium level of technical knowledge	High level of technical knowledge
Institutional	No formal organization needed	Moderate level of organization	High level of organization
Land requirement	Small land	Medium land	Large land

After classifying the technologies into levels, each level represents by number as shown in the (Table 19). Then, to calculate the overall technology's score, all factor must be combined then divide by 50.

Table 19: Points for Technology Score

Level	Points
Low	1
Medium	5
High	10

Planning, designing and implementation of sanitation systems faces many aspects, it includes technical and nontechnical aspects. Malfunction of technologies strongly affected by many of non-technical issues. Technical requirements take into account for counter the identified challenges on a technical basis, however non-technical requirement (Financial and public health) issues must be consider in the background of technologies. So that, technical and non-technical requirements complement each other.

Chapter Four:

4. Results and Discussion

4.1. Technology Alternative Capacity Level Assessment

4.1.1. By using Modified-CFA.

In this chapter, set of alternative treatment technologies assessed by using technology level assessment (TLA). These technologies were use in Palestine as centralized and decentralized plants. Just a small set of technologies will be evaluate in order to check the research's model. After evaluating each technology, the results will present in a radar graph because this graph provide clear scale to understand the advantages and disadvantages of each technology.

4.1.1.1 Activated sludge technology

The activated sludge process is one of several biological alternatives of wastewater treatment. When the activated sludge added to the wastewater, the organisms in the mixed water start quickly decomposing the waste in wastewater. After required ventilation period in the ventilation tank, the mixed liquid usually flows into a separate tank called the clarifying tank, where activated sludge allowed settling and the remaining liquid drained as treated wastewater as shown in (**Figure 5)**. Stable sludge is either disposed of in activated sludge or Re-used in the aeration tank as a booster sludge. Some sludge should always be return to ventilation tanks to maintain a sufficient number of organisms.

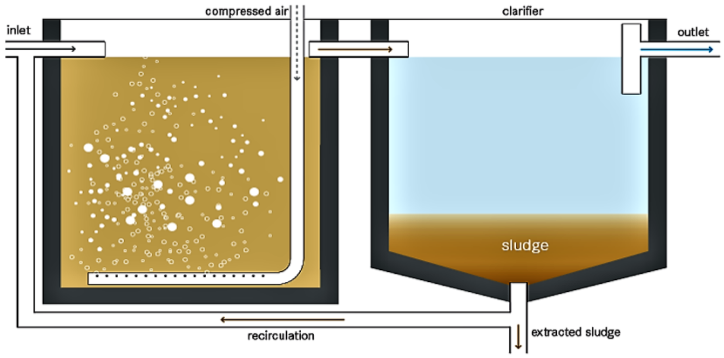

Figure 5 : Typical scheme of activated sludge system.

Source: (Tilley, E. et al. 2014)

The main advantages of this technology is that it has low installation cost, good quality effluent and low land requirement. Otherwise, it has many disadvantages such as, high operation cost; sludge disposal is required large area, not suitable for industrial waste and need high technical requirement. Given this set of experiences, the TLA of activated sludge technology is calculated, and **(Figure 6)** shows the summary.

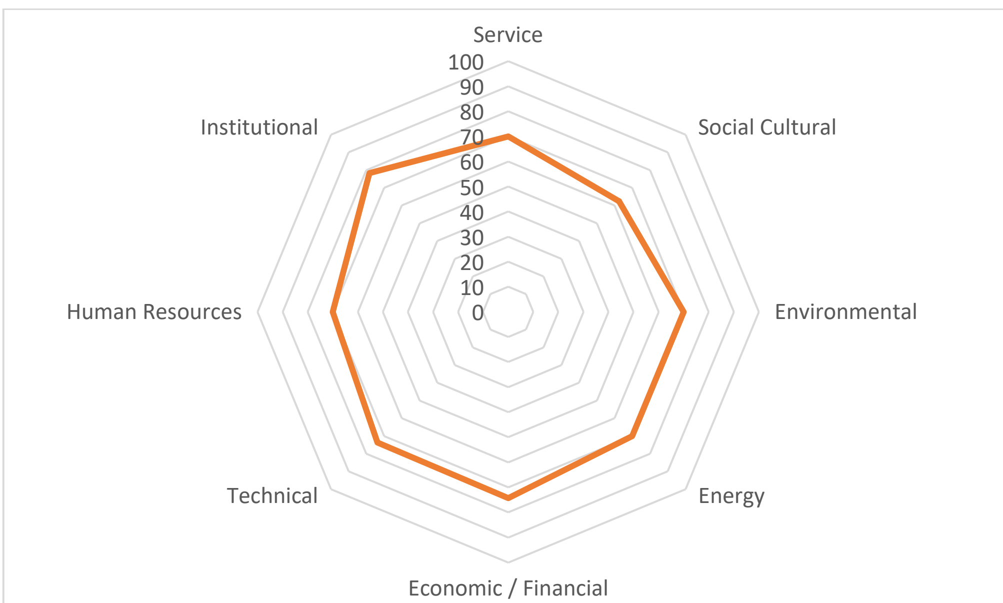

Figure 6 : Technology Capacity Level of Activated Sludge.

The community must have the minimum requirements for the technology to reduce the failure; from the Figure 6 above the maximum capacity factor is institutional with capacity factor 78%. Therefore, the TLA for Activated sludge is stage four.

4.1.1.2 Lagoons technology

Lagoon systems is one of the most popular treatment technologies around the world. Moreover, it considers one of the simple stand least expensive. Moreover, it has low energy consumption while they used the natural energy for wastewater treatment. In addition, one of the most cost-effective wastewater treatment options for many homes and communities.

There are many types of lagoons treatment technologies. Lagoon technologies consist of one or more ponds that designed to receive, hold and treat the wastewater. Wastewater in the lagoon receive treatment by combination of physical, chemical and biological processes as shown in **(Figure7)** below. Usually the treatment happened naturally, but some technologies used an aeration device to increase the efficiency of the treatment by adding more oxygen. In the construction of the lagoon systems, clay and an artificial liner used to prevent the wastewater leak to the ground water. The summary of its TLA shown in **(Figure 8)**.

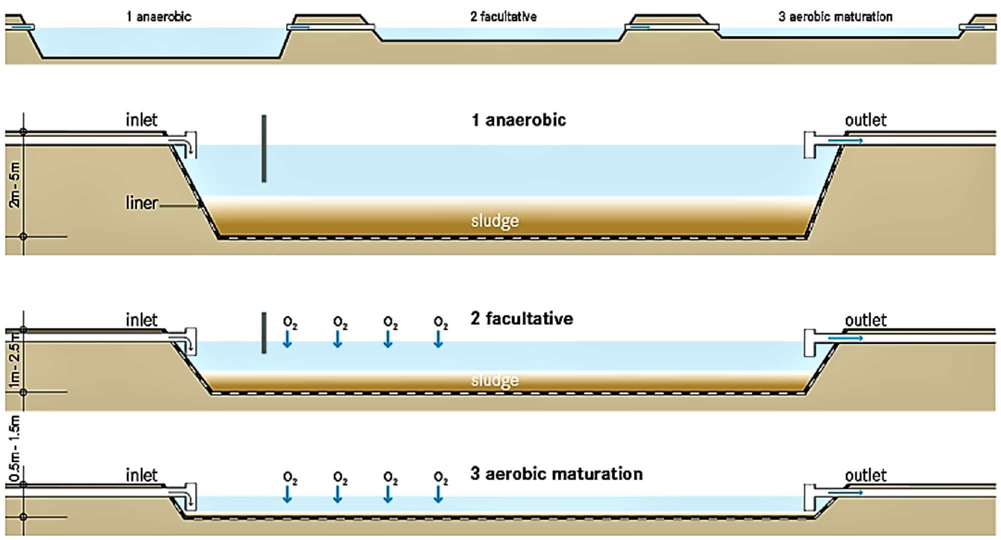

Figure 7 : Typical scheme of Lagoon system.

Source: (Tilley, E. et al. 2014)

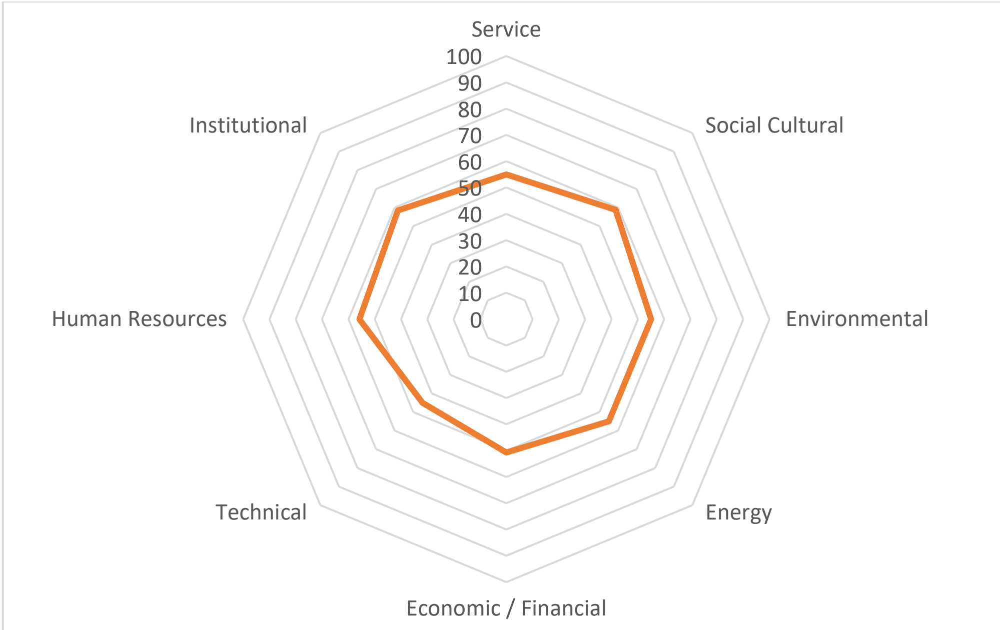

Figure 8 : Technology Capacity Level of Lagoon.

4.1.1.3 Constructed wetland technologies:

1. **Vertical constructed wetland technology**

In vertical constructed wetland (VFCW), the wastewater drained from the bottom of the pond. The pre-treated wastewater enters onto the surface of the pond by mechanical systems to spread the wastewater all above the area. Then, the wastewater flows vertically through filters like gravels with different sizes where the wastewater treated by combination of physical and biological processes. After that, the treated water collected by drainage pipes as shown in (Figure 9) below. The treated water can used for irrigation or recharge the groundwater and surface water. The different between vertical and horizontal constructed wetland not just the way of wastewater flows, but also the aerobic conditions.

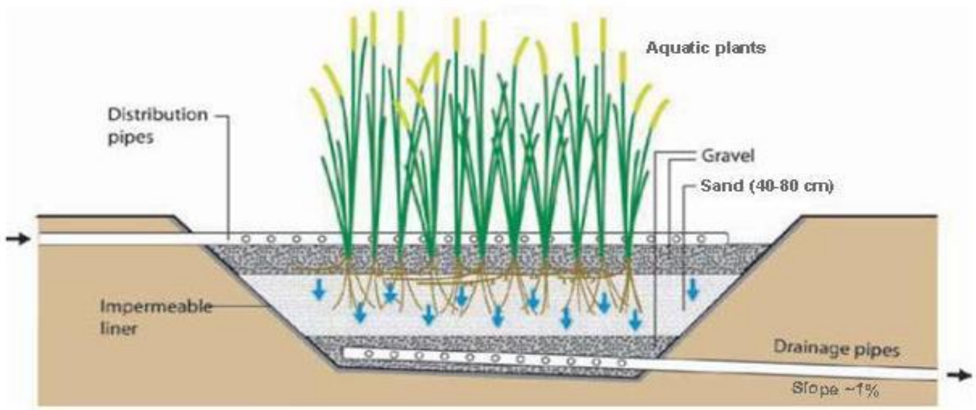

Figure 9 : Vertical constructed wetland technology.

Source: (Morel, A.; Diener, S. 2006).

2. Horizontal constructed wetland technology

Horizontal constructed wetland (HFCW) is the same with vertical constructed wetland, but the pre-treated wastewater flows in horizontal direction through a planted filter bed where the plants provide the proper environment for the organisms by transfer the oxygen to the root zone. Solid and organic matter are remover by filtration process as shown in (Figure 10).

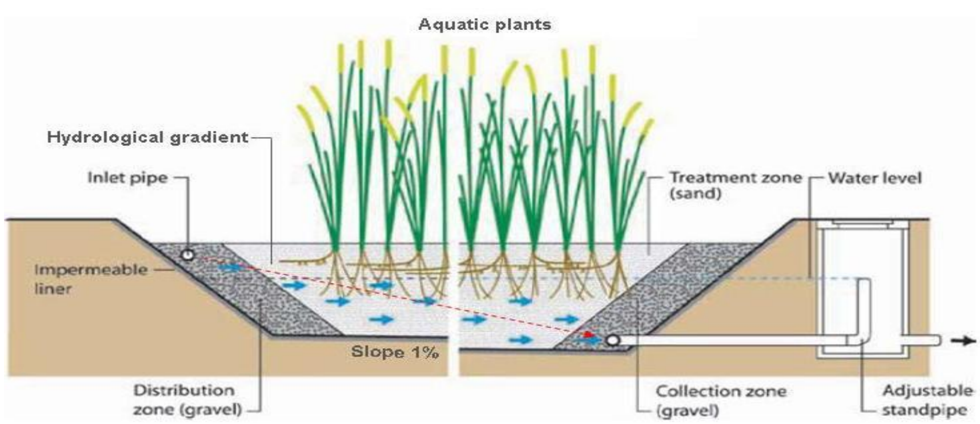

Figure 10 : Horizontal constructed wetland technology.

Source: (Morel, A.; Diener, S. 2006).

Both of HFCW and VFCW are natural system, which mean they required more land and time to treat the water. However, it characteristics with low cost because of low operation and Maintenance cost, where non-skilled people can operate it. Moreover, it required no or little energy for operation. In addition, non-skilled people can operate and maintain these technologies because there are no needs for spare parts. The TLA for HFCW and VFCW are shown in (Figure 11) and (Figure 12) respectively.

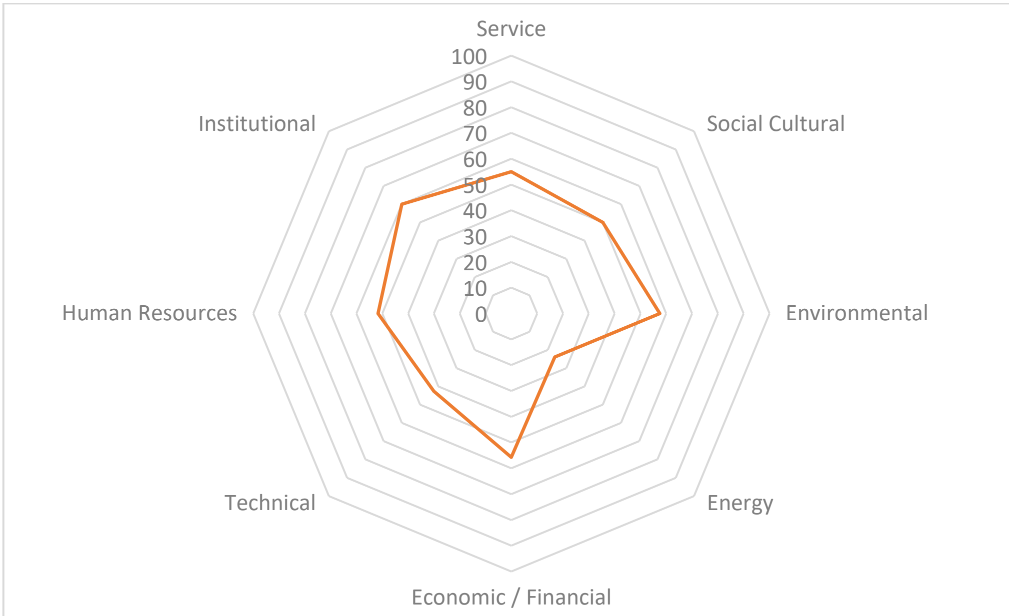

Figure 11 : Technology Capacity Level of HFCW

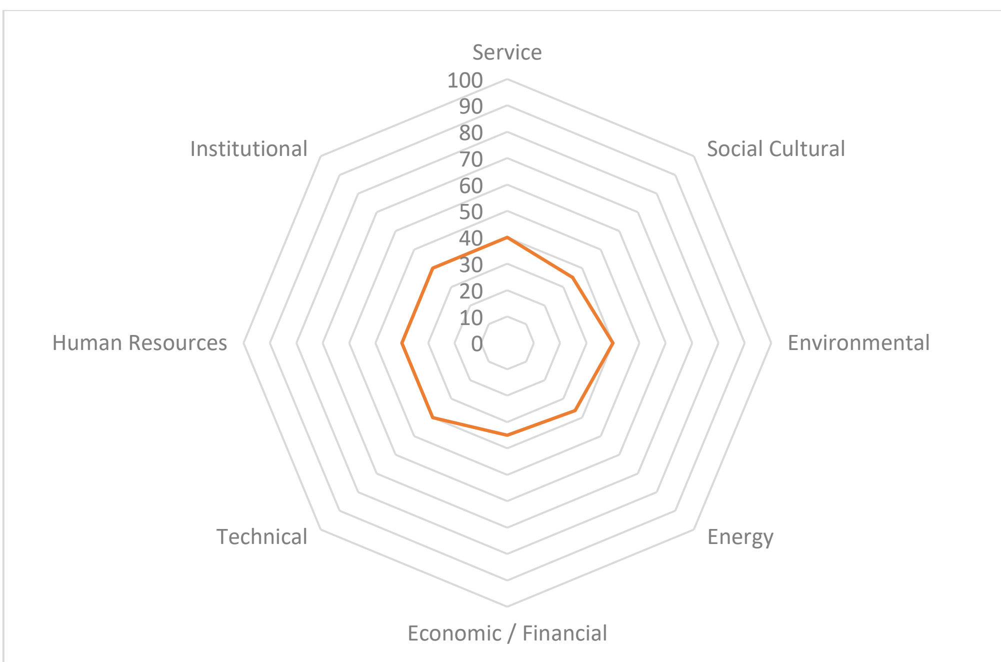

Figure 12 : Technology Capacity Level of VFCW

4.1.1.4 Up-flow anaerobic sludge blanket reactor

The up-flow anaerobic sludge blanket reactor (UASB) consist of single tank. Where the wastewater enters from the bottom, flows upward, the suspended sludge works on treat, and filter the wastewater while it flows. The microorganisms are degraded form organic matters that comprised of microbial granules. Through the breathing process of the microbe's gases are released, which rising bubbles that mix with sludge without any mechanical parts. The slope of the tank at the top prevent the material to reach the top then goes downward again. Finally, the treated water flows through drainage pipes at the top of the tank as shown (Figure13).

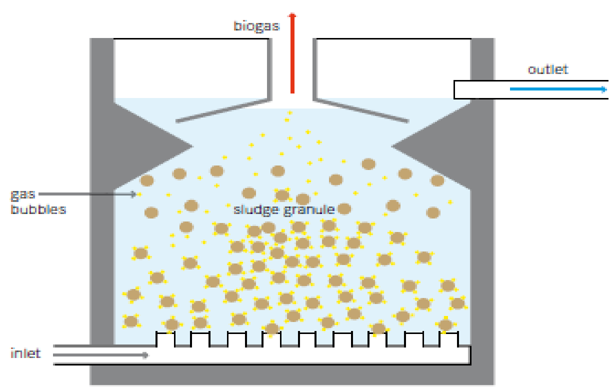

Figure 13 : Up-flow anaerobic sludge blanket reactor technology.

Source: (Tilley, E. et al. 2014)

UASB is not appropriate for small or rural communities without water and energy supply. Because it required constant low energy supply. Moreover, the land requirements are small. In addition, UASB has the potential to produce high quality effluent. The UASB is a Centralized technology that must be operate and maintain by experts. A skilled operator is required to monitor the reactor and repair parts. TLC for UASB calculated as shown in the (Figure 14).

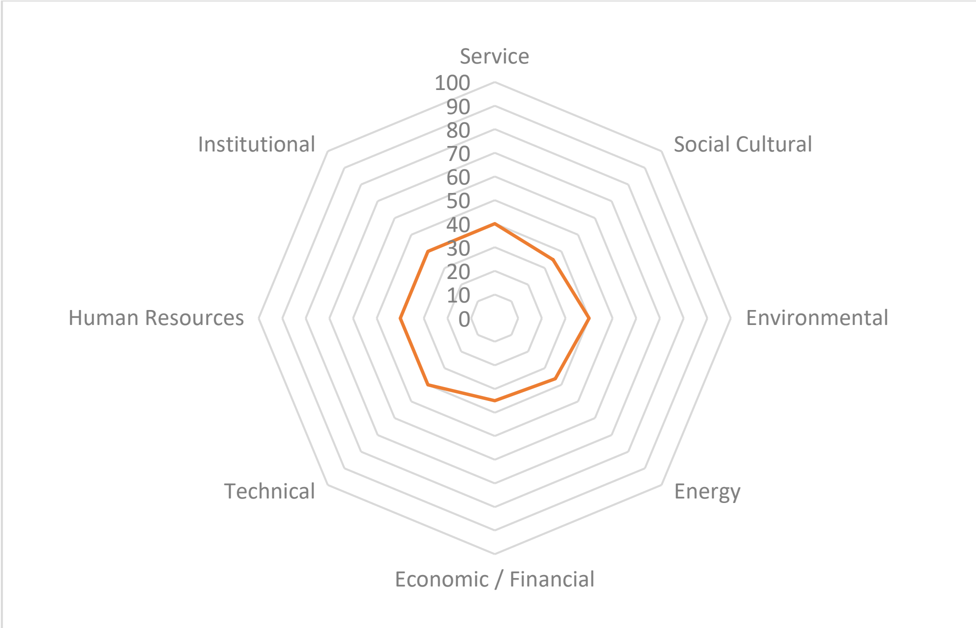

Figure 14 : Technology Capacity Level of UASB

4.1.1.5 Septic tank technology

The septic tank constructed from concrete or PVC watertight tank. Where black and gray water get primary treatment. The solid and organic matter reduced by settling and anaerobic processes. The wastewater flows into the tank and heavy matters sink to the bottoms. The settling particles are degraded an aerobically. While the scum flows to the top, which must remove periodically form 2-5 years as shown in the (Figure 15).

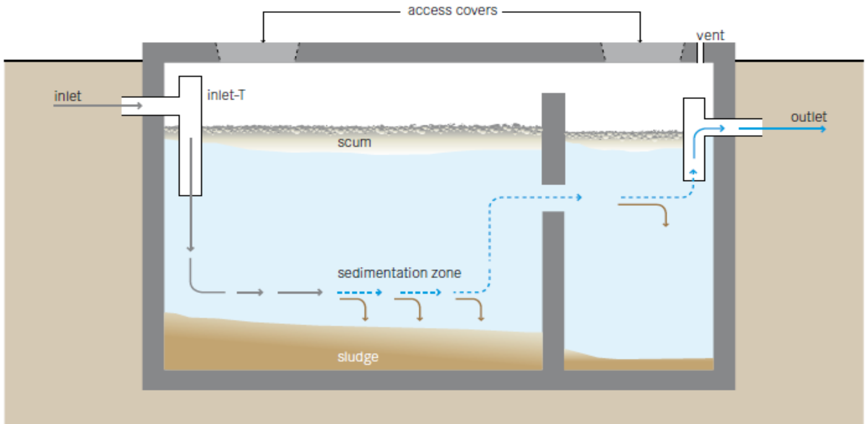

Figure 15 : Septic tank technology.

Source: (Tilley, E. et al. 2014)

Septic tank is appropriate for house to neighborhood level, where there is transportation to remove the sludge and scum. Septic tank has many advantages such as, low cost, energy consumption and land requirements. TLC for septic tank calculated as shown in the (Figure 16).

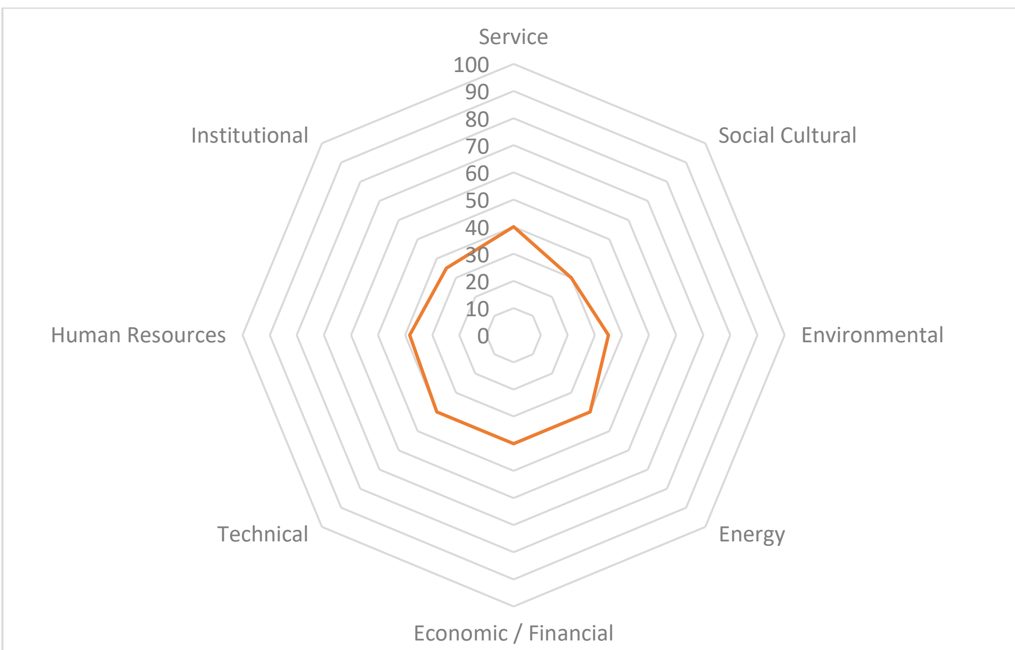

Figure 16 : Technology Capacity Level of Septic tank

4.1.1.6 Rotating Biological Contactor

The rotating biological contactor (RBC) is secondary wastewater treatment technology that consist of rotating shaft surrounded by plastic discs. Where about 40% of the rotating disc immersed in wastewater as shown in the (Figure 17) below. The microorganisms that used to treat the wastewater are growth on the surface area of the disc. The treatment process done by sticking the organic matter in the wastewater with the biological growth on the disc. Where the movement of the rotating disc provided the oxygen of the microorganisms.

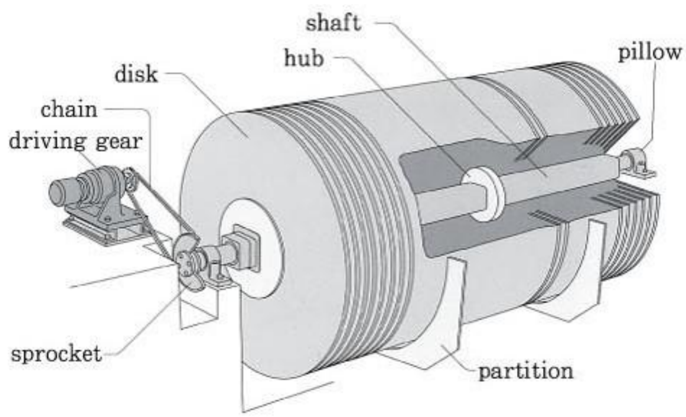

Figure 17 : Septic tank technology.

RBC technology represents an appropriate option for wastewater treatment. it provides high quality effluent due to the high contact time. Moreover, it has low land requirement, low energy consumption but continuous electricity supply (0.30-0.50 % of activated sludge consumption) (Desai, R., 2006). However, High construction costs as well as operation and maintenance costs. Requires permanent skilled technical labors for operation and maintenance and its spare parts are not available locally. TLC calculated for RBC as present in (Figure 18) below.

Figure 18 : Technology Capacity Level of RBC

4.2. Five criteria evaluation:

4.2.1. Technology evaluation

(Table 20) lists common treatment technologies in Palestine that may use alone or in combination to create a treatment system, which meet performance requirements. In this research, we will focus of the technologies bellow. Any other option can added, provided the following criteria are analyze.

Table 20: Common wastewater treatment technologies in Palestine

Acronyms	Treatment
AS	Activated sludge
ST	Septic tank
LA	Lagoons / pond systems
VFCW	Vertical flow constructed wetland
HFCW	Horizontal flow constructed wetland
RBC	Rotating biological contactor
UASB	Up-flow anaerobic sludge blanket reactor
MBR	**Membrane bio reactor**

4.2.2. Evaluation Criteria:

3. Cost

The most appropriate wastewater treatment technology among its alternatives that meet the needs and standards may chose according to the low cost. Generally, the lower the cost, the better the system. but, but at times, the low cost of wastewater treatment plants will not be sustainable because this depend on the real availability of the funds provided from households. In this case, the wastewater treatment option considers sustainable if the householders have the ability to cover at least the operation and maintenance expenses.

The cost of wastewater treatment technology divided into:

1.1.Construction cost

Construction costs are the costs for the physical components of the project. Construction costs are part of the fixed component of the total cost. They are normally incur one time but also include cost of rehabilitation or replacement of equipment's during the life of the system. Capital costs are estimate for equipment, materials, construction and other assets as shown in (Table 21).

Table 21: Construction cost for selected treatment technologies

Acronyms	Construction cost (US$/inhab)	Estimated const. cost (US$/inhab)	Source
AS	40-65	50	Rodríguez et al
ST	25-40	35	M. Sperling (2007)
LA	20-35	30	M. Sperling (2007)
VFCW	12	12	
HFCW	15	15	
RBC	50-60	55	M. Sperling (2007)
UASB	12-20	15	M. Sperling (2007)
MBR	1.1	1.1	

1.2.Maintenance and operation cost

Maintenance and operation are important and need to be consider in terms of the sustainability of the project at the community level. (Table 22) shows O&M cost for the selected technologies depend on literature.

Table 22: Operation & Maintenance cost for selected treatment technologies

Acronyms	O & M cost (US$/inhab. year)	Estimated O&M cost (US$/inhab. year)	Source
AS	4.0-8.0	6	Sperling , M. (1996)
ST	1.2-2.0	1.6	Sperling , M. (1996)
LA	2.0-3.5	2.5	Sperling , M. (1996)
VFCW			
HFCW			
RBC	4.0-6.0	5	Sperling , M. (1996)
UASB	1.0-1.5	1.5	Sperling , M. (1996)
MBR	0.1	0.1	

Table 23: Cost calculation for wastewater treatment technologies (Ahmad, 2004).

Acronyms	Construction cost (US$/inhab)	O & M cost (US$/inhab. year)	O & M cost for 5 years (US$/inhab.)	Net Present Value	level	score
AS	50	6	24.6	74.6	High	10
ST	30	1.6	6.6	36.6	Medium	5
LA	25	2.5	10.2	35.2	Medium	5
VFCW	12	0.0	0.0	12.0	Low	1
HFCW	15	0.0	0.0	15.0	Low	1
RBC	50	5	20.5	70.5	High	10
UASB	15	1.2	4.9	19.9	Low	1
MBR	1.1	0.1	0.4	1.5	Low	1

Source: Modified after Ahmad, 2004

The operation and Maintenance cost calculated for five years with depreciation rate 10%. Then net present values is equal to construction cost plus O&M for 5 years.

Depreciation formula = $\sum_{k=0}^{n}(O\&M)0.9^{n}$, n=0-4

Depreciation for AS = 6 + (6*0.9) + (6*0.9*0.9) + (6*0.9*0.9*0.9) + (6*0.9*0.9*0.9*0.9) =24.6

Scoring:

(Table 24) shows the scoring system for the treatment technologies based on cost criterion (Ahmad, 2004).

Table 24: scoring system for cost criterion

Range(US$/inhab)	Points	Level
X≤20	1	Low
40≥X>20	5	Medium
X>40	10	High

4. Energy consumption

Energy consumption is one of most important criteria for sustainable implementation of wastewater treatment infrastructure under the different conditions; the energy consumption will depend on the flow, effluent quality, types of processes adopted and quality of the effluent. (Table 25) shows the energy consumption for different technologies.

Table 25: Energy consumption for selected treatment technologies

Acronyms	Energy Consumption (kWh/ inhab. year)	Estimated Energy Con. (kWh/ inhab. year)	Source
AS	18-26	22	Sperling , M. (1996)
ST	0	0	Sperling , M. (1996)
LA	11-18	14	Sperling , M. (1996)
VFCW	0	0	Sperling , M. (1996)
HFCW	0	0	Sperling , M. (1996)
RBC	0	0	Sperling , M. (1996)
UASB	0	0	Sperling , M. (1996)
MBR	20-40	30	Sperling , M. (1996)

Scoring:

(Table 26) shows the scoring system for the treatment technologies based on energy consumption criterion (Ahmad, 2004).

Table 26: Scoring system for energy consumption criterion

Range (kWh/ inhab. year)	Points	Level
X≤10	1	Low
20≥X>10	5	Medium
X>20	10	High

5. Technical requirement:

Usually, technical requirement in high tech technologies is more than in simple technologies, where in high tech technologies electromechanical equipment and expert are more needed; while in simple technologies mostly need greater workforce. (Table 27) shows the technical requirement for different technologies.

Table 27: technical requirement for wastewater treatment technologies.

Acronyms	Technical requirement	Point	Source
AS	+++	5	Bremerhaven, 2012
ST	++	1	
LA	+	1	
VFCW	++	1	
HFCW	+++	5	
RBC	+++	5	
UASB	++++	10	
MBR	+++++	10	

Scoring:

(Table 28) shows the scoring system for the treatment technologies based on technical requirements criterion (Ahmad, 2004).

Table 28: Scoring system for technical requirements criterion

Range	Points	Level
+/++	1	Low
+++	5	Medium
++++/+++++	10	High

6. Land requirement:

(Table 29) shows how much area space needed for each type of treatment technologies in meter square per inhabitants.

Table 29: Land requirements for selected treatment technologies

Acronyms	Land Requirement (m^2 / inhab.)	Estimated Land req. (m^2 / inhab.)	Source
AS	0.12-0.25	0.2	M. Sperling (2007)
ST	1.2-2.0	1.6	M. Sperling (2007)
LA	0.25-0.50	0.35	M. Sperling (2007)
VFCW	1.0-3.0	2	A. Albold (2011)
HFCW	3.0-5.0	4	A. Albold (2011)
RBC	0.10-0.20	0.15	Sperling , M. (1996)
UASB	0.03-0.10	0.06	Sperling , M. (1996)
MBR	0.15-0.30	0.22	

Scoring:

(Table 30) shows the scoring system for the treatment technologies based on land requirement criterion (Ahmad, 2004).

Table 30: Scoring system for land requirement criterion

Range (m^2 / inhab.)	Points	Level
X≤20	1	Low
0.40≥X>0.20	5	Medium
X>0.40	10	High

The scores for all treatment technologies shown in the (Table 31). Where net score are is equal the score divided by 50. Because there are five evaluation criteria.

Table 31: Wastewater treatment scores

Acronyms	Cost	Energy consumption	Technical requirement	Institutional capacity	Land requirement	Score	Net score
AS	High	High	Medium	High	Low	36	**0.72**
ST	Medium	Low	Low	Medium	High	22	**0.44**
LA	Medium	Medium	Low	Medium	Medium	21	**0.42**
VFCW	Low	Low	Low	Medium	High	18	**0.36**
HFCW	Low	Low	Medium	Medium	High	22	**0.44**
RBC	High	Low	Medium	High	Low	27	**0.54**
UASB	Low	Low	High	High	Low	23	**0.46**
MBR	Low	High	High	High	Medium	36	**0.72**

(Table 32) shows the summarize scoring for all operation unites. The option score is equal = $(\sum_i^n score + 0.1\ (scroei * .. scoren))/0.4$(Ahmad, 2004), where stage of development is calculated as shown in **(Table 33)**.

Table 32: Units option scoring

Collection	score	Transfer	score	Treatment	score	Disposal	score	Option Score	Stage of Development
Cesspit tank	0.1	Sewage truck	0.34	RBC	0.44	Drainage field	0.36	**0.30**	**Stage Two**
Cesspit tank	0.1	Sewage truck	0.34	UASB	0.36	Drainage field	0.36	**0.28**	**Stage Two**
Cesspit tank	0.1	Sewage truck	0.34	MBR	0.62	Drainage field	0.36	**0.35**	**Stage Two**
Septic tank	0.42	Conventional gravity sewer	0.6	ST	0.44	Drainage field	0.36	**0.44**	**Stage Three**
Septic tank	0.42	Conventional gravity sewer	0.6	LA	0.42	Drainage field	0.36	**0.44**	**Stage Three**
Septic tank	0.42	Sewage truck	0.34	MBR	0.62	Drainage field	0.36	**0.43**	**Stage Three**
Septic tank	0.42	Simplified sewer	0.26	AS	0.54	Drainage field	0.36	**0.39**	**Stage Two**
Septic tank	0.42	Simplified sewer	0.26	ST	0.44	Drainage field	0.36	**0.36**	**Stage Two**

Table 33: Stage of Development

Option score	Level
X≤20	Stage one
0.40≥X>0.20	Stage two
0.60≥X>0.40	Stage three
0.80≥X>0.60	Stage four
X>0.80	Stage five

Source: Ahmad, 2004

4.3. Procedure:

First thing to do is name the community that has the need for sanitation service and made a complete assessment using the capacity factor assessment method regarding the eight factors as shown in Appendix 1. Once the assessment complete, the result will used as input to determine the community development stage. The inputs for the community assessment are:

- The community name
- Community type includes the area and institutional capacity and population
- Community capacity factors and their scores.

The interface model made for the assessment shown in Table 34. In this phase, the inputs form will used to calculate the community development stage by choose the minimum score from the eight factors and convert it into 1-5 levels.

Table 34 : Appropriate Matching Entry Form for WWT Options Selection

Wastewater Testament Technologies Selection			
Governorate			*Selected by user*
Community			*Selected by user*
Population			
Capacity factor No	**Capacity Factor**	**Formula**	**Score**
f_1	Service capacity	$\sum C_{1j}w_j$	*Value from Appendix 1*
f_2	Score Institutional	$\sum C_{2j}w_j$	*Value from Appendix 1*
f_3	Score Human Resources	$\sum C_{3j}w_j$	*Value from Appendix 1*
f_4	Score Technical	$\sum C_{4j}w_j$	*Value from Appendix 1*
f_5	Score Economic and Financial	$\sum C_{5j}w_j$	*Value from Appendix 1*
f_6	Score Energy	$\sum C_{6j}w_j$	*Value from Appendix 1*
f_7	Score Environmental	$\sum C_{7j}w_j$	*Value from Appendix 1*
f_8	Score Social-Cultural	$\sum C_{8j}w_j$	*Value from Appendix 1*
Minimum score			

Stage of development	

The first step of matching process done by selecting the wastewater treatment technology that has TLA equal or less than the stage of development level. In most cases, many option where selecting if some of them have the same level, in this case other limitation may use to reduce the options, such as the water quality and quantity needed for the community. However, in this research,   this limitations will not be used and be for future work.

Last, the selection process completed with selecting WWT options that have can be implemented and operated by a community that fit with the option's requirement. In last step the of selection process, the 1-5 level scale use instead of 1-100 scale. This gave the tool more flexibility in matching process without compromising the general similarity of capabilities of low communities. For example, if the score of CF3 of the community is 31, this mean level 2 in 1-5 scale. Therefore, any community with CF3 between 20 and 41 score will have the same CF3 other community. Table 35 represent the symmetry between score of CFs on scale 1-5 and on scale 1-100.

Table 35 : Correspondence between CF Scores and the 1-5 Level Scale

CFs Score	1-20	21-40	41-60	61-80	81-100
1-5 levels	1	2	3	4	5

At the end of matching process, if the model work successfully through all it phases, the model will present a report of all appropriate options that match the host community. The appropriate options means that the WWT technologies has TRL equal or less than the CCL for the host community.

Table 36 : Report Appropriate WWT Options

Wastewater Treatment Option	Stage of Development	Decision
AS - Activated sludge	***Stage Four***	***Not Valid***
ST - Septic tank	***Stage Two***	***Valid***
LA – Lagoons	***Stage Three***	***Not Valid***
VFCW - Vertical construction wetland	***Stage Two***	***Valid***
HFCW - Horizontal construction wetland	***Stage Three***	***Not Valid***
RBC - Rotating biological contactor	***Stage Three***	***Not Valid***
UASB - Up-flow anaerobic sludge blanket reactor	***Stage Two***	***Not Valid***
MBR - Membrane bio reactor	***Stage Four***	***Not Valid***

In case if one or more options match and fit the host community's capacity level, the model appear and mark them as shown in Table 36.

Each wastewater treatment technology has many parameters that have to be study for their sustainability. The criteria that influence the decision-making process are determined based on experience. In this research, eight WWT technology will be evaluate through five factors as shown in table 37.

Table 37: Alternative options Vs classification criteria

Wastewater Treatment Option	Cost score	Energy score	Technical score	Institutional score	Land score
AS - Activated sludge					
ST - Septic tank					
LA - Lagoons					
VFCW - Vertical construction wetland					
HFCW - Horizontal construction wetland					
RBC - Rotating biological contactor					
UASB - Up-flow anaerobic sludge blanket reactor					
MBR - Membrane bio reactor					

- **Cost**

The cost score consider by calculate the construction cost, operation and maintenance cost. The Avg. Present worth of annual O&M calculate by using the formula:

$$\text{Avg. Present annual O\&M} = \Sigma\ (\text{O\&Mcost} + (\text{O\&Mcost}*0.9_{(1-i)})),\ i=1\text{-}5$$

Table 38: Construction and O&M cost

WWT Option	Construction cost (US$/inhab)	O & M cost (US$/inhab. year)	Avg Present worth of annual O&M	Net Present Value	level	score
AS	50	6	24.6	74.6	High	10
ST	30	1.6	6.6	36.6	Medium	5
LA	25	2.5	10.2	35.2	Medium	5
VFCW	12	0	0.0	12.0	Low	1
HFCW	15	0	0.0	15.0	Low	1
RBC	50	5	20.5	70.5	High	10
UASB	15	1.2	4.9	19.9	Low	1
MBR	1.1	0.1	0.4	1.5	Low	1

Net present value (**NPV**) calculated by summation of construction cost and the Avg. Present annual O&M cost. The level calculated by using the following formula:

Level=IF(NPV>=41;"High";IF(NPV >=21;"Meduim";IF(NPV >=0;"Low")))

Finally, the score for each option calculated by using the following formula;

Score=IF(NPV =41;"10";IF(NPV >=21;"5";IF(NPV >=0;"1")))

- **Energy consumption:**

The energy consumption (**EC**) for each alternative option collected from lectures, and the level calculated for each option by dividing the annual consumption into three levels as shown in the following formula:

Level=IF(EC>=21;"High";IF(EC >=11;"Meduim";IF(EC >=0;"Low")))

Finally, the score for each option calculated by using the following formula;

Score=IF (EC>=21(kWh/ inhab. Year)**;"10";IF(EC >=11**(kWh/ inhab. Year)**;"5";IF(EC >=0**(kWh/ inhab. Year)**;"1")))**

Table 39 : Energy consumtion for Alternative WWT options

Acronyms	Energy Consumption (kWh/ inhab. year)	level	score
AS	22	High	10
ST	0	Low	1
LA	14	Medium	5
VFCW	0	Low	1
HFCW	0	Low	1
RBC	11	Medium	5
UASB	6	Low	1
MBR	30	High	10

- **Land requirement:**

The land requirement (**LR**) for each alternative option collected from lectures, and the level calculated for each option is dividing into three levels as shown below:

Level =IF (LR>=0.41(m2 / inhab.)**;"High"; IF (LR >=0.21**(m2 / inhab.)**;"Meduim"; IF (LR >=0**(m2 / inhab.)**;"Low")))**

Finally, the score for each option calculated by using the following formula;

Score= IF (LR >=0.41;"10"; IF (LR >=0.21;"5"; IF (LR >=0;"1")))

Table 40 : Land requirements for Alternative WWT options

Acronyms	Land Requirement (m^2 / inhab.)	Level	Score
AS	0.2	Low	1
ST	1.6	High	10
LA	0.35	Medium	5
VFCW	2	High	10
HFCW	4	High	10
RBC	0.15	Low	1
UASB	0.06	Low	1
MBR	0.22	Medium	5

- **Institutional requirements:**

The options have been classified regarding to the Institutional requirements (IR)through previous researches, as each option needs a certain level of conditions and laws that govern the use of this option or not. The chosen WWT technologies evaluated as shown in the (Table 41), the score calculated as the same method of other factors as follow:

Score= IF (IR =1;"Low"; IF (IR =5;" Medium "; IF (IR =10;"High")))

Table 41 : Institutional requirements for Alternative WWT options

Acronyms	Level	Score
AS	Medium	5
ST	Low	1
LA	Medium	5
VFCW	Low	1
HFCW	Medium	5
RBC	Medium	5
UASB	Medium	5
MBR	Medium	5

- **Technical requirement;**

Each option need specific needs for operation and maintenance, some options need high skilled labors and others need less depend on the technologies used in this option, the score calculated as the same method of other factors as follow:

Table 42 : Technical requirements for Alternative WWT options

Acronyms	Level	Score
AS	Medium	5
ST	Low	1
LA	Low	1
VFCW	Low	1
HFCW	Medium	5
RBC	Medium	5
UASB	Medium	5
MBR	High	10

The next step is to calculate total score for each option by summation of each factor then calculating the net score for them by dividing the score, over five (number of factors)

Nscore= Score/ 5

Table 43 : net score for alternative treatment options

Treatment option	Cost	Energy	Technical	Institutional	Land	score	nscore
AS	10	10	5	5	1	31	**0.62**
ST	5	1	1	1	10	18	**0.36**
LA	5	5	1	5	5	21	**0.42**
VFCW	1	1	1	1	10	14	**0.28**
HFCW	1	1	5	5	10	22	**0.44**
RBC	10	5	5	5	1	26	**0.52**
UASB	1	1	5	5	1	13	**0.26**
MBR	1	10	10	5	5	31	**0.62**

Final step is to calculate the stage of development for each option; this can be due by using the following formula:

Stage of Development = IF(nscore>=0.81;"stageFive";IF(nscore>=0.61;"Stage Four"; IF (nscore>=0.41;"Stage Three"; IF(nscore>=0.21;"Stage two"; "Stage One"))))

Table 44: Stage pf development for alternative treatment options

Treatment	nscore	Stage of Development
AS - Activated sludge	0.62	Stage Four
ST - Septic tank	0.36	Stage Two
LA - Lagoons	0.42	Stage Three
VFCW - Vertical construction wetland	0.28	Stage Two
HFCW - Horizontal construction wetland	0.44	Stage Three
RBC - Rotating biological contactor	0.52	Stage Three
UASB - Up-flow anaerobic sludge blanket reactor	0.26	Stage Two
MBR - Membrane bio reactor	0.62	Stage Four

Chapter Five:

Application of the model in local municipalities:

5.1. Case study -system boundaries-:

This research funded by the DUPC2 project, which responds to the needs in many low and middle-income countries to strengthen their water and development sectors and being able to better tackle urgent water problems. DUPC2 project in Palestine aims to reduce the flow of wastewater in Kidron/Wadi Nar that is consider as the main pollution source for the Dead Sea. Study the surrounded Palestinian communities of this Wadi by helping them to create sustainable sanitation services.

Four major Palestinian communities are located close to Kidron/Wadi Nar. 1) EL-Ezaria, 2) Abu Diss, 3) Asawahreh and 4) Al Ubeidiya. El-Ezaria, Abu Diss and Asawahreh follow Jerusalem governorate and Al Ubeidiya follow Bethlehem governorate. The choice of these town is based on face that these towns the most populated areas. Moreover, each town is planning to build its own wastewater treatment facilities. According to the Palestinian Central Bureau of Statistics (PCBS) around 56,000 people living in these communities. Figure () shown the population of each town.

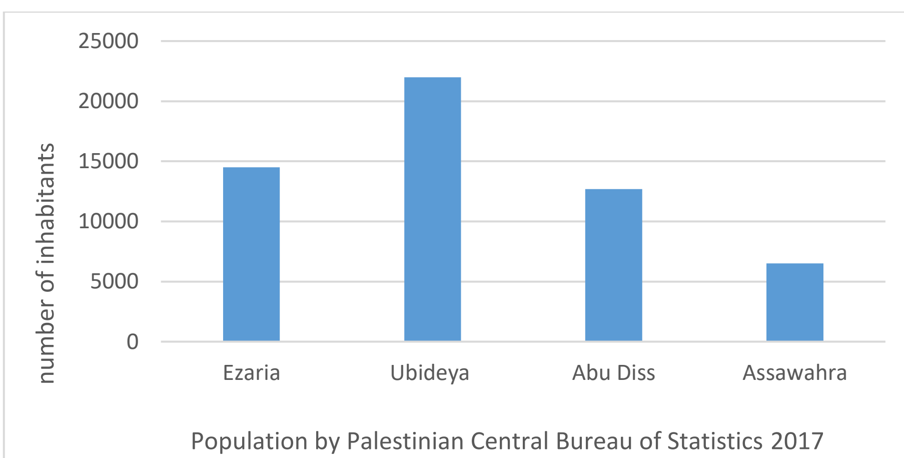

Figure 19 : Population number of East Jerusalem towns

The majority of the population in these communities is living in area C where the Palestinian Authority is responsible for providing medical and educational services to the Palestinians in the area, but Israel has security and administrative control. This led to a decrease in the area permitted for construction in this area in general. Whereas, it is impossible to obtain a permit for construction and expansion in this area according to the Oslo (II) Agreement.

All the towns are located in the eastern slopes of the West Bank and around 23 km far of Dead Sea. The highest elevation for Al Ubeidiya, El-Ezaria, Abu Diss and Asawahreh are, respectively, 530, 550, 630 and 520 meters. In addition, the annual participation in the area is varies from 246 to 306 mm. the average temperature is 18 coleuses (Arij, 2012).

The population in this region depends on many economic activities to live. As they depend on the government and private sector and the workforce in the Israeli market in general. Secondly, as well as agriculture and trade. Table below shows the main economic activities in the study area.

Table 45: the main economic activities in the study area

Community name	Services sector (%)	Workforce in Israeli market (%)	Government and private sector (%)	Trade (%)	Agriculture (%)
Abu Diss	19	1	80	0	0
El Ezaria	10	30	30	15	5
Asawahreh	3	80	10	4	1
Al Ubeidyia	8	38	26	6	19

5.2. Evaluation of the classification tool:

This tool based on evaluating the levels of treatment plants and communities to measure their development level. Where the level of development can measured in two ways. The first evaluation method is to measure the level of the community and then choose the appropriate technology for it, and the second evaluation method is to evaluate the existing technology and determine whether these technologies are appropriate for the community in which they are located or not.

5.2.1. Evaluation of low communities:

In the first evaluation method. The data collected through interviews with people in authority in some developing communities in Jerusalem and Bethlehem will be used to verify whether the TRL of the implemented treatment of plants in these areas matches CAL of these communities. Two communities will be studying, Al-Ubaidiya town in the Bethlehem governorate. In addition, the Abu Dis town in the Jerusalem governorate.

1. **Al-Ubaidiya town:**

Al Ubaidiya, a Palestinian town belonging the Bethlehem Governorate. it has a total population of 15,617 in 2021. The economy in Ubeidiya depends on several economic sectors, the most important of which are: The Israeli labor market, which absorbs 38% of the labor force in the town. The total area of Al-Ubaidiya is about 97232 dunums, of which 96,032 dunums are arable land, and 563 dunums are residential lands. Agricultural production in Ubaidiya is mostly dependent on rainwater. As for the irrigated fields, they depend on the public water network and household harvest tanks.

The water quantity supplied to Al ‘Ubeidiya in 2017 was about 364,626 cubic meters/year, thus, the estimated rate of water supply per capita is about 67 liters/day (PEBC,2018).The town lacks a public sewage network. Most of the housing units in Ubaidiya (96%) use cesspits to dispose of sewage.

Based on estimates of daily per capita water consumption, the amount of wastewater generated per day estimated at 484 m3 or 177 thousand m3 annually. At the individual township level, it estimated that per capita wastewater production is about 45 liters per day. Wastewater collected by cesspits discharged by sewage tanks directly to open areas or adjacent valleys, without any regard for the environment.

Through collection data for Al-Ubaidiya's village, an evaluation conducted to measure the CFA for Al-Ubaidiya community, the results recorded in the data collection form for community development in the tool, and the following results obtained, which are show in the following table (46):

Table 46 : CFs Scores - Al-Ubaidiya community

CF	Capacity Factor	Score
f_1	service capacity	40.0
f_2	Score Institutional	44.0
f_3	Score Human Resources	48.0
f_4	Score Technical	45.0
f_5	Score Economic and Financial	38.0
f_6	Score Energy	45.0
f_7	Score Environmental	60.0
f_8	Score Social-Cultural	45.0

The community capacity level (CCL) for Al-Ubaidiya community is determine regarding to the lowest score from the capacity factors which in this case the economic and financial capacity factor (38) as shown in appendix 2 (Page 79), therefor the stage of development for this town is level 2. Based on the community level, the most appropriate technologies that match the community level shown the table below:

Table 47: Appropriate treatment technology- Al-Ubaidiya community

Appropriate treatment technology	Stage of Development
ST - Septic tank	Stage Two
VFCW - Vertical construction wetland	Stage Two
UASB - Up-flow anaerobic sludge blanket reactor	Stage Two

Al-Ubaidiya community has implemented a UASB WWTP in 2019. UASB, used by the community has a TRL score of 2. We note that the WSS technology option, selected and implemented by Al-Ubaidiya matches its capacities. We can conclude that, the WSS technology option selected by Al-Ubaidiya community should be sustainable, UASB has many advantages such as, simple construction and low operation and maintenance cost due to local availability of construction material and other parts and required constant low energy supply. Moreover, the land requirements are small. In addition, UASB has the potential to produce high quality effluent.

VFCW option will be difficult to implement because of the occupation policies in West Bank, as these option need large areas for their establishment, and the municipality of Al-Ubaidiya owns these spaces, but according to the Oslo agreement, 82% of the lands of the municipality of Al-Ubaidiya are classified as C and the municipality has not the permit to build any facility there.

Septic tank option could be a suitable solution for wastewater treatment in the town, as this option can be built for one housing unit or for several housing units. However, the majority of Al-Ubaidiya's housing units (96%) use cesspits for wastewater disposal. The wastewater collected by cesspits is discharged by wastewater tankers directly to open areas or nearby valleys, without any regard for the environment. Building septic tanks requires a suitable space around the lanes or around the population units, but the population does not have this space, According to Oslo Interim Agreement, 8,858 dunums of Al-Ubaidiya lands (9.1 percent of the total area of the town) were classified as area A. And that the high population density of this town will constitute a future burden on this option if it is implemented, as any facility must be able to accommodate the population increase for at least 20 years, so choosing this option will be a great challenge for the municipality of Al-Ubaidiya

If the WSS technology option, selected and implemented by Al-Ubaidiya community, does not match its capacities. We can conclude Al-Ubaidiya is at risk of not being able to operate and maintain their WSS infrastructure in the long run.

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Chapter Six:

6.1 Conclusion:

Wastewater treatment remains faces challenges for all low communities around the world. Despite the social and economic situation, lack of experience, corruption and lack of energy and many reasons remain the prime source of failure of wastewater treatment plants for low communities in the whole world. Louis methodology for capacity analysis suggested being a possible framework that can address to predict the defects of failures. This methodology can be sustainable and reduce the failure by involving the institutional level and the community members on one hand, with the treatment technology in the other hand.

By studying and evaluating wastewater treatment technologies in Palestine, taking into account that Palestine faces water scarcity and poor water quality, as well as operational challenges in water supply in general, two technologies prevalent in the Palestinian territories are first considered, which are active sludge and pons systems, where The active sludge has a low installation cost, good quality liquid water and low land requirements, as Palestine suffers from a big problem in the land due to the Israeli occupation, which prevents construction in most areas, which faces a great challenge to build treatment systems. Moreover, the active sludge produces high quality water that can used in agriculture, thus reducing pressure on pure water. It may also face a major failure due to its total dependence on the continuity of electricity, spare parts high technical requirements and the expansion of facilities periodically to accommodate sewage flows.

Finally, the relationship between domestic and economic uses of water must clearly defined, and people should be educated about the necessity of using treated water for agricultural and industrial purposes. In addition, alternative means of financing and budgeting for infrastructure-related projects should be consider to reduce corruption, increase the rate of return on investment in existing projects, and develop cadres to manage these data and reduce failure.

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6.3 Appendix:

1. Community analysis

	Capacity Factors	20-Jan	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C11	**Service capacity**	< 20 l/p/c	20 - 40 l/p/c	40 - 60 l/p/c	60 - 80 l/p/c	80-100 l/p/c	
f₁	**Score Service CF**					Σ Cij wj =	
2	**Institutional**						
C21	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	
C22	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	
C23	**Administrative agencies**	None	National	Regional	Local	Village, city, town	
C24	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	
C25	**Stable Governance**	None	Low	Medium	High	Very High	
C26	**Partnership with NGOs**	None	Low	Medium	High	Very High	
f₂	**Score Institutional CF**					Σ Cij wj =	
3	**Human Resources**						
C31	**Professionals**	None	Accountant	Administrative supervisor	Administrative manager	Administrative manager	
				Health scientist	Health scientist	Health scientist	
				Accountant	Accountant	Accountant	
					Engineer	Engineer	
						Public relations manager	
C32	**Skilled Labor**	None	Mechanic	Maintenance technician	Maintenance technician	Maintenance technician	

	Capacity Factors	20-Jan	21 - 40	41 - 60	61 - 80	81 - 100	Score
				Laboratory technician	Laboratory technician	Laboratory technician	
				Plant Operator	Health inspector	Plant Operator	
					Administrative assistant	Health inspector	
					Plant Operator	Administrative assistant	
						IT technician	
C33	**Unskilled Labor**	Guard	Guard	Guard	Guard	Guard	
			Driver	Mechanic assistant	Mechanic assistant	Mechanic assistant	
				Driver	Driver	Driver	
C34	**Illiterate**	Clean Worker	Clean Worker II	Clean Worker III			
C35	**Access higher Education**	None	State	Regional	Local	Town, village, city	
C36	**Training**	None	Low	Medium	High	Very High	
*f*3	**Score Human Resources CF**					Σ Cij wj =	
4	**Technical**						
C41	**Operations**	Water use	Treatment Supervisor	Treatment Supervisor	Treatment Supervisor	Treatment Supervisor	
				Read meters	Read meters	Read meters	
					Quality control	Quality control	
						Monitor network	
C42	**Maintenance**	None	Clean treatment systems	Check treatment systems	Maintain treatment systems	Maintain treatment systems	
			Minor repair	Major repair	Major repair	Major repair	
					foreman	foreman	
						Maintain IT systems	
C43	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	
C44	**Spare parts**	None	National supplier	Regional supplier	Local supplier	Local supplier	

	Capacity Factors	20-Jan	21 - 40	41 - 60	61 - 80	81 - 100	Score
						National manufacturer	
f4	**Score Technical CF**					Σ Cij wj =	
	Capacity Factors	**1-20**	**21 - 40**	**41 - 60**	**61 - 80**	**81 - 100**	**Score**
5	**Economic and Financial**						
C51	**Private sector %**	None	Global	Regional	Local	Town, village	
C52	**Bonds Rating**	None	National	Regional	State	Local	
C53	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	
C54	**Budget**	None	Basic accounting	Annual	Quarterly	Monthly	
C55	**Asset values**	None	Equipment	Equipment	Equipment	Equipment	
				Real estate	Real estate	Real estate	
					Cash	Cash	
						Stocks	
C56	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	
C57	*** Willing to pay and use**	Very low	Low	Intermediate	High	Very high	
f5	**Score Economic / Financial CF**					Σ Cij wj =	
6	**Energy**						
C61	**Primary source**	None	Non-conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	
C62	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	
						Solar energy	
C63	**% of Budget**	Very High	High	Moderate	Low	Very low	
C64	**Rate of outage**	Very High	High	Moderate	Low	Very low	
f6	**Score Energy CF**					Σ Cij wj =	

	Capacity Factors	20-Jan	21 - 40	41 - 60	61 - 80	81 - 100	Score
7	**Environmental**						
C71	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	
C72	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	
f $_7$	**Score Environmental CF**					Σ Cij wj =	
8	**Social and Cultural**						
C81	**Communities**	Very low	Low	Intermediate	High	Very high	
C82	**Stability**	Very low	Low	Intermediate	High	Very high	
C83	**Equity**	Very low	Low	Intermediate	High	Very high	
C84	**Castes**	Very low	Low	Intermediate	High	Very high	
f $_8$	**Score Social Cultural CF**					Σ Cij wj =	

Modified after Bouabid (2004)

1	*Service capacity*	*20*	*40*	*60*	*80*	*100*	*wj*
C_{11}	effective service level	<20 (l/p/d)	20-40 (l/p/d)	40-60 (l/p/d)	60-80 (l/p/d)	>80(l/p/d)	40
			40				

2	*Institutional Capacity*	*20*	*40*	*60*	*80*	*100*	*wj*
C_{21}	Body of legislation	None	Basic	Intermediate	Complete	Advanced	40
			40				
C_{22}	Associated regulations	None	Basic	Intermediate	Complete	Advanced	40
			40				
C_{23}	Administrative agencies	None	State	District	Town, village	Habitation	40
			40				
C_{24}	Administrative processes	None	Basic	Intermediate	Complete	Advanced	40
			40				
C_{25}	Presence of NGOs	None	Low	Medium	High	Very High	60
				60			
							44.00

3	*Human resource*	*20*	*40*	*60*	*80*	*100*	*wj*

C31	Professionals	None	Administrative supervisor	Administrative supervisor Health Scientist	Administrative manager Health Scientist Engineer	Administrative manager Health Scientist Engineer Lawyer Public relations manager	60
				60			
C32	Skilled Labor	none	Mechanic	Maintenance technician Laboratory technician Plant Operator	Maintenance technician Laboratory technician Plant Operator Health inspector Administrative assistant	Maintenance technician Laboratory technician Plant Operator Health inspector Administrative assistant IT technician	60
				60			
C33	Unskilled Labor	yard worker	Clerk Mechanic assistant yard worker	Clerk Mechanic assistant yard worker sewage systems worker			40
			40				
3	***Human resource*** *(continued)*	***20***	***40***	***60***	***80***	***100***	***wj***

C34	Illiterate	Guard					20
		20					
C35	Access Higher Education	None	State	Regional	District	Town, village	60
				60			
							48
4	***Technical capacity***	***20***	***40***	***60***	***80***	***100***	***wj***
C41	Operations	None	Monitor pipes network	Pumping Water Control Control influent Quality	Monitor treatment systems Monitor influent and efluet Quality Control Pipes	Monitor treatment systems Monitor influent and efluet Quality Monitor pipes network IT control	40
			40				
C42	Maintenance	None	water systems Minor repair	Check water systems water systems Major repair	Maintain water systems Major repair Maintain pipes	Water systems Major repair Maintain network Maintain meter Maintain IT systems	60
				60			
4	***Technical capacity (Continued)***	***20***	***40***	***60***	***80***	***100***	***wj***

C43	Adaptation	None	Rarely	Occasionally	Usually	Frequently	40
			40				
C44	Spare parts	None	State	District	Town, village	private company	40
			40				
							45

5	***Economic and financial capacity***	***20***	***40***	***60***	***80***	***100***	***wj***
C51	Private sector investment	None	State	Regional	District	Town, village	20
		20					
C52	Bonds rating	None	Low	Medium	High	Very high	20
		20					
C53	User fees	None	Uniform flat rate	Single block rate	Increasing block rate	Per discharge	40
			40				
C54	Budget	None	Basic accounting	Annual	Tracked bi-annually	Tracked quarterly	40
			40				
C55	Asset values	None	Low	Medium	High	Very High	40
			40				
C56	dept	Very High	High	Medium	Low	None	40
			40				
C57	Willing to use and pay	None	Low	Medium	High	Very High	60
				60			
							38

6	*Energy capacity*	*20*	*40*	*60*	*80*	*100*	*wj*
C61	Primary source	None	Non-conventiona l	Conventional electricity	Electricity mid-voltage	Electricity high voltage	60
				60			
C62	Alternative source(Back-up)	None	None	Generator < 10 HP	Generator < 50 HP	Generator > 50 HP	40
			40				
C63	Dependence for service	Very low	Low	Medium	High	Very High	40
			40				
C64	Outage rate	Very High	High	Medium	Low	Very low	40
			40				
							45

7	*Environmenatl capacity*	*20*	*40*	*60*	*80*	*100*	*wj*
C71	Environment quality/Sensitivity	Very low	Low	Medium	High	Very high	60
				60			
C72	Capacity of resource system	Very low	Low	Medium	High	Very high	60
				60			
							60

8	Social and Culture capacity	20	40	60	80	100	wj
C81	Communal ownership	Very low	Low	Intermediate	High	Very high	40
			40				
C82	stability	Very low	Low	Intermediate	High	Very high	40
			40				
C83	Equity	Very low	Low	Intermediate	High	Very high	60
				60			
C84	Leadership/entrepreneurship	Very low	Low	Intermediate	High	Very high	40
			40				
							45

2. Al-Ubaydiah Community analysis