A TECHNICAL EVALUATION OF THE EXISTING WASTEWATER TREATMENT PLANTS IN THE HEBRON GOVERNORATE

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HEBRON- WEST BANK

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PALESTINE POLYTECHNIC UNIVERSITY

HEBRON- WEST BANK

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In accordance with the recommendations of the project supervisors, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfilment of the requirements of Department for the degree of Bachelor of Science in Engineering.

Project Supervisors **Department Chairman**

إهـــــداء

إلى العظيم الجبارالواحد القهار ..رب السموات والأرض

إلى بيتي الثاني جامعتي الحبيبة.. بوليتكـنـك فلسطين

إلى من ضمتني ولم تتخل عني يومـا ما.. بلدي فلسـطين

إلى الزهرة التي لا تذبل نبع الحنان.. إلى أمي

إلى الماس الذي لا يذوي نبع العطاء .. إلى والدي

إلى صاحب الفضل الأكبر في هذا المشروع الدكتور ماجد أبو شرخ

إلى ملائكة الأرض شقائق النعمان.. إلى أشقائي

إلى قناديل الدرب الشموع التي لا تنطفئ.. إلى أساتذتي

إلى رفيقات الدرب بانيات المستقبل.. إلى صديقاتي

إلى صناع الكرامة رايات المجد.. إلى شهدائنا

إلى من رفضوا الخضوع من طلبوا العزة.. إلى أسرانا

إليكم جميعا أهدي هذا الجهد المتواضع

ألاء عابدين ألاء ألشرباتي مي الحموري

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Work Team

ABSTRACT

A TECHNICAL EVALUATION OF THE EXISTING WASTEWATER TREATMENT PLANTS IN THE HEBRON GOVERNORATE

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The subject of sewage treatment is increasingly gaining interest due to the severe pollution impacts posed currently by cesspits and septic tanks in rural areas of the Hebron District. Currently, sewers and treatment plants are only available in Kharas, Nuba, Deir-Samit, and Al Aroub among all rural areas of the Hebron district. This study demonstrates in depth the performance of these four wastewater treatment plants.

Low cost wastewater treatment plants in Kharas and Nuba villages were constructed by Palestinian Hydrology Group (PHG), where wastewater treated anaerobically using Upflow Activated Sludge Blanket (UASB), and then aerobically using wet land. The system applied in Deir-Samit village is anaerobic primary treatment one. It consists of two compartment septic tanks followed four compartment biofilters and finally a storage tank. A pilot scale duckweed system was constructed in Al-Aroub secondary school by Environmental Authority. The system consists of settling tank, Duckweed lagoons (ponds) and storage reservoir.

Testing of the four systems carried out by different investigators show that the performance of the plants is very good, with little differences between each treatment plants. The removal efficiency in Kharas and Nuba treatment plants in terms of COD and BOD reaches about 90%, while for Deir-Samit and Al Aroub reaches 70%. The efficiency for other pollutants

removal was quite good. The systems were able to treat the sewage at acceptable levels and solve environmental problems.
The fieldwork of this study includes; registration of all distinguished problems along with flow measurement, frequent sampling of wastewater from different points in the treatment plants, and then testing the collected samples in the laboratory of PHG. The results of analysis for each treatment plant were compared together to recommend and adopt the most suitable small scale wastewater technology for rural areas in the Hebron Governorate.

The site visits and preliminary investigation show that there is some problems in the treatment plants such as; the wastewater treatment plant at Kharas receives high loads of olive mill effluents and the wastewater color is black and with oily appearance and odor. The duckweed plant in the first cell in Al Aroub wastewater treatment plant is died while the second cell is with complete plant cover. The wetland in Nuba wastewater treatment plant is not full of wastewater and no outflow is detected.

The water consumption in the studied rural areas is very low (about 40-70 l/c.d). Because of this, the values of some parameters are comparatively higher than the typical values. Even this the results reveals that the rural sewage is less concentrated than municipal sewage.

The whole systems at Kharas and Nuba achieved 93% removal in terms of COD, 90% in terms of TSS, 35% in terms of TS, and 20% in terms of ammonia. While the system of Deir Samit achieved 62%, 70%, 20% and -20% removals for the COD, TSS, TS and NH4. The Duckweed ponds system at Al Aroub achieved removal efficiency of 60% for COD, 70% for TSS, 27%for TS, and 55% for ammonia.

It seems that the UASB-Wetland system at Kharas and Nuba villages is more efficient in the reduction of pollutants. At optimal conditions, the septic tank-biofilter and duckweed ponds systems are a good choice for replacing the existing cesspits and could serve a cluster of houses.

The success of sewage treatment systems reported in this project make us more confident to apply these technologies in other rural communities. UASB anaerobic system followed by wetland is recommended in this study.

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ABBREVIATIONS

The following abbreviations were used in this project:

B	Born
BOD	Biochemical Oxygen Demand
Ca^{++}	Calcium
Cl^{-}	Chloride
COD	Chemical Oxygen Demand
CO_3^{--}	Carbonate
DO	Dissolved Oxygen
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
HCO_3^{-}	Bicarbonate
K	Potassium
Mg^{++}	Magnesium
Na+	Sodium
NO_2^{-}	Nitrites
NO_3^{-}	Nitrates
$NH4^{+}$	Ammonia
P	Phosphate
pH	Acidity / Basicity
SAR	Sodium Adsorption Ratio
SO_4^{-2}	Sulfate
SS	Suspended Solid
T	Temperature
TDS	Total Disolved Solids

TFCC Total Feacal Coliform Count

TN Total Nitrogen

TS Total Solids

TSS Total Suspended Solids

UASB Upflow Anaerobic Sludge Blanket

WHO World Health Organization

CHAPTER

1 *INTRODUCTION*

1.1 Preliminary Remarks

1.2 Background

1.3 Previous Studies

1.4 Objectives

1.5 Study Areas

1.6 Structure of the Report

CHAPTER ONE
INTRODUCTION

1.1 Preliminary Remarks

An efficient and cost effective wastewater treatment is becoming increasingly important due to the need for more stringent effluent quality requirements for reuse and disposal, and due to the ever increasing quantities of wastewater. Currently, Hebron District (south of the West Bank-Palestine) produces daily about 25,000 cubic meter of wastewater. This quantity is subject to a rapid increase due to increase in population and rapid extension of water supply networks as part of a national development plan in the water sector.

There are four decentralization wastewater treatment plants in the Hebron District located in Kharas, Nuba, Deir-Samit and Al-Aroub. Several technical problems have been noted in some of the existing wastewater treatment plants in the District. The aims of this project is evaluate the performance of wastewater treatment plants exists in different areas of the Hebron Governorate from technical, environmental and economical points of view, and suggest solutions to the current problems. Recommendations will be made on the planning of the future wastewater treatment plants; in terms of their capacity, effluent quality, and cost effective treatment methods and strategy.

1.2 Background

More than 60% of the water used for domestic purposes and industry turn into sewage requiring purification (treatment). After treatment of the WW (wastewater) in a in a WWTP (wastewater treatment plant) the effluent may be reused for irrigation or may be alternatively disposed. If the wastewater is not treated and is not disposed of properly, the sewage may contaminate sources of drinking water, especially shallow springs. In Palestine, water-borne diseases are very commonplace.

Currently, no piped wastewater disposal system is available in most of the rural areas in the West Bank. Wastewater from individual residence is discharged directly into subsurface pits, allowing the wastewater to seep into the surrounding soil and percolate into the underlying aquifer causing ground water contamination. This contamination will have long-term impact on ground water resources, agricultural land and creates environmental and health hazards. At the same time, the existing WW treatment plants are either non-existent, heavily overloaded or poorly operated and maintained.

In all the countries facing water shortages like Palestine, treated wastewater shall be considered as an essential element in the national water strategy and should be fully utilized. Treated wastewater has good potential in the region to be used in agriculture. The level of wastewater treatment should be sufficiently high to suit irrigation of all type of agriculture crops. Whenever possible, treated effluent should be used for industrial needs as well. Strict means should be taken to ensure that no underground water pollution or environmental problems occur due to irrigation with treated effluent.

In light of the above, reclaimed wastewater is expected to become one of the main sources of water to be developed in Palestine. Therefore, appropriate wastewater treatment and reuse technologies have to be identified for the West Bank. Several studies and projects were carried out on pilot and full scales for wastewater treatment.

In the study of wastewater treatment and reuse in the Hebron District, the Palestinian Hydrology Group (PHG) focuses on using low-cost technologies such as using biofilters and Upflow Anaerobic Sludge Blanket (UASB) as a primary treatment while using wetlands or duckweeds as a secondary treatment option. Based on experience, these systems are not only low-cost in terms of construction but also in terms of operation and maintenance costs. PHG conducted a research program in cooperation with Palestine Polytechnic University (PPU) through undergraduate student projects on the study and demonstration of simple wastewater treatment technologies, suitable for rural areas, and on the establishment of corresponding full-scale plants for treatment and reuse of treated effluent for irrigation and for the development of advanced agricultural production.

PHG constructed two low cost wastewater treatment plants in Kharas and Nuba villages. The treatment plants include two stages. In the first stage, the sewage received anaerobic treatment through UASB, and in the second stage the effluent received aerobic treatment through subsurface flow wetland. The system applied in Deir-Samit village is anaerobic primary treatment one. It consists of two compartment septic tanks followed four compartment biofilters and finally a storage tank.

Palestinian Environmental Authority testing the efficiency, capacity and appropriateness of treating wastewater using duckweed. A pilot scale duckweed system was constructed in Al-Aroub secondary school. The system consists of settling tank, Duckweed lagoons (ponds) and storage reservoir.

The previous work concentrated on the rural areas of the Hebron District, and most of the wastewater treatment plants which were constructed are decentralization treatment plants. The decentralization treatment plants reduce investment cost of sewers construction, reduce the running cost of the units of operation and require less maintenance cost. These wastewater treatment plants were designed for specific goals under specific circumstances and conditions which quite different than the local goals and conditions in rural areas of Palestine. Therefore, this study is conducted to evaluate the existing wastewater treatment plants in the Hebron Governorate.

1.3 Previous Studies

The Palestinian Hydrology Group (PHG) conducted a research program in cooperation with Palestine Polytechnic University (PPU) through undergraduate student projects on the study of simple wastewater treatment technologies, suitable for rural areas, and on the establishment of corresponding full-scale plants for treatment and reuse of treated effluent for irrigation and for the development of advanced agricultural production. The research work demonstrates the performance of Kharas and Deir Samit wastewater treatment plants.

Testing of a UASB-Wetland system at full scale at the village of Kharas (West of the Hebron District) shows COD variation from 1501.7 mg/l, at the head of the sewage works, to 98.2 mg/l as it leaves the treatment plant (93% removal). About two thirds of the COD removal took place inside the UASB. The efficiency for other pollutants removal was quite good; TS was reduced by 50% while sulfate at 97% and the effluent transparency was improved by 97%.

The treatment system of Deir Samit village, as mentioned earlier, composes of four biofilters compartments following two compartments septic tanks. The system receives 15 CM/d of domestic sewage through a small-scale sewer network. The COD varies form 1127.5 mg/l at the inlet to less than 200 mg/l at the outlet. The system was initially constructed to replace the prevailed flowing of sewage in the area's wadi. Such a primary treatment system was able to treat the sewage at acceptable levels and solve an environmental problem.

Duckweed-based pond system in Al–Aroub agriculture school treats 15 cubic meter per day of wastewater. The effluent water is used for irrigation purposes. The results of wastewater analysis show that the performance of Duckweed system in terms of COD, BOD_5, and nitrogen are quite good. The removal efficiency is more than 50%.

1.4 Objectives

The overall objective of this project is to investigate, demonstrate and evaluate the application of three advanced wastewater treatment technologies of UASB, Biofilters, and Duckweed lagoons used in wastewater treatment plants in the Hebron District, and compare them with the conventional wastewater treatment technology of a series of stabilization ponds. It is assumed that the advanced technologies are suitable for the Palestinian rural area communities since they are cost effective, easy to operate and easy to maintain. To achieve this goal five specific aims will be addressed:

1. Set the optimal design and operation parameters for domestic wastewater treatment plants by the UASB, Biofilters, and Duckweed.
2. Compare the feasibility of UASB, Biofilters, and Duckweed lagoons technologies with the conventional stabilization ponds technology.
3. Introduce a novel low-cost, low-technology biological wastewater treatment system developed and adapt it for the rural communities in the Hebron District.
4. Test the effects of the treated wastewater on the irrigated soil in study areas and analyze its chemical, and biological properties.
5. Evaluate the potential, acceptability and feasibility of this technology with rural populations residing in the Hebron District.

1.5 Study Areas

This project covered four areas in the Hebron District were wastewater treatment plants are exists. These areas are: Kharas town, Deir-Samit and Nuba villages, and Al-Aroub Camp. The location map of the study areas is shown in Figure 1.1. Brief description to each of study areas are given below.

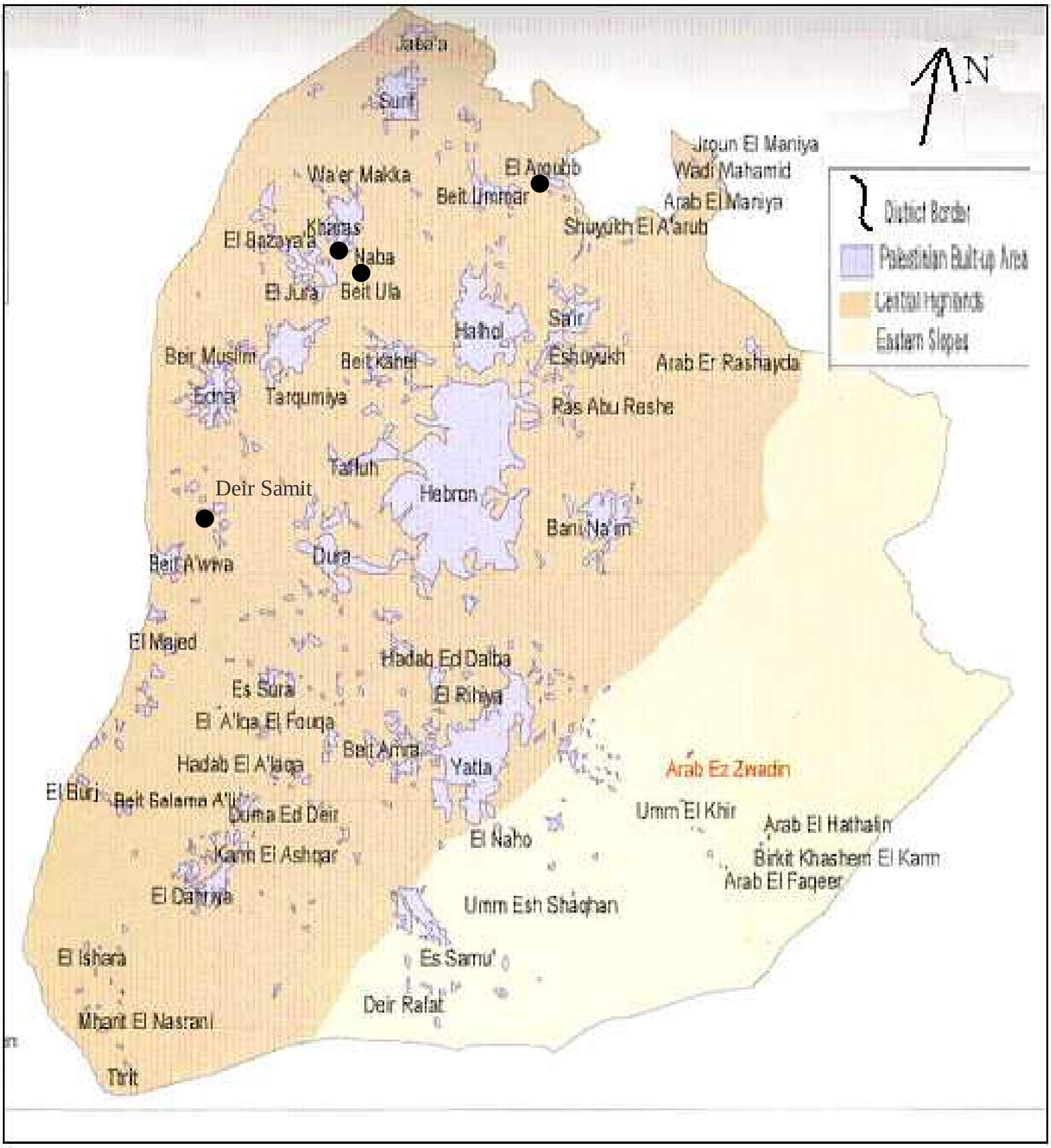

Figure (1.1): Location Map for the Study Areas

Kharas town is located 10 km north west of the Hebron city. The elevation within the area ranges from 650 m.a.s.l in center of the town to around 750 m.a.s.l in the eastern part. The present total municipal area of the town is about 18,000 dounms. The total population was estimated to be around 6,000 persons in the year 2001, and the total population is expected to grow up in the year 2017 to reach 10,000 persons.

Deir-Samit village is situated to the west of the Hebron city. The total population within the administrative borders is approximated to be about 5908 in year 2005. The elevation within the area ranges from 400 to 500 m.a.s.l.

Nuba village is located 20 km to the north west of the Hebron city. The average elevation of the town is 540 m with respect to sea level. The present total administrative area of the town is about 215 hectare. The total population was estimated to be around 4,328 person in the year 2005.

Al-Aroub camp is located 15 Km north of the Hebron city in way to Jerusalem. The total population of the camp is around 3000 person, and the elevation of the camp with respect to sea level is 800 m. The wastewater treatment plant was constructed in agriculture secondary school.

In general, the climate of the study areas tends to be cold in winter and warm in summer and relatively humid. The average maximum temperature is about 28 °C in summer while the average minimum temperature is 5 °C in winter. The average annual rainfall is about 450 mm and the relative humidity varies between 30-75%.The main water sources for all the areas is ground water and per capita water consumption does not exceed 60 liter per day.

1.6 Structure of the Report

The study report has been prepared in accordance with the objectives and scope of work. The report consists of five chapters.

The title of **Chapter One "Introduction"** outlines the background, previous studies, project objectives, study areas and structure of the report.

Chapter Two entitled **"Wastewater Treatment in Palestine"** reviews of the wastewater disposal and collection, characteristics of wastewater, wastewater production, and wastewater treatment in the West Bank.

Chapter Three entitled **"Wastewater Treatment-Overview"** presents treatment objectives, wastewater treatment process, biological wastewater treatment, important factors in process selection, and wastewater reuse applications.

Chapter Four labled **"The Existing Wastwater Treatment Plants"** describes the existing wastewater treatment plants in the Hebron District.

Chapter Five entitled **"Materials and Methodology"** describes field survey and flow measurements, wastewater quality analysis, and discussion of parameters tested.

Chapter Six labled **"Discussion of Results"** presents the flow rate data, characteristics of raw sewage and treated wastewater, the efficiency of the treatment plants, and the appropriate wastewater treatment plant .

The overall **"conclusions "** are given in **Chapter Seven**.

CHAPTER

2 *WASTEWATER TREATMENT IN PALESTINE*

2.1 Preliminary Remarks

2.2 Wastewater Disposal and Collection

2.3 Characteristics of Wastewater

2.4 Wastewater Production

2.5 Wastewater Treatment in the West Bank

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CHAPTER TWO

WASTEAWTER TREATMENT IN PALESTINE

2.1 Preliminary Remarks

In the West Bank, only 30-35% of the population as a whole is connected to sewage networks. The majority of the population uses individual or communal cesspits for wastewater disposal. Cesspits are emptied by vacuam tanker, which usually dump their contents onto open ground or wadis. In spite of the low overall percentage of access to sewage, approximately 70% of houses in the main West Bank cities are connected. Most villages have no sewage system, and refugee camps sewage flows through open drains.

Due to water scarcity, wastewater in the West Bank is highly concentrated. Low per-capita water consumption within Palestinian households affects the sewage composition by increasing the organic constituents and influent salinity. Wastewater has the characteristics of domestic wastewater since only light industries are prevailing. The total annual quantity of wastewater in the West Bank is estimated at 40 million cubic meter. Only about 14 million cubic meter is collected through sewer networks while cesspits and septic tanks receive the rest.

In West Bank, wastewater treatment has been neglected to a certain extent, with most attention focused on measures to solve water quantity and supply problems. The existing wastewater treatment plants in the West Bank are inadequate to serve the volume of wastewater being discharged. Wastewater treatment and reuse offer an increasingly attractive option to meet the growing water shortages facing urban, industrial and agricultural consumers in the West Bank. At the same time, wastewater treatment nowadays becomes more and more important for the protection of the enviroment and community. Wastewater treatment strategies has to be put forward in order to expliot this unconventional source of water, mainly in agriculture.

This chapter is devoted to a brief review of investigation on wastewater treatment and reuse in the West Bank. The studies included in the present review cover the experimental as well as the theortical works.

2.2 Wastewater Disposal and Collection

As mentioned earlier, about 65-70% of the total population in the West Bank are using cesspits as the final disposal system of wastewater. Cesspits are considered the traditional method of wastewater in West Bank. Only now with the cooperation between PECDAR and the Palestinian Authority, there are new projects to construct sewer networks (Sultan & Shalan, 1999).

Septic tank, which are preferable cesspits, are rarely used in Palestine because of its cost and lack of enviromental awareness. In the refugee camps which are directed by the UNRWA, open channels are used to move the waste a way from homes. During in the rainy season, the channels often over flow allowing waste to flood the streets and sometimes peoples homes. However, recently the UNRWA has undertaken to improve sewage collection systems, which will be connected to the nearby municipal systems or treatment facilities, Table (2.1) shows the percentage of the people connected to sewage network in the districts of the West Bank (Sultan & Shalan,1999).

Table (2.1) : Percentage of the Population Connected to Sewage Network

District	%Population Using Cesspits and Open Channels	%Population Connected to Sewage Network
Tulkarm	70	30
Nablus	62	38
Jenin	87	13
Ramallah	78	22
Jerusalem	60	40
Jericho	100	0
Bethlehem	65	35
Hebron	83	17

2.3 Characteristics of Wastewater

Several investigaters have studied the characteristics and water quality of wastewater. Most of the wastewater in the West Bank is municipal wastewater that contains domestic, industrial and commercial waste. The raw wastewater characteristics for each of the West Bank districts are shown in Table (2.2).

Table (2.2): Characteristics of Raw Wastewater in the West Bank Districts

Parameter	Location (district)				
	Ramallah	**Tulkarm**	**Hebron**	**Bethlehem**	**Jenin**
Ph	_	6.5	6.0	6.5	7.5
COD	1390	540	2736	2724	1446
BOD	525	250	520	660	1100
TSS	1290	398	1794	688	1088
Chloride	350.0	801	3540	1080	1400
Phosphate	13.1	17.9	134	45.6	46.0
Phosphorus	_	5.7	414	141	15.3
Nitrate	_	123	33.4	250	182
Sodium	_	252	839	411	700

All concentrations are in mg/l except the pH.

According to the internatioal classifications of domestic wastewater, West Bank has a strong wastewater due to the low per capita water consumption which leading to high values of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solid (TSS) (Elayyan et al,1997).

Wastewater in the West Bank contains BOD concentration from 250-1100 mg/l and COD concentration from 540-2736 mg/l, while developed countries have BOD between 200-300 mg/l and COD from 400-500 mg/l, which is mainly due to higher availability and consumption of water in these countries (Sultan & Shalan,1999).

2.4 Wastewater Production

The amount of domestic wastewater generated in the West Bank and Gaza Strip can be estimated based on the water consumption and the percentage of waste. The per capita consumption of water for domestic use in the West Bank ranges between 30-40 m^3/year. Nashashibi, M. and Van Duijl, L.A.(1995) estimated the quantity of wastewater in the West Bank district and Gaza Strip. The data are shown in Table (2.3).

Table (2.3): Wastwater Production in the West Bank and Gaza Strip for Year 2005

Area		Connected Population in thousand	Wastewater Production	
			l/c.d	m^3/d
West Bank	Hebron	146	40	5860
	Ramallah	30	70	2070
	Al-Bierh	24	70	1680
	Nablus	134	60	7970
	Jenin	27	60	1630
	Tulkarem	26	60	1540
	Bethlehem	39	70	2740
Gaza Strip	Gaza City	229	70	16020
	Rafah	107	70	7500
	Jabalia	165	70	11540

2.5 Wastewater Treatment in the West Bank

There are seven old treatment plants in the West Bank and Gaza Strip. Four are located in West Bank cities, namely Ramallah, Jenin, Tulkarem and Hebron (Al-Khalil). Three are in Gaza Strip in the cities of Biet Lahia, Gaza and Rafah. All have operational difficulties and are not functioning effectively, and some are not functioning at all. Most of these plants are over loaded, under-designed or have experienced mechanical failures (UNEP, 2003).

2.5.1 Existing Wastewater Treatment Plants

1. Ramallah wastewater treatment plant

The treatment plant is a stabilization pond system with 1.33 ha area, 2600 m^3/d influent flow rate and one week retention time. The system consist of 2 parallel-anaerobic lagoons with 1700 m^2 surface area, 3800 m^3 volume, 3.7 m depth and 2.5 d retention time each. After that the water flows to two serial facultative lagoons. The first facultative lagoon has 5400 m^2 surface area, 5400 m^3 volume and 1.5 d retention time. The second facultative pond is of 4500 m^2 surface area, 4500 m^3 volume and 2.5 d retention time. The influent wastewater of the system is that collected through the sewer system which equals 2490 m^3/d and about 100 m^3/d as septage. The influent and the effluent characteristics are shown in Table (2.4). The effluent of the treatment plant is disposed by an underground 12 inch pipeline that extends for about 2 km south of the treatment plant and it flows out freely to the surface of Wadi Bitunia (Ayalon) (Awadallah, 2000).

2. Al-Bireh wastewater treatment plant

The plant is located in Wadi Al-Ein over 2.2 ha area. The plant is extended aeration system newly constructed, with influent design flow rate of 5750 m^3/d, and overall retention time of 20 days. The treatment process includes preliminary treatment by grit removal and screening. After screening the wastewater is diverted equally to two parallel aeration tanks each with volume capacity of 7000 m^3, surface area of 1000 m^2 and 6 m depth. The effluent of aeration tanks is diverted to two parallel final clarifiers.

Most of the sludge accumlated in the clarifiers is returned to the aeration tanks while the excess sludge goes to the thickener for dewatering. The water passing the carifiers goes to disinfection by UV radiation, and collected in reservior of 1200 m^3 capacity. The final effluent is discharged through Wadi Al-Ein by 5 km pipeline to be reused for irrigation, in Dir-Dabwan land where large uncultivated areas exist (Awadallah,2000).

Table (2.4): The Influent and the Effluent Data of Ramallah Wastewater Treatment Plant

Parameter	Influent	Effluent	Removal Efficiency
BOD (mg/l)	>1000	-	-
COD (mg/l)	3342	2000	40%
Kj-N(mg NH^{+}_{4}-N/I)	67.4	45.6	32%
NH_4-N (mg/l)	48.8	41.1	16%
NO^{-3}-N (mg/l)	0.36	0.51	-
NO^{-2}-N (mg/l)	0.02	0.01	62%
SO^{-2}_{4} (mg/l)	299	115	-
PO^{-3}_{4}- P (mg/l)	8.3	14.6	-
P^{-} total (mg/l)	-	-	-
Cl^{-} (mg/l)	741	970	-
S^{-2}	1.1	1.3	-
pH	7.7	7.3	-
T (C)	17.2	12.4	-
DO (mg/l)	2.9	0.1	-
Fecal coliforms/100ml	$4.8*10^{8}$	$4*10^{5}$	99.9%

Data based on the average of 10 samples by the author.

3. Jenin wastewater treatment plant

The incoming flow rate is more than 1000 m^3/d. The system comprises 10500 m^2 of serial pond system of aerated, facultative and maturation ponds. The influent BOD is in the range of 1000-1100 mg/l, while the effluent BOD is in the range of 400-500 mg/l. The system suffers from overloading and poor maintenance. The system flood to the nearby lands and Wadis joining El-Muaqatta. The effluent flows through the Wadi and is collected in an earthen reservoir and used for cotton irrigation by the Israeli settlements (Awadallah,2000).

4. Tulkarem wastewater treatment plant

Approximately 70% of the city is connected to the sewer system which has more than 50% leakage. The treatment plant comprises 3 serial stabilization ponds with an influent flow rate value of 700 m^3/d. The effluent of the plant flows to Wadi Zomer where it joins other wastewater flows from Nablus and Anabta. Half of the wastewater quantity flowing through Wadi Zomer, is used by the Israeli side for cotton irrigation after treatment in an earthen resevoir (Awadallah,2000).

2.5.2 On-site Pilot Plants

1. Bir-Zeit university wastewater treatment plant

The system treated the produced wastewater from the university with an average flow rate of 22 m^3/d. The treated wastewater is used for toilet flushing and landscape irrigation in the university. The system performance in terms of COD removal is 80% (Awadallah,2000).

2. Al-Aroub agricultural school wastewater treatment plant

A duckweed-based pond system treating 10 m^3/d of wastewater from the agricultural school, Al-Aroub college and the adjacent stable of the cows. The effluent water is used for producing seedlings in a forest-tree nursery constructed for this purpose. In terms of BOD and COD the effluent meets the WHO guidelines for reuse in irrigation or groundwater recharge Table(2.5) (Awadallah,2000).

3. On-site wastewater treatment plant for one houshold in Bilien village in Ramallah district

A septic tank-trickling filter-based system treating 0.5 m^3/d of gray wastewater for a house of 13 persons. The influent COD is 650 mg/l and after the system approaches steady-state the effluent COD value is 60 mg/l. Effluent water is used for irrigating citrus and olive trees around the house (Mustafa, 1997).

Table (2.5): Data About Al-Aroub School Wastewater Treatment Plant

Parameter	Influent after Settling	Effluent	Removal Efficiency (%)
BOD (mg/l)	-	<20	-
COD (mg/l)	125.4	<50	>70
NH^+_4-N (mg/l)	89	<30	66.3
NO^-_3-N (mg/l)	0.5	2.3	-
TDS (mg/l)	1630	1476	-
PH	7.45	8	-
DO	0.5	>2	-

Data based on the average of 5 samples analyzed by the author. (Awadallah,2000).

2.5.3 Treated Wastewater Reuse for Agriculture

The use of sewage effluents for irrigation of agricultural crops is an attractive and popular wastewater reuse option. Wastewater can supplement available freshwater resources. Agriculture can beneficially use not only water, but also, within certain limitations, the additional resources found in wastewater, such as organic matter, nitrogen, phosphorous, potassium, minor elements and other nutrients. Moreover, irrigation is relatively flexible with respect to water-quality requirements. Stonecrops may be irrigated with low quality water without major risks, and some water quality problems can be solved by suitable agronomic practices. Reclaiming municipal wastewater for agricultural reuse is the currently adopted strategy in many countries. Irrigation with treated wastewater has been practiced in a number of contries on a variety of crops and has been successful (Sultan and Shalan, 1999).

The study of assement of treated wastewater reuse for irrigation in the Hebron city has been conducted by Al-Zeer, 2000. The results show that an area of about 18250 dounm in south Hebron city can be irrigated with treated wastewater.

Sultan and Shalan (1999) studied wastewater treatment and reuse using dukweed. By using treated effluent in irrigation, it was found that irrigation with 50% of total water demand using treated wastewater produced crop yeilds that compared with those from the fully irrigated plots, regardless of whether the full irrigation was from recycled or portable sources. Based upon these simple preliminary results, it was concluded that a balance between water consumption, nutrient addition and crop production was achieved and this justified an expansion of the experimental ponds to become a larger pilot activity.

2.5.4 Wastewater Treatment Strategies

The West Bank extends over the central highlands of Palestine. This area is the recharge area of the West Bank aquifer. The improper disposal and reuse methods of wastewater especialy in the highly permeable areas of limestone overlying the West Bank aquifer endangers the quality of the ground water. Any mismanagement will cause serious proplems, especially to ground water. The recycling and reuse of wastewater, if properly carried out with sufficient health, ecologicail and enviromental safeguards, can be a highly beneficial enviromental and water conservation strategy (Sultan and Shalan, 1999).

The appropriate technology for wastewater treatment should meet the needs for a range of physical, geographic and climatic conditions. The most appropriate wastewater treatment to be applied before effluent use is that which will produce an effluent meeting the recommended standards both at low cost and with minimal operational and maintenance requirement. Adopting as low a level of treatment as possible is specially desirable in the West Bank not only from the point of view of cost but also in acknowledgment of the difficulty of operating complex systems reliably. As a conclusion, compact, enclosed and covered treatment system are recommended for large or dense urban areas. Where land is available and inexpensive, it is recommended to use natural treatment systems with minimal cost and low energy consumption (Elayyan,1997).

CHAPTER

3 *WASTEWATER TREATMENT-OVERVIEW*

3.1 Preliminary Remarks

3.2 Treatment Objectives

3.3 Wastewater Treatment Process.

3.4 Biological Wastewater Treatment

3.5 Important Factors in Process Selection

3.6 Wastewater Reuse Applications

CHAPTER THREE
WASTEWATER TREATMENT–OVERVIEW

3.1 Preliminary Remarks

Wastewater collected from municiplities and communties must ultimately be returned to receiving wastes or to land or reused. The complex question facing the design engineer and public health officials is: what level of treatment must be achieved in a given application to ensure protection of public health and the environment? The answer to this question requires detailed analysis of local conditions and needs, application of scientific knowledge and engineering judgment based on past experience and consideration of local regulations. An overview of wastewater treatment is provided in this chapter. The treatment objectives along with the treatment process, important factors in process selection, and wastewater reuse applications are discussed in the following sections.

3.2 Treatment Objectives

Many compounds and various pathogenic bacteria and protoza are present in wastewater that can cause the pollution of surface water courses and ground water, if disposed directly without treatment. These pathogens present in raw wastewater can survive in the soil and on crops which cause environmental and health hazards.

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. The objectives involving the removal of suspended and floatable materials, destroy pathogenic micro-organisms and elemination of the most suspended and dissolved biodegradable organic materials.

Other objectives of wastewater treatment include, removal of objectionable items, nutrients and heavy metals. A secondary purpose of the sewage treatment is to treat and dispose of the solids, or sludge, generated by the treatment processes. For sewage from industrial sources, special attention must be given to removal toxic substances.
Wastewater treatment and reuse offer an increase singly attractive option to meet the growing water shortage facing urban, industrial and agriculture consumers in the world.

The technology selection eventually will depend upon the quality of the wastewater and on the desired quality of the treated effluent. The later depends on the expected use of the receiving water body. This typically aims to protect public health, to preserve the oxygen content in the water, to prevent eutrophication, to avoid settling of deposits, to avoid toxic compounds accumulating in the water and food chain, or to stimulate water reuse. These water uses are translated into emission standards or, in many countries, water quality classes, i.e. pertaining to the quality of the receiving water body. Depending on these, emission or effluent standards can be set which also take the technical and financial feasibility of treatment into account. Standards or guidelines may differ between countries.

3.3 Wastewater Treatment Process

3.3.1 Introduction

Treatment process include mechanical, biological and physicochemical treatment. Biological treatment is used principally for removed of organic matter, and is the most common of all wastewater treatment processes. There are two methods in wastewater treatment: conventional and innovative methods. Conventional treatment methods are more common in which will be discussed in this section.

Conventional treatment processes used generally for treatment of wastewater for restricted and unrestricted irrigation comprise various types of biological treatment, and at times chlorination of the effluents. The conventioal treatment processes are grouped into four general categories or stages according to the final result to be achieved and to the technology used. These stages are: preliminary treatment, primary treatment, secondary or biological treatment and teritiary or advanced treatment. The classification of common wastewater treatment is presented in Table (3.1).

A number of innovative processes have been developed recently for production of effluents of a quality suitable for unrestricted irrigation, including soil treatment, comprising recharge of effluents through an unsaturated cross-sectional of the subsurfaces. Of these processes, the most common one is the soil aquifer treatment process, based on recharge at a rapid rate to the groundwater and pumping of the recharged water by means of production wells.

Table (3.1): Classification of Common Wastewater Treatment Processes (FAO, 1987)

Preliminary	Primary	Secondary	Tertiary	Advanced
Coarse screening(CS)	Bar or bow screen	Activated sludge	Nitrification	Chemical treatment
Grit Removal(GR)	Grit removal	Extended aeration	Denitrification	Reverse osmosis
Comminution large Objects	Primary sedimentation	Aerated lagoon	Chem. Precipitation	Electrodialysis
_	Comminution	Trickling filter	Disinfection	Carbon adsorption
_	Oil/fat removal	Rotating bio-discs	(Direct) filtration	Selective ion exchange
_	Flow equalization	Anaerobic UASB	Chemical oxydation	Hyperfiltration by mem
_	pH neutralization	Anaerobic filter	Biological P removal	Technologies
_	Imhoff tank	Stabilization ponds	Constructed wetlands	_
_	-	Constructed wetlands	Duckweed ponds	_
_	-	Aquaculture	Aquaculture	_

3.3.2 Level of Treatment

Methods of treatment in which the application of physical forces predominate are known as unit operations. Methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions are known as unit processes. At the present time, unit operations and processes are grouped together to provide various levels of treatment known as mentioned earlier preliminary, primary, secondary, teritary, and advanced treatment. Breif description for each level is given below:

1. Preliminary treatment: the following preliminary processes are used in municipal wastewater treatment: coarse screening (bar racks), medium screening, comminution, flow measuring, pumping, grit removal, and preaeration.

2. Primary treatment: consist of physical processes involving mechanical screening, grit removal and sedimentation, aiming at removal of oil, fats, settelable and floating solids. Simultaneously at least 30% of BOD and 25% of TKN and total P are removed. Fecal coliforms are reduced with 1-2-log units only; whereas 5-6 is required for making it fit for agricultural reuse.

3. **Secondary treatment**: mainly converts biodegradable organic matter (BOD) and (TKN) to carbon dioxide, water and nitrates, by microbiological processes. These aerobic processes oxygen has to be supplied by extensive mechanical aeration. For sewage with relatively elevated temperatures anaerobic processes can also be applied. The efficiency is slightly lower, but it does not necessitate expensive energy input (on the contrary, it may produce energy rich biogas).

In primary and secondary treatment, sludge is produced which in volume only comprise less than 0.5% of the wastewater flow but heavy metals and other micro-pollutants tend to accumulate as these often adsorb onto suspended particles. Increasingly the problems of wastewater treament shift from the water line towards treatment and disposal of the sludge generated.

Natural wastewater treatment by ponds, constructed wetlands of aqua-culture using macrophytes can to large extend provide adequate secondary and tertiary treatment. As the biological processes are not accelerated by mechanical equipments largeland areas are required to provide sufficient retention time (between 1 to 2 weeks) to allow for a high degree of contaminant removal.

4. Tertiary treatment: is designed to remove TN and TP nutrients from the secondary treated effluents. Additional suspended solids and BOD removal is achieved through microbiological and/or physico-chemical processes. The objective of tertiary treatment is mainly to reduce eutrophication to occur in sensitive surface water bodies.

5. **Advanced treatment**: by ion exchange, adsorption, hyper-filtration, precipitation as well as oxidative disinfection and detoxification processes is applied mainly for industrial wastewater. In case a high quality effluent is to be produced in view of its reclamation for ground water recharge or recreation, advanced treatment steps may be added to the conventional treatment plant. (FAO, 1987).

The achievable efficiency for domestic wastewater treatment processes are presented in Table (3.2).

Table (3.2):Achievable Efficiencies for Domestic Wastewater Treatment Processes

Type	Effluent Concetration or Process Removal Efficiency				
	BOD	TSS	Ammonia	Phosphorus	Faecal Coliform
Preliminary	0% removal	0-10%	0%	0%	0
Primary	25-40% removal	40-70%	0-10%	0-10%	0-1
Secondary	5-40% removal	5-40%	1-10%	5-10%	1-2
Advanced	>50 removal	>50	25-50%	>50	>50

3.4 Biological Wastewater Treatment

Biological treatment is the most important step in processing municipal wastewaters. Physical treatment of raw wastewater by sedimentation removes only about 35% of the BOD, owing to the high percentage of non settleable solids (colloidal and dissolved) in domestic wastes. In biological treatment soluble organic and degradable substances are either oxidized to stable end products (e.g. CO_2, H_2O) or are converted into settleable solids like biomass. Chemical treatment, although used in domestic wastewater treatment, is not favord because of high chemical costs and inefficiency of dissolved BOD removal by chemical coagulation. A modern treatment plant uses a varity of physical, chemical, and biological processes to provide the best, most economical treatment.

Biological processes are classified according to presence of dissolved oxygen into aerobic, anaerobic, and combination of aerobic/anerobic (facultative). Anaerobic treatment converts the organic pollutants (COD, BOD) in wastewater into a small amount of sludge and a large amount of biogas (= methane gas + carbon dioxide), while leaving some pollution unremoved. In contrast, aerobic processes produce a lot of excess sludge, and no biogas, while also leaving some pollution, though less than after anaerobic treatment, unremoved. The main advantages of anaerobic treatment, particulary for bigger plants, are:

1. Low operation costs.
2. Low space requirments.

3. Valuable biogas production.
4. Low sludge production.

Aerobic processes use bacteria that need oxygen to live, anaerobic bacteria do not. In the absence of oxygen, many different groups of anaerobic bacteria "work" together to degrade complex organic pollutants into methane and carbon dioxide (biogas). The microbiology is more complex and delicate than in case of aerobic processes, were most bacteria "work" individually.

3.5 Important Factors in Process Selection

The most important factors that must be evaluated in process analysis and selection are identified in Table (3.3) (Metcalf & Eddy, 2003).

Table (3.3): Important Factors Considered in Selecting Unit Operations and Processes

Factors	Comment
1. Process applicability	The applicability of a process is evaluated on the basis of past experience, data from full-scale plants, published data, and from pilot-plant studies. If new or unusual conditions are encountered, pilot-plant studies are essential
2. Applicable flow range	The process should be matched to the expected range of flowrates. For example, stabilization ponds are not suitable for extremely large flowrates in highly populated areas
3. Applicable flow variation	Most unit operations and processes have to be designed to operate over a wide range of flowrates. Most processes work best at a relatively constant flowrate. If the flow variation is too great, flow equalization may be necessary
4. Influent wastewater characteristics	The characteristics of the influent wastewater affect the types of processes to be used (e.g., chemical or biological) and the requirements for their proper operation
5. Inhabiting and unaffected constituents	What constituents are present and may be inhibity to the treatment processes? What constituents are not affected during treatment?
6. Climatic constraints	Temperature affects the rate of reaction of most chemical and bioLogical processes. Temperature may also affect the physical operation of the facilities. Warm temperatures may accelarate odor generation and also limit atmospheric dispersion

7. Process sizing based on reaction kinetics or process loading criteria	Reactor sizing is based on the governing reaction kinetics and kinetic coefficients. If kinetic expressions are not available, process loading criteria are used. Data for kinetic expressions and process loading criteria are derived from experience, published literature, and the results of pilot-plant studies
8. Process sizing based on mass transfer rates or process loading criteria	Reactor sizing is based on mass transfer cofficients. If mass transfer rates are not available, process loading criteria are used. Data for mass transfer coefficients and process loading criteria are used. Data for mass transfer cofficients and process loading creteria usually are derived from experience, published literature, and the results of pilot-plant studies
9. Performance	Performance is usually measured in terms of effluent quality and its variability, which must be consistent with the effluent discharge requirements
10. Treatment residuals Influent wastewater characteristics	The types and amounts of solid, liquid, and gaseous residuals produced must known or estimated. Often, pilot-plant studies are to identify and quantify residuals
11. Sludge processing	Are there any constraints that would make sludge processing and disposal infeasible or expensive? How might recycle loads from sludge processing affect the liquid unit operations or processes? The selection of the sludge processing system should go hand in hand with the selection of the liquid treatment system
12. Environmental constraints	Environmental factors, such as prevailing winds directions and proximity to residential areas, may restrict or affect the use of certain processes, especially where odors may be produced. Noise and traffic may affect selection of a plant site. Receiving waters may have special limitations, requiring the removal of specific constituents such as nutrients
13. Chemical requirements	What resources and what amounts must be committed for a long time for the successful operation of the unit operation or process? What effects might the addition of chemicals have on the characteristics of the treatment residuals and the cost of treatment?
14. Energy requirements	The energy requirements, as well as future energy cost, must be known if cost-effective treatment systems are to be designed
15. Other resourses	What, if any, additional resources must be committed to the successful implementation of the proposed treatment system using the unit operation or process being considered?
16. Personnel requierments	How many people and what levels of skills are needed to operate the unit operation or process? Are these skills readily available? How much training will be required?
17. Operating and maintenance requirements	What specail operating or maintenance requirements will need to be provided? What spare parts will be required and what will be their availability and cost

18. Ancillary processes	What support processes are required? How do they affect the effluent quality, especially when they become inoperative?
19. Reliability	What is the long-term reliability of the unit operation or process being considered? Is the operation or process easily upset? Can it stand periodic shock loadings? If so, how do such occurrences affect the quality of the effluent?
20. Complexity	How complex is the process to operate under routine or emergency conditions? What levels of training must the operators have to operate the process?
21. Compaitibility	Can the unit operation or process be used successfully with existing facilities? Can plant expansion be accomplished easily?
22. Adaptability	Can the process be modified to meet future treatment requirements?
23. Economic life-cycle analysis	Cost evaluation must consider initial capital cost and long-term operating and maintenannce costs. The plant with lowest initial capital cost may not be the most effective with respect to operating and maintenance costs. The nature of the available funding will also affect the choice of process
24. Land availability	Is there sufficient space to accommodate not only the facilities currently being considered but possible future expansion?

3.6 Wastewater Reuse Applications

In the planning and implementation of water reclamation and reuse, the reclaimed water application will usually govern the wastewater treatment needed to protect public health and the environment, and the degree of reliability required for the treatment processes and operations. The seven principal categories of municipal wastewater reuse are listed in Table (3.4) in descending order of projected volume of use along with potential constraints for their application (Metcalf & Eddy, 2003)

1. The first category, agriculture irrigation, is the largest current use of reclaimed water. This reuse category offers significant future opportunities for water reuse.
2. The second category, landscape irrigation, includes the irrigation of parks; playgrounds; golf courses; freeway medians; landscaped areas around residences.
3. The third major use of reclaimed water is in industrial activities, primarily for cooling and process needs.
4. The forth reuse application for reclaimed water is groundwater recharge, via either spreading basins or direct injection to ground water aquifers.

5. A fifth use of reclaimed water, recreational/ environmental uses, involves a number of nonpotable uses related to land-based water features such as the development of recreational lakes, marsh enhancement, and stream-flow augmentation.
6. The sixth reuse category, nonpotable urban uses, includes such uses as fire protection, air conditioning, toilet flushing ,construction water, and flushing of sanitary sewers.
7. The seventh reuse opportunity involves potable reuse, which could occure by blending in water supply storage resevoirs or, in the extreme, by direct input into the water distribution system (i.e., so called " pipe-to-pipe" potable reuse).

Table (3.4): Categories of Municipal Wastewater Reuse and Potential Issues/Constraints

Wastewater Reuse Categories	Issues/Constraint
1. Agriculture irrigation, crop irrigation commmercial nurseries	• Surface and groundwater contamination if not managed properly • Marketability of crops and public acceptance
2. Landscape irrigation, parks school yards, freeway medinas, golf courses, cemeteries, greenbells, residential	• Effect of water quality, particularly salts, on soils and crops • Public health concerns related to pathogens (e.g., bacteria, viruses, and paraasies) • Use area control including buffer zone may result in high use costs
3. Industrial recycling and reuse, cooling water, boiler feed, process water, heavy construction	• Constituents in reclaimed water related to scaling, corrosion, biologicail growth, and fouling • Public health concerns, particulary aerosol transmission of pathogens in cooling water • Cross connection of potable water lines
4. Groundwater recharge, groundwater replenishment, salt water intrusion control, Subsidence control	• Possible contamination of groundwater aquifer used as a source of potable water • Organic chemicals in reclaimed water and their toxicological effects • Total dissolved solids, nitrates, and pathogens in reclaimed water
5. Recreational/ environmental, lakes and ponds, marsh enhancement, stream flow augmentation, fisheries, snow making	• Health concernes related to presence of bacteria and viruses (e.g., enteric infections and ear, eye, and nose infections) • Eutrophication due to nitrogen and phosphorus in receiving water • Toxicity to aquatic life

6. Non urban uses, fFire protection, air conditioning, toilet flushing	• Public health concernes about pathogens transmitted by aerosols • Effects of water quility on scaling, corrosion, biological growth, and fouling • Cross connection of potable and reclaimed water lines
7. Potable reuse, blending in water supply reservoirs, pipe-to-pipe water supply	• Constituents in reclaimed water, especially trace organic chemicals and their toxicological effects • Aesthetics and public acceptance • Health concerns about pathogen transmission, particlarly enteric viruses

CHAPTER

4 *THE EXISTING WASTEWATER TREATMENT PLANTS*

4.1 Preliminary Remarks

4.2 Kharas Wastewater Treatment Plant

4.3 Deir-Samit Wastewater Treatment Plant

4.4 Nuba Wastewater Treatment Plant

4.5 Al-Aroub Wastewater Treatment Plant

CHAPTER FOUR

THE EXSITING WASTEWATER TREATMENT PLANTS

4.1 Preliminary Remarks

For the purpose of this project, and in order to evaluate the existing wastewater treatment in the Hebron District, four wastewater treatment plant located in rural area of the Hebron Governorate were studied and evaluated. These treatment plants are located in Kharas, Deir-Samit, Nuba, and Al-Aroub rural communities. The name, location, population served, type of treatment, and effluent quantity of treated wastewater for each treatment plant are presented in Table (4.1).

Table (4.1): Wastewater Treatment Plants in the Hebron District

No.	Name	Population Served	Type of Treatment	Effluent Quantity
1	Kharas WWTP	2000	Anaerobic treatment processes (UASB) followed by aerobic treatment (wetlands)	120 m^3/day
2	Deir-Samit WWTP	400	Septic tanks followed by biofilters.	40 m^3/day
3	Nuba WWTP	1000	Anaerobic treatment processes (UASB) followed by aerobic treatment (wetlands)	60 m^3/day
4	Al-Aroub agriculture school WWTP	300	Duck weed –based pond system	12-15 m^3/day

As given in Table (4.1), the treatment processes in Kharas and Nuba villages is aerobic and anaerobic (UASB followed by wetlands). Al-Aroub wastewater treatment plant consists of Duck weed-based pond system, settling tank, and reservoir. Deir-samit wastewater treatment plant uses anaerobic system which is sedimentation tanks, and biofilters. The description of each of the treatment plants are given in following paragraphs.

4.2 Kharas Wastewater Treatment Plant

4.2.1 Introduction

The village of Kharas is located some 10 km to the west of the Hebron City. The sanitation options, before the year 2002, were the disposal of domestic wastewater through cesspits. These cesspits allowed infiltration of sewage through the soil profile and it even overflows frequently and thus polluting the adjacent yards and streets. The public health sector was suffering from water-born diseases due to infiltration of sewage into the water network and also to water storage facilities such as cisterns. In the year 2002, the Palestinian Hydrology Group (PHG) designed and implemented a project on wastewater collection and treatment in the village (Awadallah, 2002). The overall goals was to improve the hygienic conditions, protect water quality, reduce pollution loads and create a demonstration for sound treatment and collection of wastewater that could enhance surrounding towns to carry out such projects in their areas.

4.2.2 Description of the Plant

The design capacity of the treatment plant was 120 m^3/day which equivalent to 300 houses service. The fenced treatment plant site is 2 dounms area of which the treatment plant itself is 1063 m^2 area. The layout and general view of Kharas wastewater treatment plant are shown in Figure 4.1 and Figure 4.2. As given in Figure 4.1, the treatment processes consists of six stages as follow:

A: Bar screen.

B: Sand and grit removal channel

C: Anaerobic treatment stage using UASB.

D (D1, D2): Aerobic treatment stage using wetlands.

E*:* Effluent storage tank.

F: Sludge drying bed.

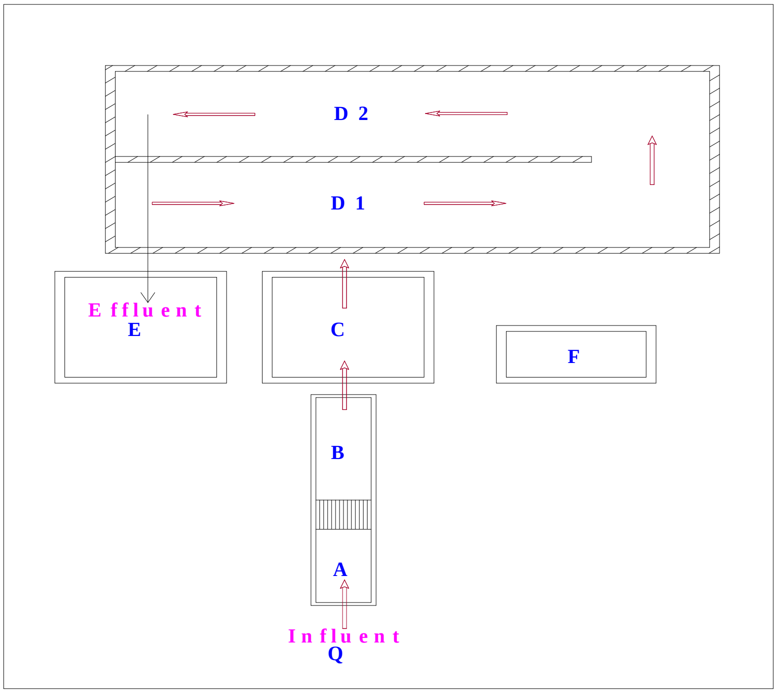

Fig (4.1): The Layout of Kharas Wastewater Treatment Plant

Fig (4.2): General View of the Wastewater Treatment Plant in Kharas Town

The name and description of each of the stage are given below:

1. Bar rack screen

This is designed to trap coarse material such as any type of solid waste with diameter higher than 2 cm. The picture of the bar screen is presented in Figure 4.3

2. Sand and grit removal channel

The channel is to remove sand and gravel and should be cleaned manually by replacing a removable plastic mesh placed inside the channel body Figure 4.4.

3. Anaerobic treatment stage using (UASB)

This is a tank with 5 m depth and has a square surface area (4m*4m). The schematic diagram of the UASB is illustrated in Figure 4.5 and the picture of the same is shown in Figure 4.6. The sewage inters the tank bottom through 4 vertical 4" PVC pipes, which split the flow into equal amounts. The water leaving the tank is draining through the V-notch channel at the water level meeting point. The hydraulic retention time inside this tank is 1.33 d based on the current flow rate and will be 0.67 d based on maximum flow capacity. The reactor is equipped with Gas-Liquid-Solid (GLS) separator inclined at angle of 50^o; this is made of protected steel plates. The GLS is dipped inside the water to occupy more than 1/3 of the reactor height. Below the GLS exists the deflector, which directs the water to the GLS and it is also made of protected steel. Closed to the V-notch channel, at the top of the reactor, exists the scum baffle. After the water leaves the V-notches it passes through water locked manhole. There are four 4" PVC pipes dipped into the reactor to enable removing sludge through a submersible pump. The most interesting thing is that the reactor is equipped with a gas collection system, which allows collection and storage of all the gas produced from the reactor and this take place through a non-return pathway. Figure 4.6 show the inlet feeding pipe of sludge and the gas pipe.

Fig (4.3): Picture of Bar Screen and Channel

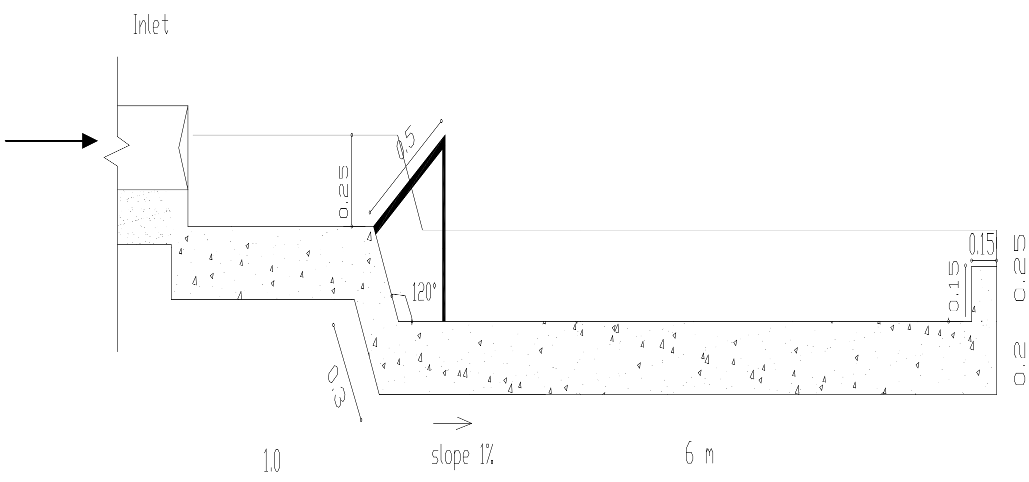

Fig (4.4): Cross Section for Sand and Grit Channel

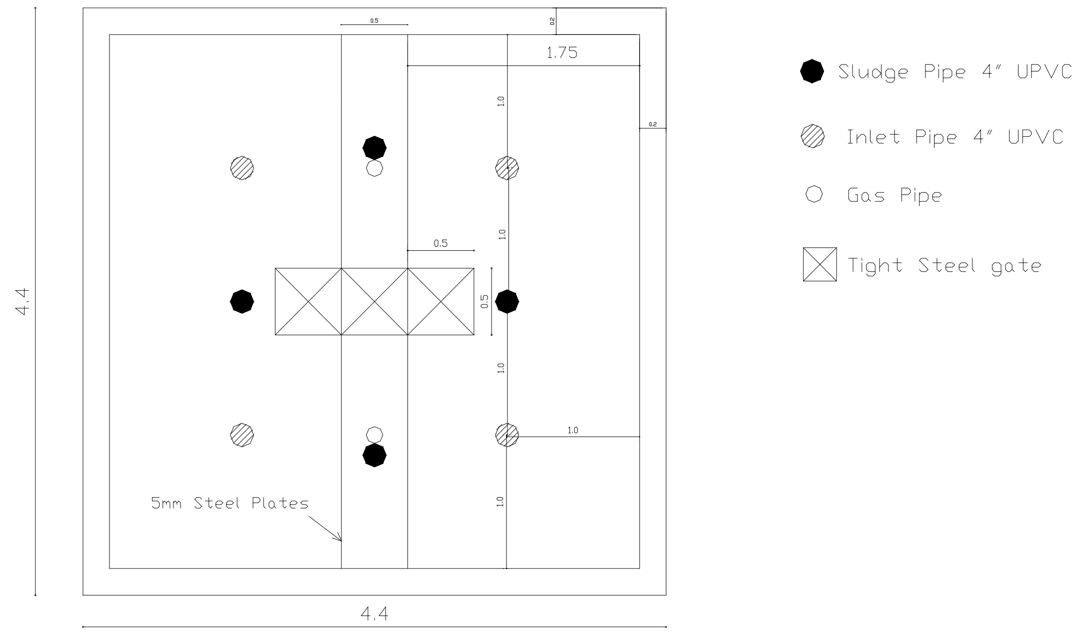

Figure (4.5): Schematic Diagram of UASB at Kharas WWTP

Fig (4.6): Picture of the UASB Tank

4. Aerobic treatment using subsurface flow wetlands:

The wetland, which is selected, is subsurface flow wetlands and is covered with reed plants that absorb the nitrogen and phosphate (see Figures 4.7 and 4.8 for the wet land at Kharas wastewater treatment plant). This stage contains lagoons lined in base and sides with high density polyethylene (HDPE) that prevents any expected leakage to the ground water. The wetlands include different sizes of gravel; the smallest are placed on the surface while the largest at the bottom, with reed plants planted at the surface. These plants make aeration in the upper half-meter of the water column through developing some 60 cm root zone. This enables the treatment to be aerobic. The basic biochemical reaction is the nitrification.

5. Effluent storage tank

This tank has 80 m^3 storage capacities and is equipped with a pump (2HP) to facilitate effluent reuse options. In normal situation, the water overflows from the tank surface, after the tank gets full, to flow through gravitational forces into the wadi through a subsurface drainage pattern. Figure 4.9 shows the picture of the storage tank.

6. Sludge drying bed

It contains gravel with size decrease from bottom to top. It drains the water from its bottom and it daily treats 2 m^3 of wet sludge. The drained water that results from this sludge dewatering process receives treatment in the wetland through conveyance pipes that carry it to the wetlands. The scraped sludge is currently disposed of in the area landfill that treats the solid waste. Figure 4.10 shows the sludge drying bed at Kharas wastewater treatment plant.

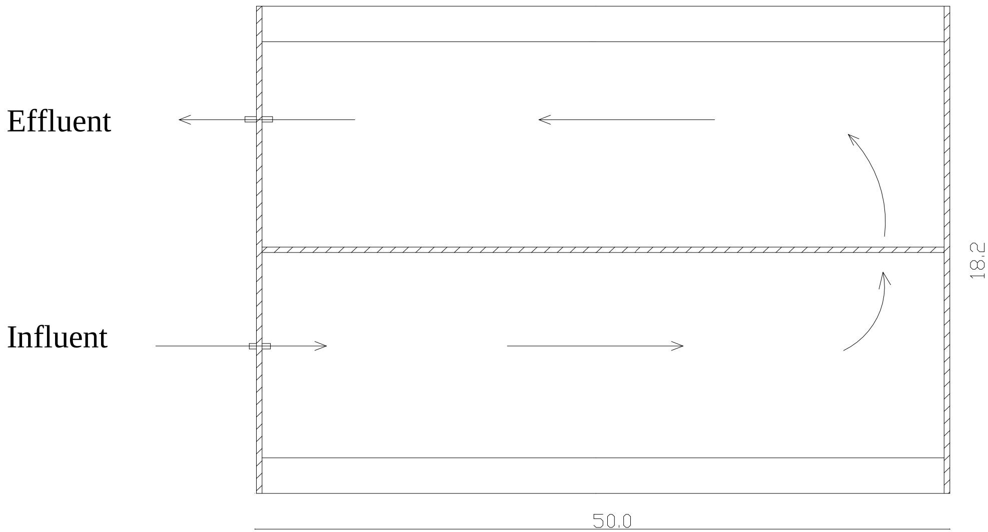

Fig (4.7): The Layout of the Wet Land

Fig (4.8): Wet Land at Kharas Wastewater Treatment Plant

Fig (4.9): Picture of the Storage Tank

Fig (4.10): Sludge Drying Bed at Kharas Wastewater Treatment Plant

4.3 Deir-Samit Wastewater Treatment Plant

4.3.1 Introduction

As other villages in the West Bank, Deir Samit inhabitants use cesspits as the main wastewater disposal option. In Deir Samit, a water network with intermittent flow exists; the water supply comes through the national water carrier for the western Hebron district areas. According to water meters readings, the average water consumption approaches 60 liter/capita.day.

Due to socioeconomic constraints evolved from cesspits, some houses clusters agree to make a wastewater collection system in the area. Around 50 houses householders construct a sewer system consisting of 4" pipes, which carry the sewage to the adjacent wadi. The sewage there creates stagnant wastewater pools, which allowed insects breeding and created nuisance and health problems. Figures 4.11 and 4.12 show how the situation in the wadi before implementing the project was.

The village council asks local NGOs to solve the problem. The Palestinian Hydrology Group (PHG) implemented a sanitation project aiming at solving the existing environmental problems.

4.3.2 Description of the Plant

A sewer network consisting of 6" UPVC pipes was constructed for a distance of 1000 meter length and it replaces the previously sewers which are done in a non-technical way. More than 40 houses and a school were connected to the sewer lines. The sewer outfall was connected to a wastewater treatment plant. Below Figure 4.13, that shows the treatment plant site. In fact the plant is inside a residential area and adjacent to a school. Because its surface is close, it does not allow mosquito or odor release to adjacent people.

The expected sewage flow, according to our field survey and meetings with the village council, in the system is within the range 12-25 cubic meters per day. The treatment plant is a primary treatment system. Figure 4.14 shows that the system is composed of 2-compartment septic tank followed by 4-compartment biofilters. The treatment plant is composed of the following units of operation:

Fig. (4.11): The Situation of the Wadi Before Building the Treatment Plant

Fig (4.12): The Situation Before the Plant Construction

Fig (4.13): The Site of Wastewater Treatment Plant in Deir Samit Village

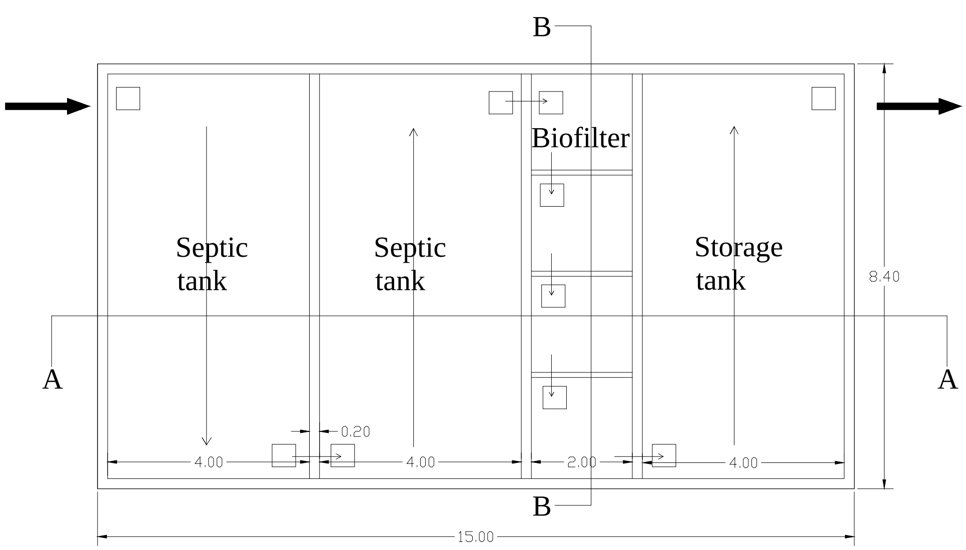

Fig (4.14): The Treatment System components

1. Two compartment septic tank:

The first compartment is with a surface area of 32 m^2 and a depth of 4 m. The active water depth is 3.5 m with a compartment volume of 128 m^3 of which the water occupies 112 m^3. The second compartment is similar but the active water depth is 3.45 m. Based on the expected flow conditions the retention time for the first compartment of the septic tank is (V/Q) =112/12 to 112/25 day which equal 9.3 to 4.5 days based on using flow rate input data of 12 and 25 m^3/d, respectively. The second compartment enables similar retention time. This means that the total retention time inside the septic tank will be 10 to 20 days.

According to the PHG design criteria taken into consideration, the system receives 15 cubic meters per day of wastewater. The design hydraulic retention time (HRT) was 15 days for the septic tank. The design was based on removing 65% of the influent COD at this stage. The COD is expected, according to design, to change from 1200 mg/l to 420 mg/l. The following Figure 4.15 shows the section A-A in the system component shown in Figure 4.14.

2. Four compartment anaerobic biofilters:

These are designed as up flow tanks. Each tank is feeded with wastewater by means of 6” UPVC pipe, which extends some 20 cm over its base. Water feeds the tank from top to bottom while it leaves each compartment from bottom to top.

These are four compartments with equal size. Each is with 5 square meters surface area. The only difference among these compartments is the size of gravel and the water depth. The hydraulic gradient from one compartment to the next ensures drop in the water level by 5 cm intervals. The first compartment is with a gravel size of 5-10 cm diameter, the second compartment is with gravel size of 2-4 cm and the second and the third compartment are identical with pea size gravel.

The total hydraulic retention time for all of these biofilter compartments as a sum is ranging from 5.7 d to 2.7 d based on using flow rate data on 12, 25 cubic meters, respectively. These filters were expected to remove 80% of the organic pollution. COD is expected to change form 420 mg/l to 84 mg/l which complies (and even much lower) with the Jordanian standards for wastewater disposal upon wadi’s or groundwater recharge. Figure 4.16 shows the anaerobic

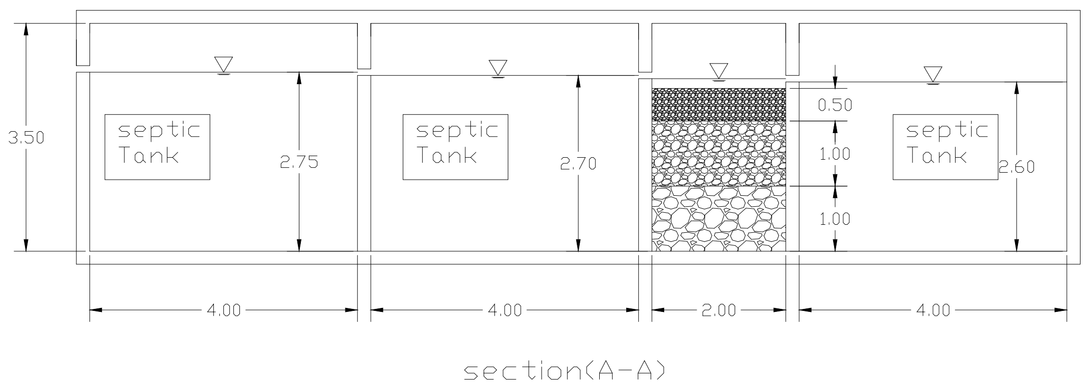

Fig (4.15): Section A-A in the System component

Fig (4.16): Anaerobic Biofilter Opening

biofilter first compartment. Bubbling of biogas is clear in this compartment and it indicates the occurrence of anaerobic treatment which converts macromolecules to monomers and finally to methane gas. Figure 4.17 shows the section B-B of the four compartments of the anaerobic biofilter and gravel size.

3. Storage tank for treated effluent:

This tank has a capacity of 105 cubic meters. It aims at making available the required volumes of treated wastewater for the target expected reuse.

In the design, it was planned to use the surplus effluent for groundwater recharge. This was done through constructing underground-perforated 6” pipeline, which allows effluent infiltration. Later on, it was observed that the soil infiltration capacity for the water was poor and that water comes to the surface. To alleviate water appearance at the soil surface, currently the effluent is transported via tankers and used for forests irrigation.

Due to land availability and economic constraints, the treatment level decided for Deir Samit was primary at that time. A low cost technology with small land space requirement was selected. The focus was given to COD and BOD removal rather than other parameters. This is to comply with local and regional wastewater disposal standards. Figure 4.18 shows a top view of the storage tank for treated effluent.

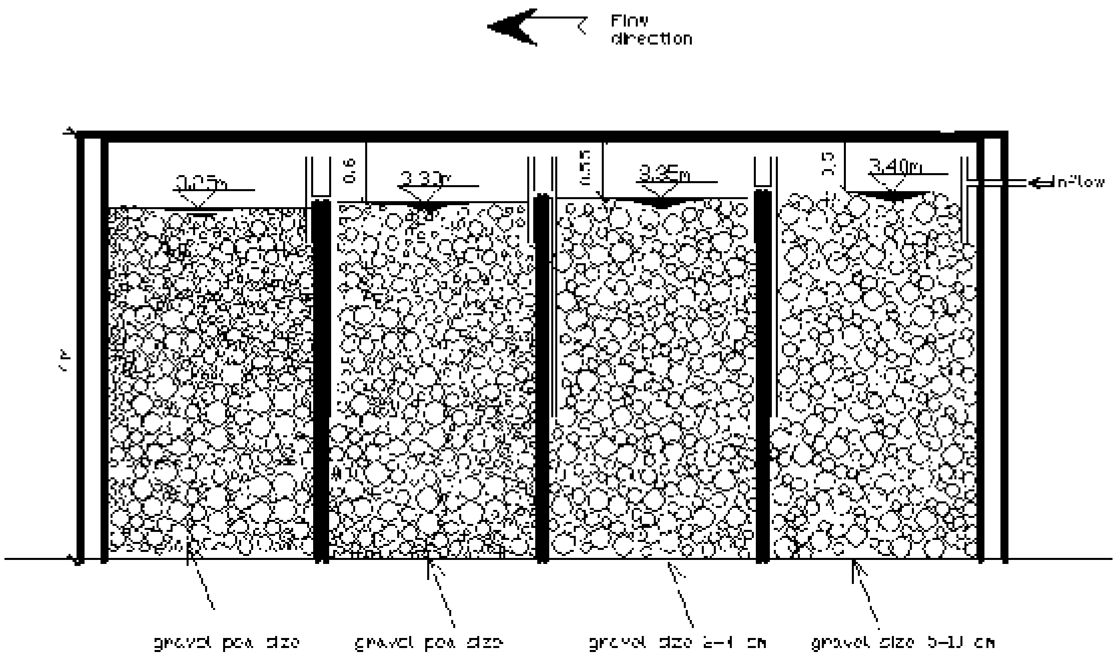

Fig (4.17): Four Compartments of the Anaerobic Biofilters and Gravel Size

Fig (4.18): Top View of the Storage Tank

4.4 Nuba Wastewater Treatment Plant

4.4.1 Introduction

Nuba is located 20 km to the north west of the Hebron city. The average elevation of the town is 540 m with respect to sea level. The present total administrative area of the town is about 215 hectar. The total population within the administrative borders was estimated to be around 4,328 persons in the year 2005. The climate of Nuba tends to be cold in winter and warm in summer. The average maximum temperature is about 34ºC in summer and the average minimum temperature is 2 ºC in winter. The average rainfall is about 350 mm per year.

Wastewater collection disposal and treatment has been neglected in the town, like many places in Palestine. As the town is considered to be unsewered area, using cesspits and open drains, which cause different environmental problems and pollution of ground water. These conditions bring the whole area to a bad condition. In 2004, the town is supplied with main sewer pipline to serve around 250 families, and Palestinian Hydrology Group constructed wastewater treatment at the outfall of sewer line at desing capacity of 60 m^3/day.

4.4.2 Description of the Plant

Nuba wastewater treatment plant system is similar to Kharas wastewater treatment plant. Wastewater is treated using anaerobic Upflow Anaerobic Sludge Blanket (UASB) followed by aerobic treatment using wetland. As mentioned earlier, this plant was in operation during 2005 with a total design capacity of 60 m^3 per day. Part of the reclaimed water is planned to be used for irrigation of rainfed trees within the plant and the reminder is discharged to near valley. The main components of the plant are: Bar screen, Sand and grit removal channel**,** and anaerobic treatment stage using UASB, aerobic treatment stage using wetlands, effluent storage tank, and sludge drying bed. These components are described in details in the layout shown in Fig 4.19.

The wastewater treatment plant using UASB and wetland at Nuba town is shown in Fig 4.19. Figures 4.20 through 4.26 show the pictures of the treatment plant.

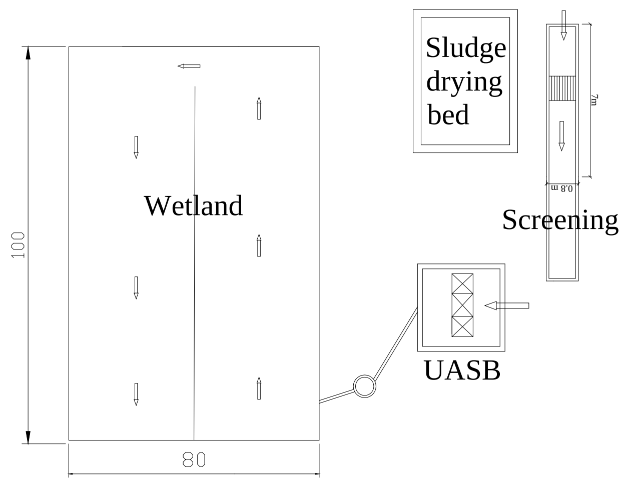

Fig. (4.19): The Layout of Nuba Wastewater Treatment Plant

Fig. (4.20): Wastewater Treatment Plant in Nuba Village

Fig. (4.21): Bar Screen Photo in the Treatment Plant

Fig (4.22): Picture of Screening and the Channel

Fig (4.23): UASB Storage Tanks

Fig (4.24): Sludge Drying Bed

Fig (4.25): Wet Land at Nuba Wastewater Treatment Plant

Fig. (4.26): View of the Wet Land at Nuba Wastewater Treatment Plant

4.5 Al-Aroub Wastewater Treatment Plant

4.5.1 Introduction

Al-Aroub Wastewater Treatment Plant shown in Figure 4.27 and Figure 4.28 was constructed in 1997.A proper infrastructure were added to the plant such as sewer line, manholes and three small ponds with a dimension of 2*3*0.5 m. Plastic sheet were installed at the bottom of the ponds to prevent seepage. Duckweed (*Lemna gibba*) fronds were brought and installed in a mixture with wastewater and tap water for cultivation and adaptation, and then it was installed in the ponds. Duckweed-based pond system shown in Figure 4.30 treats 12-15 m^3/day of wastewater from the agriculture school that composed of Al –Aroub College and the adjacent stable of the cows. The effluent water is used for producing seedling in a forest-tree nursery constructed for reuse in irrigation or groundwater recharge.

4.5.2 Description of the Plant

The general layout of Al Aroub wastewater treatment plant described in Figure 4.29 and Figure 4.30. The system consists of settling tank, two Duckweed ponds and storage reservoir. The wastewater coming from Al Aroub secondary school and Al Aroub Technical College enters the treatment plant through the plastic pipeline and bar screen installed for this purpose to the settling tank (see Fig.4.31).Then the wastewater goes to constructed Dukweed ponds. Duckweed (lemna gibba) fronds were brought and installed in a mixture of wastewater and tape water for cultivation and adaptation. After that, lemna gibba fronds were installed in the ponds that slowly grew and covered the whole surface. The treated wastewater is stored in a storage tank, where then taken and used for irrigation of plants in Al Aroub Complex Farm.

Duckweed is a small, green, flat, flowering, aquate plant, within the taxonomic family called lemnaceae shown in Figure 4.32.It grows rapidly if its primary needs for nutrients and solar radiation are met. All species occasionally produce tiny, almost invisible flowers and seeds, but what triggers flower production is unknown. Duckweed size, in general, ranges from 1-15 mm. distinct leaves and stems are replaced by fronds. In each frond there are one or two meristematic regions which produce new fronds. At least two daughter fronds are produced during duckweed's short life cycle. The growth rate is quite high and the biomass can be doubled in two to three days.

Fig (4.27): The Site of Al-Aroub Wastewater Treatment Plant

Fig (4.28): Al-Aroub Wastewater Treatment Facilities, *(MOFAJ, 1999*)

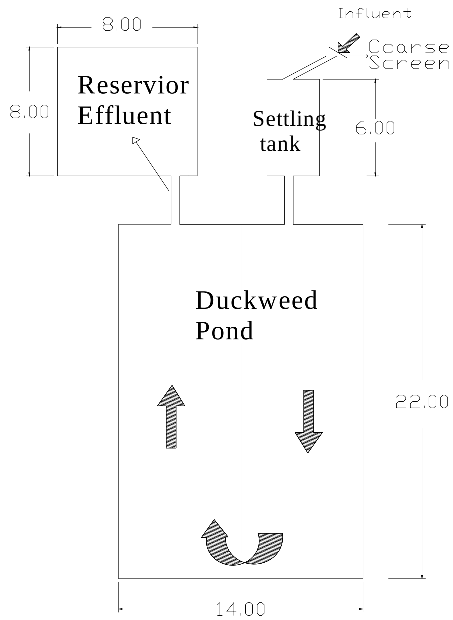

Fig (4.29): General Layout of Al-Aroub Wastewater Treatment Plant

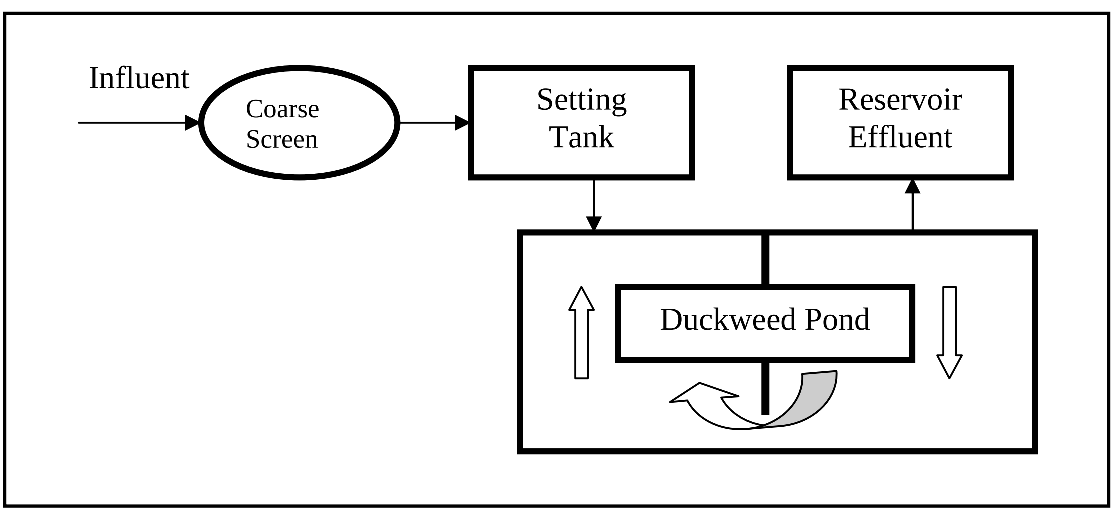

Fig (4.30): Wastewater Treatment Plant Using Duckweed at Al-Aroub School

Fig (4.31): Settling Tanks at Al Aroub Wastewater Treatment Plant

Fig (4.32): Duck weed Plant

The duckweed system is competitive with existing secondary and tertiary treatment methods. In aquatic systems, wastewater is treated principally by means of bacterial metabolism and physical sedimentation as is the case in conventional activated sludge and trickling filter systems. Once microorganisms are established they form a symbiotic relationship with duckweed plants. Microbial decomposition of organic materials into mineral components such as C, N and P are converted into protein by the duckweed and will cause anaerobiosis which is maintained by the duckweed mat and this mat subsequently prevents re-aeration.

Duckweed based wastewater treatment is very efficient in removing nutrients from the wastewater. One of the major advantages of this system is that it turns the waste into valuable duckweed meal to return a net profile against both capital and operational costs (see Fig.4.33 for Duckweed pond at Al Aroub treatment plant). The duckweed crop is enriched with nutrients during the treatment and can be used as animal fish or chicken food. Harvesting of duckweed is easier than that of hyacinth. So, ease of harvesting makes the system more economically attractive, this plant could die because of some oils reach to it as what happening in one of the wetlands which appeared clearly in Figure 4.34.

Duckweed systems are also known for their capabilities to control mosquitoes and odors. Mosquitoes require open and stagnant water for breeding, which can be prevented by maintaining a full surface cover of duckweed as a physical barrier. This barrier also reduces by preventing gaseous exchange. Moreover; duckweed ponds are commonly preceded by settling tanks or anaerobic ponds to reduce the organic load and to hydrolyze organic nitrogen which is the preferred nitrogen source for uptake by duckweed, then the treated wastewater reached the storage tank presented in Figure 4.35.

Fig (4.33): Duckweed Ponds at Al Aroub Wastewater Treatment Plant

Fig (4.34): Ponds With Dead Duckweed

Fig (4.35): Storage Tank at Al Aroub Treatment Plant

CHAPTER

5 *MATERIALS AND METHODOLOGY*

5.1 Preliminary Remarks

5.2 Field Survey and Flow Measurement

5.3 Wastewater Quality Analysis

5.4 Discussion of Parameters Tested

CHAPTER FIVE
MATERIALS AND METHODOLOGY

5.1 Preliminary Remarks

An understanding of the nature (characteristics) of wastewater is essential in wastewater treatment processes including the design of the treatment plants, suitability of wastewater for irrigation use, and in evaluation the performance of the existing wastewater treatment plants. This chapter covers the survey of wastewater quality and quantity of the studied treatmet plants.

The main objective of this chapter is to explain the methodology carried out to find out the characteristics of raw wastewater before and after the treatment, along with the measurment of the inflow rate, and the observations recorded through site visits, in order to determine the efficiency of the studied wastewater treatment plants.

5.2 Field Survey and Flow Measurement

5.2.1 Introduction

In this project, an attempt is made to study and evaluate the existing wastewater treatment in the Hebron Distinct. The study concentrated on technical evaluation through determining the quality of treated wastewater and the problems in the management and operation systems. Site visits for the treatment plants were carried out many times, where some problems are registered. These problems are:

1. The wastewater treatment plant at Kharas receives high loads of olive mill effluents (estimated at 20 m^3/d prevailed for about 2 weeks) and the wastewater color is black and with oily appearance and odor.

2. The duckweed plant in the first cell in Al Aroub wastewater treatment plant is died while the second cell is with complete plant cover. The influent wastewater contains high fractions of manure.

3. The wetland in Nuba wastewater treatment plant is not full of wastewater and no outflow is detected.

5.2.2 Flow Rate Measurements

The inflow rate was measured by using a volumetric container as shown in Fig 5.1 and stop watch. Flow measurement was carried out during 8:00 am–3:00 pm. After that the flow rate was calculated using the following equation:

$$Q = \frac{V}{t} \tag{5.1}$$

Where:

Q: is flow rate (l/s)

V: is volume of collected waste water in a volumetric container (l).

t: is the time required to collect V-volume of waste water(s).

Fig (5.1): **Measurement of the Flow Rate in the Field.**

5.3 Wastewater Quality Analysis

5.3.1 Wastewater Sampling

In order to study the characteristics of raw wastewater in the treatment plants, eight samples were collected, tested, and analyzed. Sampling took place during day time from the outfall place two times during the course of the research for chemical and biological analysis. The samples are then tested and analyzed in the Palestinian Hydrology Group (PHG) labratories and the results were obtained.

In sampling wastewater for quality analysis, glass bottels 250 ml volume was used, one bottel for each chemical and biological analysis. After sterilizing the bottels in an ordinary oven for one hour at 170ºC and rinsing them and the stopper with distilled water, the samples are then collected in the morning time and securely saled, this is done by the help of cleaned bucket. Samples were stored at 4ºC in iceboxes and brought back immediately to the laboratory for analysis. Sampling was performed in accordance with the standard sampling procedure of American Society for Testing and Materials (ASTM).

5.3.2 Laboratory Analysis and Measurements

A complete wastewater quality analysis was performed at the laboratory two times during the course of the research to assess wastewater quality in the treatment plants. Tests are conducted at the Palestinian Hydrology Group labratories.

The laboratory analysis included the following tests which were performed:

1. Temperature (T).
2. pH value (pH).
3. Electric Conductivity (EC).
4. Total Solid (TS).
5. Total Suspended (TSS).
6. Total Dissolved Solids (TDS).
7. Chemical Oxygen Demand (COD).
8. Dissolved Oxygen (DO).
9. Salinity (S).
10. Ammonia (NH_4^+)
11. Chloride (Cl^-)
12. Total Coliform (TC).

The procedures for the the test are given in Appendix B.

5.4 Discussion of Parameters Tested

1. Temperature (T):

The temperature of wastewater is slightly higher than that of water supply. Temperature has effect upon microbial activity, solubility of gases, and viscosity. The temperature of wastewater varies slightly with the seasons, but is normally higher than air temperature during most of the year and lower only during the hot summer months.

2. pH:

The hydrogen-ion concentration is an important quality parameter of both natural water and wastewater. The usual means of expressing the hydrogen-ion concentration is as pH, which is defined as the negative logarithm of the hydrogen-ion concentration.

The concentration range suitable for the existence of most biological life is quite narrow and critical (typically 6-9). Wastewater with an extreme concentration of hydrogen-ion is difficult to treat by biological means, and if the concentration is not altered before discharge, the wastewater effluent may alter the concentration in the natural water. For treated effluent discharged to the environment the allowable range usually varies from 6.5 to 8.5.

3. Electrical Conductivity (EC):

The Electrical Conductivity (EC) of a water is a measure of the ability of a solution to conduct an electrical current; because the electrical current is transported by the ions in solution, the conductivity increases as the concentration of ions increases. In effect, the measured EC value is used as a surrogate measure of Total Dissolved Solids (TDS) concentration. At present, the EC of water is one of the important parameters used to determine the suitability of water for irrigation. The salinity of treated wastewater to be used for irrigation is estimated by measuring its electrical conductivity. The electrical conductivity is expressed as millisiemens per meter (mS/m) or micromhos per centimeter (µmho/cm). It should be noted that 1 mS/m is equivalent to 10 µmho/cm.

4. Turbidity:

A measure of the light-transmitting properties of water, is another test used to indicate the quality of waste discharges and natural water with respect to colloidal and residual suspended matter. The measurement of turbidity is based on comparsion of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same conditions. The results of turbidity measurements are reported as nephelometric turbidity units (NTU).

5. Total Solids (TS):

The most important physical characteristic of wastewater is its total solids content, which is composed of floating matter, settleable matter, colloidal, and matter in solution.

Total Solid (TS) are obtained by evaporating a sample of wastewater to dryness and measuring the mass of the residue.

6. Total Suspended Solids (TSS):

Total suspended solids in wastewater may be due to sand, silt, clay, and organic matter. The typical total suspended solids concentration in municipal wastewater is 230 mg/l. The suspended solids when discharged into the natural water may increase turbidity of the water and when they settle to the bottom may ruin the spawing and breeding grounds of a quatic animals.

7. Total Dissolved Solids (TDS):

Total dissolved solid can be defined as the solids that pass through a filter with nominal pore size of 2 microns or less. Yet it is known that wastewater contains a high fraction of colloidal solids. The size of colloidal particles in wastewater is typically in the range from 0.01 to 1.0 µm. The number of colloidal particles in untreated wastewater and after primary sedimentation is typically in the range from 10^8 to 10^{12} per milliter.

8. Chemical Oxygen Demand (COD):

The COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in an acid solution. It is a chemical test using a strong oxidizing agent (potassium dichromate), sulfuric acid and heat. The results of the COD test can be available in just two hours, a definite advantage over the 5 days reqired for the standard BOD test. COD values are always higher than BOD values for the same sample, but there is generally no consistent correlation between the two tests for different wastewaters.

9. Biochemical Oxygen Demand (BOD):

Biochemical Oxygen Demand (BOD) is defined as the amount of oxygen utilized by a mixed population of microorganisms under aerobic condition to stabilize the organic matter (or is a measure of organic material in wastewater). Oxygen is required to break down large organic molecules into smaller molecules and eventually into carbon dioxide and water.

5-day Biochemical Oxygen Demand (BOD5) is the most commonly used parameter to express the strength of municipal and industrial wastewaters. The BOD5 test is important for the design of biological treatment facilities, determining organic loadings to treatment plants, and evaluating the efficiencey of treatment systems.

10. Dissolved Oxygen (DO):

Dissolved oxygen is required for the respiration of aerobic micro-organisms as well as all other aerobic life forms. However, oxygen is only slightly soluble in water. Dissolved oxygen is used extensively in biological wastewater treatment facilities. Air or sometimes pure oxygen, is mixed with sewage to promote the aerobic decomposition of the organic wastes. Because the rate of biochemical reactions that use oxygen increases with increasing temperature, dissolved oxygen levels tend to be more critical in the summer months.

11. Total Salt Concentration:

Total salt concentration is one of the most important agricultural water quality parameters. This is because the salinity of the soil water is related to, and often determined by; the salinity of the irrigation water. According to, plant growth, crop yeild and quality of produce are effected by the total dissolved salts in the irrigation water. Equally, the rate of accumulation of salts in the soil, or soil salinization, is also directly affected by the salinity of the irrigation water. Total salt concentration is expressed in milligrams per liter (mg/l) or parts per million (ppm).

12. Ammonia ($NH4^+$):

Nitrogen may be present in wastewater in both inorganic and organic forms and in both reduced and oxidized states. In untreated wastewater it is chiefly present as ammonia or as a constituent of protein (organic nitrogen). Its concentration is determined by a digestion-distillation process followed by colorimetric, titrimetric, or electroophoretic analysis.The relative standard deviation for ammonia determinations ranges from less than 10 to nearly 70 percent. Organic nitrogen determinations have relative standard deviations ranging from about 40 to over 100 percent.(McGhee,T.J.,1991).

13. Chloride (Cl^-):

Chloride is a constituent of concern in wastewater as it can impact the final reuse applications of treated wastewater. Chloride in natural water result from the leaching of chloride-containing rocks and soils wit hich the water comes in contact, and in coastal areas from saltwater intrusion. In addition, agricultural, industrial, and domestic wastewaters discharged to surface waters are a source of chlorides.

Human excreta, for example, contain about 6 g of chloride per person per day. In addition areas where the hardness of water is high, home regeneration type water softeners will also add large quantities of chloride. Beause conventional methods of waste treatment do not remove chloride to any significant extent, higher than usual chloride concentrations can be taken as an indication that a body of water is being used for waste disposal. Infilitration of ground water into sewers adjacent to saltwater is also a potential source of high chlorides as well as sulfate. (Metcalf & Eddy, 2003).

14. Total Coliforms (TC):

The municiple wastewater contains micro-organisms that play an important role in biological waste treatment. The principal groups micro-organisms of significance in wastewater treatment include bacteria, fungi, protozoa and alge. The most important biological indicator of water equality and pollution is the group of bacteria called coliforms. Coliform bacteria are hardy organisms that survive in water longer than most pathogens. They are also relatively easy to detect.

Coliforms are actually a broadly defined group of micro-organisms. They occur naturally in the soil as well as the digestive tract of warm-blooded animals, including humans. It is necessary to make a distinction between two groups: total coliforms and fecal coliforms. Total coliforms refer to all the members of the group regardless of the origin. Fecal coliforms are those from the intestines system of warm blooded animals; E. Coli are fecal coliforms from humans.

CHAPTER

٦ *DISCUSSION OF RESULTS*

6.1 Preliminary Remarks

6.2 Flow Rate Data

6.3 Characterstics of Raw Sewage

6.4 Characterstics of Treated Wastewater

6.5 Efficiency of the Treatment Plants

6.6 Appropriate Wastewater Treatment Plant

CHAPTER SIX
DISCUSSION OF RESULTS

6.1 Preliminary Remarks

This part of the project introduces our results of the monitoring process of the four treatment plants which took place for more than 6 months. Each stage of the treatment process (unit of operation) was monitored. This will help in understanding the performance of each system, thus analyzing the different process mechanisms that took place. The chapter will introduce the efficiency analysis for the UASB-wetlands system at Kharas and Nuba villages, septic tank-biofilter system at Deir Samit village, and Duckweed system at Al Aroub Camp.

The discussion will start by introducing the wastewater quality at different treatment stages starting from raw sewage to second and third stages of treatment, and finally to storage tank. This was done in terms of concentration or values of each parameter tested. After that the percentages of change (increase or decrease) of each parameter value were determined in order to evaluate the performance of each unit. Then, the performance of whole of the treatment plant as one unit was carried out in order to assess the system whole performance without partition. Finally, appropriate wastewater treatment plant was recommended for the wastewater treatment in the rural areas of the Hebron Governorate.

6.2 Flow Rate Data

The flow rate measurements provide information about the hydraulic load of the treatment plants, so that we can know whether the system is coping with minimum required hydraulic retention time. As mentioned earlier, the flow rate was measured using a volumetric container and a stop watch, and calculated from equation ($Q = \frac{V}{T}$).

The values of flow rate were measured in 13/4/07 at 12:00 o'clock noon. At this time, the flow rate is the maximum, since people start to prepare the lunch, clothes washing and so water consumption is the highest; after breakfast, houses activities started. The data obtained are given in Table (6.1).

Table (6.1) The Data of Flow Rate

Parameter	**Wastewater Treatment Plant**			
	Kharas	**Deir Samit**	**Nuba**	**Al Aroub**
Flow Rate (l/s)	0.46	0.23	0.35	0.12

6.3 Characteristics of Raw Sewage

The characteristics of black wastewater are impacted by water consumption rates, population density, and habits of population. Black wastewater contains over 90 percent water. The remaining materials include suspended and dissolved organic and inorganic matter as well as microorganisms. These materials given physical, chemical, and biological qualities that are characteristic of wastewater. In this section, chemical and biological qualities, and variaties in constituents and loading in raw wastewater are discussed for the study treatment plants.

Based on the three sampling sets, the average values for the raw sewage characteristics for the four rural areas (Kharas, Deir-Samit, Nuba and Al Aroub) are shown in Table (6.2). The average for the averages are also given in the table as a representitive for the rural area of the Hebron Governorate. These averages can reflect the wastwewater characteristics for the rural area in the Hebron District or even the rural areas of the West Bank in general.

By introducing representative values expressing sewage characteristics for rural areas, we make it easier for designer to design sewage facilities in rural areas relying in actual data taken from rural sewered areas rather than using data belonging to the West Bank cities. This is important because these three sites have sewers while most sites of other rural areas in the West Bank are non-sewered. Planers for sewage treatment in rural areas can use this data for selecting and designing units of operation.

Table (6.2) : Results of the Analysis of Raw Wastewater Samples.

Parameter	Unit	Site of the Treatment Plant				Average for Rural Areas
		Kharas	Deir Samit	Nuba	Al Aroub	
pH	-	7.5	7.7	8	7.8	7.75
EC	µs/cm	2417	3680	3290	2750	3034
TS	mg/l	1953	2511	2092	1812	2092
TSS	mg/l	751	2300	1567	1649	1567
TDS	mg/l	1225	1657	1693	1462	1509
COD	mg/l	1614	1315	1756	2376	1765
DO	mg/l	0.8	0.8	0.4	0.5	0.63
Salinity	mg/l	1.2	2.4	1.7	1.4	1.7
NH_4^+	mg/l	198	157	153	116	156
Cl^-	mg/l	238	415	343	377	343
TC	#/100ml	$7x10^5$	$2.0x10^5$	$3.8x10^5$	$2.5x10^5$	$3.8x10^5$

Obviously, the data show a COD value of 1765 mg/l, an ammonia content of 156 mg/l, a TDS 1509 mg/l, and a TSS value of 1567 mg/l. These data and when compared with the corresponding data of the West Bank cities wastewater, indicate that sewered rural areas wastewater is with lower COD and higher TSS content. In comparison with Table (6.2) data, the cities wastewater of the West Bank showed COD of 2088 mg/l and TSS of 897 mg/l (Awadallah, 2002). The variation detected between the characteristics of the rural and cities wastewater is a result of incorporation of industries in the cities, while the water consumption is not affecting the characteristics here because in these four rural areas water networks having an adequate flow rates are available.

The water consumption in these rural areas is very low (about 40-70 l/c.d), and wastewater is mainly of domestic source. Because of this, the values of some parameters such as COD, NH_4^+, and TS are comparatively higher than the typical values.

The results reveal that the values of EC, TS, TSS, TDS, and Cl^- for Deir Samit are the highest. This could be attributed to that the sewers available currently at Deir Samit are only serving a cluster of houses (collecting about 12-15m^3 of wastewater).

6.4 Characteristics of Treated Wastewater

6.4.1 Introduction

This section shows how pollutants values changed along the treatment line in Kharas, Deir Samit, Nuba, and Al Aroub wastewater treatment plants. The measured values of all parameters after each treatment unit will be presented, disscused and compared with each others, in order to see the range of the removals in each part or unit. This will allow the reader to see how wastewater characteristics changed when it traveled from one unit operation to the other parts.

6.4.2 Kharas Wastewater Treatment Plant

The characterstics of the wastewater from the UASB and wetland were measured three times during the research work. The average of the data obtained are given in Table (6.3) along with data of raw sewage.

Tables (6.3): Wastewater Characteristics at Different Stages of Kharas WWTP

Parameter	Unit	Part of Treatment Plant			Efficiency (%)
		R.S.	UASB	W.L.	
pH	-	7.5	7.32	8.1	-8
EC	µs/cm	2417	٣٢٢٠	2600	-8
TS	mg/l	1953	1625	1235	37
TSS	mg/l	751	137	72	90
TDS	mg/l	1225	1654	1316	-7
COD	mg/l	1614	609	109	93
DO	mg/l	0.8	2.6	5.2	-550
Salinity	mg/l	1.2	1.7	1.2	0
NH_4^+	mg/l	198	٢٨٣	161	19
Cl^-	mg/l	238	259	284	-19
TC	#/100ml	$7x10^5$	-	-	-

R.S.: Raw Sewage, UASB: Up Flow Anaerobic Sludge Blanket, W.L.: Wet Land

From the data presented in Table (6.3), one can conclude the following about treated wstewater experimental parameters:

- The primary treatment using UASB achieves most of the COD,TSS and other parameters removal in comparison with the secondary treatment by wetland.
- The removal efficiency in trems of COD and TSS is more 90%, which means that high percent of organic pollutants is removed by such anaerobic treatment.
- In the UASB, pH value goes down due to producing fatty acid in it, while in wetlands algae and plant (reed) respiration and photosynthesis caused alkaline pH.
- Conductivity, salinity and TDS values are increased in UASB due to mineralization reaction after that the values are decreased due to absorption of nutrients by reed plant.
- The value of DO is very high in wetland since it is aerobic treatment stage.
- The UASB allows degradation of large molecules into small NH4 molecules that nitrified and observed by bacteria and reed plant in the wetland. Because of this the value of ammonia is increased in the UASB.

6.4.3 Deir-Samit Wastewater Treatment Plant

The characteristics of wastewater at different stages of Deir Samit wastewater treatment plant are presented in Table (6.4), in which the following points are observed.

Tables (6.4): Wastewater Characteristics at Different Stages of Deir Samit WWTP

Parameter	Unit	Part of Treatment Plant			Efficiency (%)
		R.S.	S.T.	B.F.	
pH	-	7.7	7.52	7.4	4
EC	µs/cm	3680	٣٥٩٢	3513	5
TS	mg/l	2511	٢٣٥٨	1998	20
TSS	mg/l	2300	١١٠٠	682	70
TDS	mg/l	1657	١٥٨٠	1507	9
COD	mg/l	1315	٩٨١	499	62
DO	mg/l	0.8	٠.6	0.5	38
Salinity	mg/l	2.4	2.1	1.8	25
NH_4^+	mg/l	157	168	189	-20
Cl^-	mg/l	415	419	423	-2
TC	#/100ml	$2.0x10^5$	-	-	-

R.S.: Raw Sewage, S.T.: Septic Tanks, B.F.: Bio-Filters

õ The results indicate that the removal efficiency in terms of COD and TSS are 62% and 70% percent respectively, where 50% is removed in septic tanks and 50% in biofilters. The removal efficiency for such primary treatment system is quite good.

õ The values of pH,TDS and conductivity changes slightly at different stages of treatment processes because some of soluble products produced in this system are consumed.

õ Hence the system at Deir Samit is anaerobic one, the value of DO is decreased.

õ Ammonia is normally produced in anaerobic systm as a result of converting protiens into amino acid and finally into ammonia nitrogen. Therefore, the value of ammonia is increases by 20%.

õ The values of cloride remain almost the same in different stages of the treatment plant.

6.4.4 Nuba Wastewater Treatment Plant

The system in Nuba village is the same as that in Kharas village, in which wastewater is treated anaerobically using UASB then aerobically using wetlands. The results of wastewater characteristics at different stages are listed in Table (6.5). The results almost meet with the results obtained from Kharas wastewater treatmt plant, that the removal efficiency for different constitues are quite good.

Tables (6.5): Wastewater Characteristics at Different Stages of Nuba WWTP

Parameter	Unit	Part of Treatment Plant			Efficiency (%)
		R.S.	**UASB**	**W.L.**	
pH	-	8	7.75	7.9	1.25
EC	µs/cm	3290	٢643	3٣٨٠	-2.7
TS	mg/l	2092	1920	1390	33.6
TSS	mg/l	1567	340	220	86
TDS	mg/l	1693	1204	827	51
COD	mg/l	1756	410	170	90
DO	mg/l	0.4	0.49	3.12	-680
Salinity	mg/l	1.7	1.4	1.2	29
NH_4^+	mg/l	153	137	122	20
Cl^-	mg/l	343	349	356	-3.8
TC	#/100ml	$3.8x10^5$	-	-	-

R.S.: Raw Sewage, UASB: Up Flow Anaerobic Sludge Blanket, W.L.: Wet Land

6.4.5 Al-Aroub Wastewater Treatment Plant

Samples from the out flow of the settling tanks and from storage tank after the wastewater passes the duckweed ponds are taken, tested and analysis. The results of analysis are given in Table (6.6), which shows the characteristics of wastewater at different stages of Al Aroub wastewater treatment plant**.** The data of raw wastewater and removal efficiency are also shown in the table. The results indicate a number of important conclusions as explained below.

Tables (6.6): Wastewater Characteristics at Different Stages of Al Aroub WWTP

Parameter	Unit	Part of Treatment Plant			Efficiency (%)
		R.S.	S.T.	D.P.	
pH	-	7.8	7.61	7.3	6
EC	µs/cm	2750	2860	3310	-20
TS	mg/l	1812	1567	1315	27
TSS	mg/l	1649	984	492	70
TDS	mg/l	1462	1588	1699	-16
COD	mg/l	2376	1233	946	60
DO	mg/l	0.5	0.92	1.24	-148
Salinity	mg/l	1.4	1.5	1.7	-21
NH_4^+	mg/l	116	87	52	55
Cl^-	mg/l	377	396	411	-9
TC	#/100ml	$2.5x10^5$	-	-	-

R.S.: Raw Sewage, S.T.: Settling Tank, D.P.: Duckweed Pond

- In this system, quite high removal efficiency was achieved in all parameters. It was found that the removal efficiency in the duckweed ponds is better than tht in the settling pond.
- The COD varies from 2376 mg/l as raw sewage to 1233 mg/l as settling tank effluent to 946 mg/l as a final effluent by duckweed ponds. The removal efficiency is around 60%. At the same time, the value of TSS changes from 1649 mg/l to 492 mg/l at the final duckweed pond effluent (70% removal efficiency). This means that the primary treatment system at Al Aroub Camp is good.
- It was noticed that there was a slight decrease in the EC, the average conductivity reduction was about 20%. The same conclusion can be drawn for TDS and salinity where the values of these two parameters are reduced by 20%.
- Table (6.6) shows the progress in the removal efficiency of ammonia that reach 55%.
- The TS varies from 1812 mg/l as raw sewage to 1315 mg/l as duckweed pond effluent, in which the removal efficiency is 27%.
- Hence the system is aerobic one, the value of DO is increased by more than 100%.

6.5 Efficiency of Treatment Plants

Comparing performance of the UASB-wetlands system at Nuba and Kharas villages with septic tanks-biofilters system at Deir Samit village , and settling tank-Duckweed ponds system at Al Aroub camp (as all are primary treatment technologies) shows that for a system such as septic tanks-biofilters one, sludge removal and filter media backwashing are a key determinant factor for system operation, and the system could allow more removal of pollutants. Of course, the three systems have advantages over each others such as the available treatment surface area, and the design capacity. Based on averaged long term data (including those of sludge accumulation) the efficiency of the three systems are compared in Table (6.7). The results show the following variation:

- The whole systems at Kharas and Nuba achieved 93% removal in terms of COD, 90% in terms of TSS, 35% in terms of TS, and 20% in terms of ammonia. While the system of Deir Samit achieved 62%, 70%, 20% and -20% removals for the COD, TSS, TS and NH4. The Duckweed ponds system at Al Aroub achieved removal efficiency of 60% for COD, 70% for TSS, 27%for TS, and 55% for ammonia.
- It seems to be that the three systems remove the same percent of COD (60-65%) if only UASB is used in Kharas and Nuba systems. Otherwise, the removal efficiency of COD reaches 95% if we use UASB and wetlands at Kharas and Nuba.
- The three systems enabling ammonification reactions but the UASB and Duckweed are producing more ammonia rich effluent.
- Negative sign indicates for some constitutes means that the percent increase in the value compared with entering wastewater value for the parameter.
- The system at Kharas, Nuba and Al Aroub enable the production of aerated effluent while that Deir Samit produces a yellowish anaerobic effluent due to absence of aerobic treatment stage.
- It seems that the UASB-Wetland system at Kharas and Nuba villages is more efficient in the reduction of pollutants. This indicates good treatment proceeding and enables that can be reused for different purposes and is complying with many regional and local standards in terms of COD.

Table (6.7) The Efficiency of the treatment Plant Based in the Average Values

Parameter	Unit	Kharas			Deir Samit			Nuba			Al Aroub		
		RS	TW	RE (%)	RS	TW	RE (%)	RS	TW	RE (%)	RS	TW	RE (%)
pH	-	7.5	8.1	-8	7.7	7.4	4	8	7.9	1.25	7.8	7.3	6
EC	µs/cm	2417	2600	-8	3680	3513	5	3290	3٣٨٠	-2.7	2750	3310	-20
TS	mg/l	1953	1235	37	2511	1998	20	2092	1390	33.6	1812	1315	27
TSS	mg/l	751	72	90	2300	682	70	1567	220	86	1649	492	70
TDS	mg/l	1225	1316	-7	1657	1507	9	1693	827	51	1462	1699	-16
COD	mg/l	1614	109	93	1315	499	62	1756	170	90	2376	946	60
DO	mg/l	0.8	5.2	-550	0.8	0.5	38	0.4	3.12	-680	0.5	1.24	-148
Salinity	mg/l	1.2	1.2	0	2.4	1.8	25	1.7	1.2	29	1.4	1.7	-21
NH_4^+	mg/l	198	161	19	157	189	-20	153	122	20	116	52	55
Cl^-	mg/l	238	284	-19	415	423	-2	343	356	-3.8	377	411	-9
TC	#/100ml	$7x10^5$	-	-	$2.0x10^5$	-	-	3.8x10 5	-	-	$2.5x10^5$	-	-

Negative sign indicates the percent increase in the value compared with entering wastewater value for the parameter
RS: Raw Sewage; TW: Treated Wastewater; RE: Removal Efficiency

٦.٦ Appropriate Wastewater Treatment Plants

6.6.1 Introduction

The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements. Adopting as low a level of treatment as possible is especially desirable in developing countries like Palestine, not only from point of view of cost but also in acknowledgement of the difficulty of operation complex systems reliably. As a conclusion, compact, enclosed and covered treatment systems are recommended for large or dense urban areas. In this section, the appropriate sewage treatment system is presented.

6.6.2 Selection of Treatment Process

Many wastewater treatment options (processes) are described in previous section. One process or many unit operations and processes can be combined to develop a flow scheme to achieve a desired level of treatment. The level of treatment may range from removal of COD TSS, and nitrogen to complete demineralization.

The potential contaminant removal efficiency of the three wastewater treatment processes is presented in Table (6.8).

Table (6.8): Potential Contaminant Removal Efficiency

Treatment Option	Process Type	Removal Efficiency (%)			
		COD	TS	TSS	NH_4^+
UASB-Wetland	Anaerobic/aerobic	92	35	90	20
SepticTanks-Biofilters	Anaerobic	62	20	70	-20
Duckeed Ponds	Aerobic	60	27	70	55

Based on the results of this work, it is important to include anaerobic treatment as the first step, since wastewater is highly concentrated. Upflow Anaerobic Sludge Blanket (UASB) has been recommended by the work team.And in order to increase the removal efficiency, it is suggested to follow (UASB) by wetland or ponds, so the treated water can be used for irrigation perpose. We recommend the use of a 1 day settling tank before UASB, this will allow reduction of the high value of TSS entering the UASB.

CHAPTER

V *CONCLUSIONS*

CHAPTER SEVEN
CONCLUSIONS

In this project, an attempt is made to study and evaluate the existing wastewater treatment in the Hebron Distinct. The study concentrated on technical evaluation through determining the quality of treated wastewater and the problems in the management and operation systems. Site visits for the treatment plants were carried many times, where some problems are registered. The survey and analysis of wastewater quality were carried out to evaluate the suitability of treated wastewater for irrigation purpose. Finally, some suggestions to solve the existing problems will be made, and from the results of water quality analysis the best wastewater treatment process for rural communities will be selected that give an effluent fit for irrigation purposes according to the Palestinian standards. The main conclusions drawn from preliminary investigations are:

1. Wastewater treatment and reuse is considered as a promising solution to water shortage and sanitation problems in the West Bank, Palestine.

2. The water consumption in the studied rural areas is very low (about 40-70 l/c.d), and wastewater is mainly of domestic source. Because of this, the values of some parameters such as COD, NH_4^+, and TS for raw wastewater are comparatively higher than the typical values.

3. Recent data indicate that the raw sewage of the sewered rural areas of the Hebron District are characterised by COD value of 1765 mg/l, total suspended solid value of 1567 mg/l, total dissolved solid 1509 mg/l, and ammoniumm of 156 mg/l. This reveals that the rural sewage is less consentrated than municipal sewage.

4. The whole systems at Kharas and Nuba achieved 93% removal in terms of COD, 90% in terms of TSS, 35% in terms of TS, and 20% in terms of ammonia. While the system of Deir Samit achieved 62%, 70%, 20% and -20% removals for the COD, TSS, TS and NH4. The Duckweed ponds system at Al Aroub achieved removal efficiency of 60% for COD, 70% for TSS, 27%for TS, and 55% for ammonia.

5. It seems that the UASB-Wetland system at Kharas and Nuba villages is more efficient in the reduction of pollutants. This indicates good treatment proceeding and enables that can be reused for different purposes and is complying with many regional and local standards in terms of COD.

6. The UASB was capable of treating domestic sewage at an acceptable level and at low cost. A well operated and maintained UASB could ensure remval of about two third of COD load at about 1.5 days hydraulic retention time or even less. The UASB anaerobic technology is simple in design implementation and operation with minimum maintenance requirement and cost. If the effluent of the UASB is treated in a wetlands system, a final effluent COD of less than 100 mg/l could be obtained.

7. At optimal conditions, the septic tank-biofilter and duckweed ponds systems can ensure more than 70% COD removal which means that only 30% of the organic pollution is allowed to leave the system via the effluent. The key factors are the frequent desludging and filter backwashing; otherwise the efficiency may fall down to less than 50%. These systems are a good choice for replacing the existing cesspits and could serve a cluster of houses.

8. The success of sewage treatment systems reported in this project make us more confident to apply these technologies in other rural communities. UASB anaerobic system followed by wetland is recommended in this study.

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APPENDIX

A *Glossary*

APPENDIX - A

Glossary

1. Activated Sludge:

The suspended solids in an aeration tank or at the bottom of a secondary clarifier in a sewage treatment plant, consisting mostly of living microorganisms.

2. Activated Sludge Process:

A biochemical sewage treatment system in which living microbes, suspended in tents and convert them to stable substance.

3. Activated Treatment:

Purification processes used after or during secondary wastewater treatment to remove nutrients or additional solids and dissolved organics; also called tertiary treatment.

4. Aeration:

A physical treatment process which air is thoroughly mixed with water or wastewater for purification.

5. Aerobic:

Presence of dissolved oxygen.

6. Anaerobic:

Absence of dissolved oxygen.

7. Bacteria:

Microscopic single-celled organisms that do not contain chorophyll and do not contain nourish themselves by photosynthesis.

8. Biochemical Oxygen Demand (BOD):

(1) The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing wastewater strength.

9. Biosolids:

Treated sewage sludge; a primarily organic solid product, produced by wastewater treatment processes, that can be beneficially recycled.

10. Chemical Oxygen Demand (COD):

It is a measure of organic matter and represents the amount of oxygen required to oxidize the organic matter by strong oxidizing chemicals (potassium dichromate) under acidic condition.

11. Coliforms:

A group of mostly harmless bacteria that lives in the intestinal tract of warm-blooded animals and that are used as a biological indicator of water pollution.

12. Color:

Fresh wastewater is light gray. Stale or septic wastewater is dark gray or black.

13. Combined Sewer:

A pipeline that may carry a mixture of sanitary, storm, and industrial sewage, common in older cities, but not used in modern construction.

14. Composition:

The makeup of wastewater, including the physical, chemical, and biological constituents.

15. Constituents:

Individual components, elements, or biological entities such as suspended solids or ammonia nitrogen.

16. Contaminants:

Constituents added to the water supply through use.

17. Decomposition:

The process by which complex organic and inorganic substances are broken down into simpler substances by biological or physical processes; also called decay.

18. Digestion:

The decomposition of organic waste by microbes under controlled conditions in a sewage treatment plant or garbage compost facility.

19. Disinfection:

Reduction of disease-causing microorganisms by physical or chemical means.

20. Effluent:

Partially, or completely treated wastewater flowing out of a treatment plant, reservoir, or basin.

21. Electrical Conductivity:

(EC_w for water , EC_e for the soil saturation extract) – A measure of salinity expressed in millimhos per centimeter (mmho/cm) or decisiemens per meter (ds/m) at 25°C.

22. Faecal Coliform Bacteria:

Aerobic and facultative, Gram-negative, non-spore forming rod shaped bacteria capable of growth at 45.5°C, and associated with faecal matter of warm-blooded animals.

23. Gravity Flow:

Open channel flow in a pipe, ditch, or stream bed, Characterized by a free liquid surface at atmospheric pressure.

24. Heavy Metals:

Elements of heavier density than 4g/cc, which can be precipitated by hydrogen sulphide in acid solution, for examples lead, silver, mercury and copper.

25. Hydraulic Retention Time:

The time in which the wastewater is maintained within the system, measured by the volume of the system over the flow.

26. Hydrogen-Ion Concentration:

Is indication of acidic or basic nature of wastewater. A solution is neutral at pH 7.

27. Industrial Sewage:

Used water from industrial or manufacturing facilities that carries chemical waste products.

28. Influent:

Liquid that flows into a water or wastewater treatment plant or purification process.

29. Impurities:

Constituents added to the water supply through use.

30. Land Treatment:

The controlled spreading of wastewater, sludge, or hazardous waste on selected land parcels for waste treatment and/or disposal.

31. Nutrients:

Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharge to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharge in excessive amounts on land, they can also lead to the pollution of groundwater.

32. Odor:

Fresh wastewater may have a soapy or oily odor, which is somewhat disagreeable. Stale wastewater has putrid odors due to hydrogen sulfide, indol and skatol, and other products of decomposition. Industrial wastes impart other typical odors. Because of odors associated with wastewater treatment facilities, area residents have often vigorously resisted and rejected wastewater treatment plant projects.

33. Organic Compound:

A substance usually made up of complex molecules that comprise carbon with hydrogen, oxygen, and other elements.

34. Oxidation:

A chemical reaction involving combination with oxygen and/or loss of electrons.

35. Parameter:

A measurable factor such as temperature.

36. Pathogens:

Communicable diseases can be transmitted by the pathogenic organisms that may be present in wastewater.

37. Pollutants:

Constituents added to the water supply through use.

38. Preliminary Treatment or Pretreatment:

Is the very first stage, it is the removal of larger materials and grit that if not removal could hinder subsequent treatment processes. It is accomplished through the use of equipment such as bar screens, macerators, comminutors, racks and removal systems. Removal of wastewater constituents such as rags, sticks, floatables, grit, and grease that may cause maintenance or operational problems with the treatment operations, processes, and ancillary system.

39. Primary Treatment:

(1) The first major treatment in a wastewater treatment facility, usually sedimantation but not biological oxidation. (2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter. (3) Wastewater treatment processes usually consisting of clarification with or without chemical treatment to accomplish solid-liquid separation.

40. Protozoa:

Microscopic single-celled animals that consume bacteria and algea for food.

41. Raw Sewage:

Wastewater that has not yet been treated to remove pollutants.

42. Reclamation:

Treatment of wastewater for subsequent reuse application or the act of reusing treated wastewater.

43. Recycling:

The reuse of treated wastewater and biosolids for beneficial purposes.

44. Reuse:

Beneficial use of reclaimed or repurified wastewater or stabilized biosolids.

45. Screening:

A physical treatment process for water or wastewater in which relatively large floating objects are removed as the liquid passes through a coarse bar or wire mesh screen.

46. Secondary Treatment:

(1) Generally, a level of treatment that produces removal efficiencies for BOD and suspended solids of 85%. (2) Sometimes used interchangeable with concept of biological wastewater treatment, particularly the activated sludge process. Commonly applied to treatment that consists chiefly of a biological process followed by clarification with separate sludge collection and handling.

47. Settling Tank:

A steel or concrete basin in which settleable solids are allowed to separate from water of wastewater under the force of gravity; also called a clarifier.

48. Sludge:

Is the solid matter (often having a high water content) that is formed both when sewage is allowed to stand surface with the applied wastewater being treated as it flows through the plant-soil matrix.

49. Sludge Dewatering:

The process of drying liquid sludge, thereby changing its condition to that resembling potting soil.

50. Sludge Digestion:

Biochemical stabilization of organic sludge to reduce its volume, destroy pathogens, and prepare it for drying.

51. Sludge Thickening:

A process that increases the solids concentration of sludge in order to reduce its overall volume.

52. Solids:

Material removal from wastewater by gravity separation (by clarifiers, thickeners, and lagoons) and is the solid residue from dewatering operations.

53. Stabilization Pond:

A type of oxidation pond in which biological oxidation of organic matter is affected by natural or artificially accelerated transfer of oxygen to the water from air.

54. Suspended Solids:

Solids carried water or sewage that would be retained on a glass-fiber filter in a standard lab test.

55. Temperature:

The temperature of wastewater is slightly higher than that of water supply. Temperature has effect upon microbial activity, solubility of gases, and viscosity. The temperature of wastewater varies slightly with the seasons, but is normally higher than air temperature during most of the year and lower only during the hot summer months.

56. Tertiary/ Advanced Treatment:

Any physical, chemical or biological treatment process used to accomplish a degree of treatment greater than that achieved by secondary treatment. Usually implies removal of nutrients such as N and P and a high percentage of suspended solids. Terms now being replaced by preferable term, advanced treatment.

57. Total Dissolved Solids:

The sum of all dissolved solids in water or wastewater and an expression of water salinity in mg/l empirically related to electrical conductivity (EC) in mmhos/cm multiplied by 640.

58. Total Suspended Solid:

(1) Portion of organic and inorganic solids that are not dissolved. These solids are removal by coagulation or filtration. (2) portion of the total solid retained on a filter with a specified pore size, measured after being dried at a specified temperature (105°C). The filter used most commonly for the determination of TSS is the Whatman glass fiber filter, which has a nominal pore size of about 1.58µm.

59. Turbidity:

Turbidity in wastewater is caused by a wide variety of suspended solids. In general, stronger wastewaters have higher turbidity.

60. Upflow Anaerobic Sludge Blanket:

The most common type of anaerobic reactor for wastewater treatment.

61. Wastewater:

The once-used water of a community or industry which contains dissolved and suspended matter.

62. Wastewater Characteristics:

General classes of wastewater constituents such as physical, chemical, biological and biochemical.

63. Wetland:

A land area frequently submerged by surface or groundwater, and which supports vegetation adopted to saturated conditions.

APPENDIX

B *Treatment Plants Photographs*

APPENDIX - B

Treatment Plants Photographs

B.1 Kharas Wastewater Treatment Plant

Fig (B.1): Wastewater Treatment Plant in Kharas Village

Fig (B.2): Bar Screen and Channel

Fig (B.3): Upflow Activated Sludge Blanket (UASB)Tanks

Fig (B.4): Sludge Drying Bed at Kharas WWTP

Fig (B.5): Wet Land at Kharas WWTP

Fig (B.6): Schematic Flow Diagram of Reed Plant

Fig (B.7): Wet Land with Reed Plant

Fig (B.8): Treated Wastewater Storage Tank

B.2 Deir-Samit Wastewater Treatment Plant

Fig (B.9): The Situation of the Wadi before Constructing the Plant

Fig (B.10): Wastewater Treatment Plant at Deir-Samit

Fig (B.11): Top View of the Septic Tank

Fig (B.12): Anaerobic Septic Tank

Fig (B.13): Biofilter at Deir Samit WWTP

Fig (B.14): Top View of the Biofilters

Fig (B.15): Septic Tank with Methane Gas Bubble

Fig (B.16): Storage Tank

B.3 Nuba Wastewater Treatment Plant

Fig (B.17): Wastewater Treatment Plant at Nuba Village

Fig (B.18): Screening and Channel at Nuba WWTP

Fig (B.19): Wastewater Treatment by Bar Screen

Fig (B.20): Another View for the Screening Channel

Fig (B.21): Upflow Activated Sludge Blanket (UASB) System

Fig (B.22): Sludge Bed at Nuba WWTP

Fig (B.23): Wet Land at Nuba WWTP

Fig (B.24): General View of Wet Land

B.4 Al-Aroub Wastewater Treatment Plant

Fig (B.25): Al-Aroub Wastewater Treatment Plant

Fig (B.26): Settling Tanks at Al Aroub WWTP

Fig (B.27): Treatment Process by Duckweed Ponds

Fig (B.28): Duckweed Ponds at Al Aroub WWTP

Fig (B.29): Duck Weed Plant Spread Over Wastewater Pond

Fig (B.30): Pond with Dead Duckweed

Fig (B.31): Duck Weed Plant

Fig (B.32): Storage Tank at Al Aroub WWTP

APPENDIX

C Chemical Analysis Procedures

APPENDIX - C

Chemical Analysis Procedures

Measurements of Dissolved Oxygen:

Name: Dissolved Oxygen

Definition: Dissolved oxygen is required for the respiration of aerobic micro-organisms as well as all other aerobic life forms.

Apparatus: Laboratory dissolved oxygen meter (sension8).

Method: APHA standard methods, 1995

Procedure:

After the probe is properly stabilized, chemically zeroed (for measurements below 1 mg/l), and calibrated, take measurements as follows:

1. Add the weight assembly to the probe if required (3 or 15 m cable versions only).
2. If the sample salinity has been measured using an Electrolytic Conductivity Meter, enter the value in setup 4. If the meter has been moved to a different elevation or if the barometric pressure has changed, enter the new values in setups 5 and 6.
3. Insert the probe into the sample to the desired depth. The probe must be deep enough to cover the thermistor (metallic button) located on the side of the probe.
4. Agitate the probe in the sample to dislodge air bubbles from the sensing area of the probe tip.
5. Stir the sample vigorously with the probe or use a stir stand and stir bar. When measuring deep bodies of water, create sufficient flow across the probe tip by pulling on the cable to move the probe up and down. When using a stir

stand and magnetic stir bar, increase the speed of the stir bar until the displayed value no longer increases with the stirring rate.

6. When the reading on the meter stabilizes, record or store the value in the meter memory.
7. Press the CONC % key on the keypad to change the display from concentration in mg/L to % saturation.

Measurements of Total Dissolved Solids:

Name: Total Dissolved Solids

Definition: The sum of all dissolved solids in water or wastewater and an expression of water salinity in mg/l empirically related to electrical conductivity (EC) in mmhos/cm multiplied by 640.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

To determine TDS with the sension7 meter:

1. Press the TDS key on the keypad. The instrument will display the TDS value for the currently displayed conductivity measurement.
2. The standard method to determine TDS (Total Dissolved Solids) is to evaporate the sample to dryness at 180 °C, then weigh the residue.
3. Another way to estimate TDS is by calculating the concentration of sodium chloride that would have the same conductivity as the sample at the same temperature.
4. The sension7 meter reports a sample's TDS value in mg/L of sodium chloride by comparing the sample conductivity and temperature to data stored in the meter's memory.
5. Data were obtained from empirical procedures using sodium chloride solutions.

Measurements of Salinity:

Name: Salinity

Definition: The salinity of the soil water is related to, and often determined by; the salinity of the irrigation water.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

1. To determine salinity with the sension7 meter, press the SAL key on the keypad. The instrument will display the salinity value for the sample being measured.
2. Salinity, a measure of the mass of dissolved salts in a given mass of solution, is used to describe seawater, natural, and industrial waters. Salinity is a relative scale based on a KC1 solution. A salinity value of 35 is equivalent to a KC1 solution containing 32.4356 g KCI in 1 kg of solution at 15 °C. Salinity is measured in %o (ppt - parts per thousand).
3. The meter calculates the salinity based on the Extended Practical Salinity Scale of 1978, as referenced in 17th edition of Standard Methods, 25200 B. The applicable range is 0 to 42% and -2 to 35 °C.

Measurements of Conductivity :

Name: Conductivity

Definition: The Electrical Conductivity (EC) of water is a measure of the ability of a solution to conduct an electrical current.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

1. Determining conductivity with the sension7 meter is easy; just press the COND key on the keypad. The instrument will display the conductivity value for the sample being measured.
2. For conductivity, place the probe into the sample and make sure the slot on the end of the probe is totally immersed. Agitate the sample with the probe for 5-10 seconds to remove bubbles that may be trapped in the slot.

Measurements of pH:

Name: Conductivity

Definition: pH is indication of acidic or basic nature of wastewater. A solution is neutral at pH value 7.

Apparatus: Laboratory pH Meter (sension3).

Method: APHA standard methods, 1995

Procedure:

1. Place the electrode in the sample. Press READ/ENTER stabilizing.., will be displayed, along with the sample temperature and the pH or mV reading. These values may fluctuate until the system is stable.
2. If the Display Lock is enabled, Stabilizing.., will disappear and the display will “lock in” the pH or mV and sample temperature when a stable reading is reached. If the Display Lock is off, Stabilizing.., will still disappear, but the display will show the current reading and temperature and the values may fluctuate.
3. Record or store the pH and mV value.

Measurements of Turbidity:

Name: Turbidity

Definition: Turbidity in wastewater is caused by a wide variety of suspended solids. In general, stronger wastewaters have higher turbidity.

Apparatus: 2100P Turbid meter.

Method: APHA standard methods, 1995

Procedure:

1. Measurements may be made with the signal average mode on or off and in manual or automatic range selection mode.
2. Using automatic range selection is recommended. Signal averaging uses more power and should be used only when the sample causes an unstable reading. Signal averaging measures and averages ten measurements while displaying.
3. Intermediate results. The initial value is displayed after about 11 seconds and the display is updated every 1.2 seconds until all ten measurements are taken (about 20 seconds). After this, the lamp turns off, but the final measured turbidity value continues to be displayed until another key is pressed.
4. When not in signal average mode, the final value is displayed after about 13 seconds.
5. Accurate turbidity measurement depends on good measurement technique by the analyst, such as using clean sample cells in good condition and removing air bubbles (degassing**).**

Measurements of Total Coliform :

Name: Total Coliform

Definition: A group of mostly harmless bacteria that lives in the intestinal tract of warm-blooded animals and that are used as a biological indicator of water pollution.

Apparatus: Boiling Device (Heater), Oven.

Method: (Method E-1 Microbiology)

Procedure:

Step 1: Sample Size

1. For drinking water, filter 100 to l000ml volume which yields about 50 coliform colonies through a membrane filter (MF).
2. For other waters, filter three different volumes (diluted or undiluted), depending on the expected bacterial density.

Step 2: Sample Filtration-

1. P1a, a sterile MF (grid side up) over porous plate of receptacle using sterile forceps.
2. Place matched funnel unit over receptacle carefully, lock it in place, and filter the sample under a partial vacuum.

3. Rinse funnel by filtering a 20-to-30 ml portion of sterile diluted water. Disengage vacuum, unlock and remove funnel, and remove MF using sterile forceps. Place MF on selected medium with a rolling motion to avoid entrapment of air.
4. Prepare a sterile rinse water sample (100 ml) as above for every 10 sample series.

At the beginning of each filtration series, use a sterile filtration unit. If a time interval of more than 30 minutes elapses between sample filtration, begin a new series using a sterile filtration unit. Sterilize unit with flowing stream of boiling water or ultraviolet disaffection (UV).

Step 3: Culture Dish anti Incubation

1. If agar—based Endo—type medium is used: Place prepared filter directly on agar by rolling it onto agar surface without entrapping air.
2. If liquid medium is used: Place a pad in the culture dish and saturate it with 1 .8 to 2.0 ml M—Endo medium. Place prepared filter directly on pad. Invert dish.
3. Incubate the prepared dishes for 22 to 24 ii at 35 ± 0.5° C.

Step 4: Counting

1. Use a low—power (10 to 15 magnification) binocular dissecting microscope or other optical device with a white fluorescent light. Count the number of colonies that are pink-to-dark-red colored with a metallic surface sheen.
2. Atypical coliform colonies can be dark-red or nucleated without sheen. Pink, red, white and colorless colonies lacking sheen are considered to be non coliforms.

Calculations:

TC=CCC x 100/Vs

Where:

TC = total coliform colonies/100 ml.

CCC = counted coliform colonies.

Vs = volume of sample filtered (ml).

Measurements of COD :

Name: Chemical oxygen demand

Definition: It is a measure of organic matter and represents the amount of oxygen required to oxidize the organic matter by strong oxidizing chemicals (potassium dichromate) under acidic condition.

Apparatus: Thermo spectronic

Method: Closed reflux

Procedure:

1. Put 0.4g $HgSO_4$ in a reflux flask. Add 20 ml of sample, or an aliquot of sample diluted to 20 ml with distilled water. Mix well, so that the chlorides are converted into poorly ionized mercuric chloride.
2. Add 10 ml of standard $K_2Cr_2O_7$ solution. Slowly add 30 ml of sulfuric acid solution which already contains silver sulfate, and swirl the flask.
3. If the color turns green, either take a fresh sample with smaller aliquot or add more dichromate and acid. The final concentration of H_2SO_4 should always be 50% or more.
4. Connect the flask to the condenser and reflux for 2 hrs. Cool and wash down the condenser with a small quantity of distilled water. Remove the flask and add about 50 ml of distilled water.
5. Reflux a reagent blank under identical conditions preferably simultaneously with the sample.
6. For determining low COD samples follow up the same procedure using 0.05 N $K_2Cr_2O_7$ and 0.025 N FAS.

Measurements of BOD:

Name: Biochemical Oxygen Demand (BOD)

Definition: The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

Apparatus: Memmert.

Method: A standard test used in assessing wastewater strength

Procedure:

1. Neutralize the sample to pH around 7 using alkali or acid (NaOH or HCl).
2. The sample should be free from residual chlorine. If it contains residual chlorine, remove it by using Na_2SO_3 solution as given below:
   a. Take 50 ml of the sample and acidify with 10 ml of 1:1 acetic acid.
   b. Add about 1g of Kl.
   c. Titrate with sodium sulfite using starch as indicator.

Calculate the volume of Na2SO3 required per ml of the sample to be tested for BOD.

3. At least two dilutions of the sample are prepared so that the oxygen consumption will end in the range of 40 to 70 %.
   a. The required quantity of sample is taken in a one liter capacity volumetric flask.
   b. Dilute this by filling with dilution water to the mark and mix well.
   c. Rinse three BOD bottles with the diluted sample and then fill to overflowing. As far as possible avoid entrapment of air bubbles from the bottle or during filling by knocking gently the BOD bottle sides with its stopper. Stopper the bottles immediately after filling.

4. Keep one bottle of every dilution series for the determination of the initial (Zero day) dissolved oxygen concentration and incubate two bottles at 20°C for 5 days.

To the air seal neck of the bottles incubated, water should be added daily, to prevent oxygen penetration.

5. Prepare four blanks by filling only dilution water into four bottles. These bottles should be first rinsed and then filled with the dilution water. Two of these blanks should be used to determine the initial dissolved oxygen and the other two are incubated for 5 days at 20°C. Usually the oxygen consumption in the blank should not be more than 0.2 mg/l in 5 days.
6. Dissolved oxygen, initial and endpoint, is determined using DO meter.
7. If the dilution water is seeded, measure the BOD of the seed material separately according to the above method, and calculate the contribution of the BOD of the amount of seed applied in the standard test.

APPENDIX

D *Water Testing Photographs*

APPENDIX - D

Water Testing Photographs

Fig (D.1): Samples before Testing in the Laboratory

Fig (D.2): Measuring of pH Parameter

Fig (D.3): Laboratory Conductivity Meter

Fig (D.4): Chemical Oxygen Demand Meter

Fig (D.5): Explorer Balance

Fig (D.6): Boiling Device (Heater)

Fig (D.7): Biochemical Oxygen Demand Device

Fig (D.8): Filtration Motor

Fig (D.9): Filter Sample

Fig (D.10): Turbidity Meter

Fig (D.11): Oven

Fig (D.12): Samples in the Refrigerator

Fig (D.13): Different Apparatus

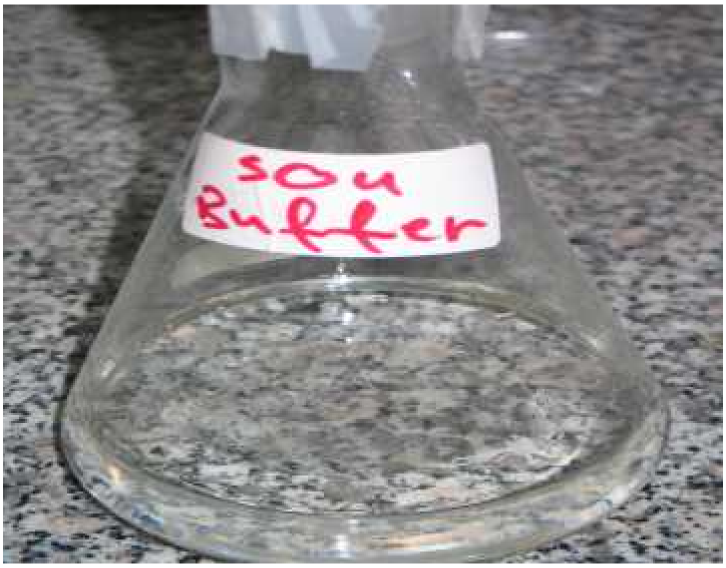

Fig (D.14): SO_4 Buffer