Development of An Integtrated UASB Biofilter System For Domestic Wastewater Treatment

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ABSTRACT

The objectives of this thesis were to develop and trial more efficient and alternative wastewater treatment systems with sustainable and cost-effective disposal options with minimal maintenance, using the latest in innovation and the best available technology.

In this thesis the first 5 months of monitoring undertaken between September 2005 and February 2006 are presented. The UASB reactor had a volume of 780 liters, being operated at an average hydraulic retention time (HRT) of 2days. The trickling filters had a useful volume of 550and 320 liters. These different operational conditions characterized three research phases. Both reactors were fed with domestic sewage pumped directly from the main interceptor of Albireh wastewater treatment plant.

This work presents the results of the monitoring of a pilot-scale plant comprising of an UASB reactor followed by an two stage biofilter system , treating actual municipal wastewater from Albireh city in west bank. The plant was intensively monitored and operated for the period divided into three different phases, working with constant and variable inflows. The plant showed good COD removal, with efficiencies ranging from 45% to 60% for the UASB reactor, from 50% to 70% for the attached growth system only and from 80% to 87% for the overall system. The final effluent suspended solids concentration was low, with averages ranging from 63 to 400 mg/l in the typical phases of the research.

The integrated UASB-biofilter effluent The results showed that the system is quite effective in removing organic pollutants. Based on the results obtained from this research study, the integrated UASB -biofilter system offered practical advantages compared to conventional septic tanks through its small size , biogas collection and utilization, and elimination of odor problems.

The UASB/biofilter system is a very promising alternative for the treatment of domestic sewage in West Bank and other developing countries, since the system can be designed with very short hydraulic retention times, resulting in a very compact and low cost treatment unit.

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LIST OF ABREVIATIONS

BOD	Biochemical Oxygen Demand
COD_t	Total Chemical Oxygen Demand
HRT	Hydraulic Retention Time
NH_4^+-N	Ammonium Nitrogen
OLR	Organic Loading Rate
SS	Suspended Solids
TDS	Total Dissolved Solids
TKN	Total Kjeldhal Nitrogen
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blank
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solid
d	day
g	Gram
hr	Hour
kg	Kilogram
L	Liter
Mg	Milligram
m_r^3	Reactor Volume

ANNEXES

Annex 1: Detailed results of the first and second run phases

Annex 2: Detailed design of biofilter

1 INTRODUCTION

1.1 Background

Conventional sewerage systems are planned and designed for urban, semi-urban and rural areas without studying other options and regardless of their compliance with the local conditions. Most of these systems are not functioning well in Palestine, even in larger cities. This is largely because none of them is funded locally, but from external sources. The criteria of affordability and sustainability are not taken into consideration (Al-Sa'ed, 2000).

In general the existing wastewater treatment plant either inadequate or non existent in Palestine ,about 6%of the total population in Palestine served with wastewater treatment plants which are not functioning properly(Mahmoud *et al*., 2004).

Wastewater generated from Palestinian cities, villages and Israel colonies is considers as the primary source of pollution in Palestine, such wastewater is discharged untreated in to open area or through cesspits where approximately 70% of the west bank is not served with sewage network (Mahamoud *et al*., 2003).

Adequate onsite management systems based on local innovative development of locally constructed onsite wastewater treatment systems to serve small Palestinian communities need to be investigated. For this purpose, a pilot scale biofilter system preceded by a pre-treatment unit was developed, erected, operated and monitored 5 months.

Biofilter 1 was filled with a low-cost natural fixed film media (sand and small rocks; known locally as Kharram stones), while Biofilter 2 was additionally filled with a synthetic media (PVC material used for thermal installations) as a srartup phase.

The system, located at Albireh central wastewater treatment plant site, was continuously fed with domestic wastewater. Operational problems were encountered in the first biofilter filled with multilayer fixed film media, where sand was washed out and the distribution lateral was replaced due to short circuiting caused by large opening pore size.

After three months (June-August 05) of the startup phase of operation, the onsite system efficacy was monitored for five months under variable hydraulic and organic loading rates (September-February).

The several favorable characteristics of anaerobic treatment technology, such as low cost, operational simplicity and low biosolids production, together with favorable environmental condition in Palestine, make it attractive to be applied for the protection of environment and recovery of natural resources as nutrients and biogas.

The required good contact between wastewater and sludge is achieved by an even feed distribution over the bottom of the reactor and by the natural mixing of the sludge bed as a result of the biogas production occurring there (Lettinga *et al*., 1997).

The endorsement of anaerobic technologies had lead to the development of various kinds of advanced anaerobic reactors, such as the upflow anaerobic sludge blanket reactor, upflow anaerobic fixed-bed reactor, the anaerobic fluidized/expanded reactors, and the anaerobic upflow bed filter. This process has the ability to retain active microbial biomass in the reactor and the solid retention time (SRT) is generally much longer than the hydraulic retention time (HRT) (Miyahara *et al.,* 1995).

Anaerobic digestion is a complex-multi steps biological reaction carried out by several types of micro-organisms that require no oxygen for their growth or activities. During the process, a gas mainly composed of methane (CH_4) and carbon dioxide (CO_2) known as biogas, is produced. The amount of gas produced varies with organic loading rates fed to the anaerobic reactor, where temperature plays a role on decomposition rate.

Based on a high technology level which not only requires a large amount of process energy in the past years, the efforts to improve water quality using modern sewage technology led to big successes in industrialized countries. Here, the commonly implemented treatment systems are mostly, but is also related to high investment and operation costs. Plant operation furthermore requires highly qualified personnel that are very often not sufficiently available in developing countries. Speaking of these countries, a process combining a low level of mechanization with a high purification performance is therefore highly desirable.

1.2 **Aim of Thesis**

The major aim of this thesis is to determine the performance of two passive aerated filters as a post treatment stage for domestic wastewater pretreated in an upflow anaerobic sludge blanket (UASB).

1.3 Objectives

The specific objectives entailed the followings:

- Design and erection of a pilot-scale UASB-biofilter system and study the efficacy of the developed system to identify the adequate local design parameters.
- Define design criteria and operational conditions to effect efficient suspended solids (SS) and organic matter (OM) removal in the system under study.
- Investigate the startup and operating conditions of the integrated UASB-biofilter system.

2 Literature Review

2.1 Existing situation of sanitation in Palestinine territories

The majority of the collected wastewater from the sewered localities is discharged into nearby wadis without any kind of treatment. About 65 % of the West Bank population is not served with sewerage networks, and uses mainly cesspits and occasionally septic tanks. The other 35% is served with sewerage networks, but less than 6% of the total population is served with treatment plants.

The situation of the sewerage system is extremely critical. About 73% of the households in the West Bank have cesspit sanitation and almost 3% are left without any sanitation system (MOPIC 1998; Abu Madi et al., 2000). In sparsely populated, poor, rural and semi-urban Palestinian communities, which form about 60% of the total population in the West Bank, a few small sewage treatment plants have been installed.

Groundwater is the present scarce and utilized as potable source without prior treatment in Palestine. The natural quantity and quality are threatened because of irregularity of water regimes, rapid urbanization, industrial and agricultural activities. Non-functioning of old sewage treatment facilities, low public environmental awareness, weak professional staff and lack of funds exacerbates the problem (Abu- Madi *et al.*, 2003).

Palestine is a semi-arid region that has very few flowing streams with sufficient capacity to serve as natural reservoirs for treated sewage effluents. The main disadvantage of using treated wastewater for agricultural purposes is the presence of pathogens as bacteria, viruses, and parasites that can pose health risks for the farmers, soil, nearby located communities, and also to the consumers of product irrigated with treated sewage. To reduce these health risks the Palestinian Water Authority has newly developed national guidelines based on recommended rules issued by the World Health Organization (PWA, 2003).

If the wastewater contains industrial effluent, chemical pollutants such as heavy metals might pose additional public health and environmental problems (Shuval, 1992).

UASB reactors have difficulties in producing effluents that can comply with the Palestinian environmental standards. Therefore, the post-treatment step is of great importance as a manner of adapting the treated effluent to the environmental discharge standards. The main objective of the post-treatment is to complement the organic matter removal, as well as to promote the removal of components which are barely affected by the anaerobic treatment (nutrients and pathogens).

The biofilters, despite their enormous potential and series of advantages, have rarely been used in West Bank. One possible reason for this is the low diffusion of this technology within the country. For this, it becomes of great importance to increase and spread the knowledge level regarding this treatment system, contributing to increase in its use.

The biofilters can find a large application in west bank since the system can be designed with very short hydraulic retention times, resulting in a very compact and low cost treatment unit. Besides, the energy consumption and the labour costs are minimal.

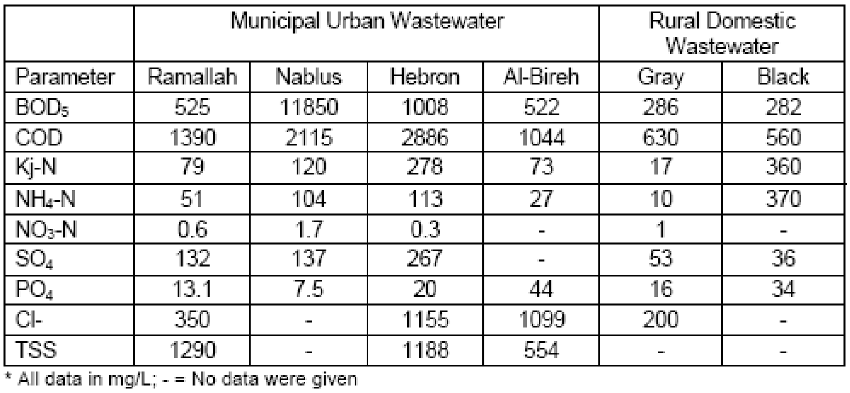
Hence, the main objective of this thesis was to evaluate the applicability of biofilters for polishing domestic sewage submitted to a preliminary treatment stage in UASB reactors. The association of these two systems can contribute enormously to the reduction of labour and energetic costs of the treatment system. With this new configuration, the whole treatment can be achieved in one single unit, with savings in area and conferring a greater simplicity on the system.

The final effluent quality is the major factor we take into consideration in the reuse purposes. Concern of Wastewater reuse as an integral part of total water balance stems from the following considerations: (I) growing water scarcity in many arid and semi-arid regions of the world increases demands for additional water supplies, (ii) high population growth leads to greater quantities of wastewater production, (iii) environmental concerns increase, reflected by stricter pollution control measures, leading to larger quantities of wastewater to be treated at high expenses, (iv) a wide range of technologies now exists to purify wastewater to acceptable levels, increasing the opportunities to reclassify wastewater as a renewable water resource rather than waste, (v) the nutrients in reclaimed wastewater add attraction for use in agriculture, and consequently reduce use of chemical fertilizers, (vi) rain-fed farming can be converted into more productive wastewater irrigated agriculture, and (vii) depending on the degree of treatment, reclaimed wastewater is a reliably available resource that may be fit for irrigation, industrial, and municipal uses at relatively low costs(Abu-Madi, 2004).

2.2 Existing characteristics of wastewater in west bank

The integrated system of UASB/Biofilter is built in Albireh wastewater treatment plant with wastewater characteristics represent a real wastewater influent in west bank as shown in table 2.1.

Table 2.1. characteristics of wastewater of some cities and rural areas in the West Bank (Al-Sa'ed, 2006).



	Municipal Urban Wastewater				Rural Domestic Wastewater	
Parameter	Ramallah	Nablus	Hebron	Al-Bireh	Gray	Black
BOD_5	525	11850	1008	522	286	282
COD	1390	2115	2886	1044	630	560
Kj-N	79	120	278	73	17	360
NH_4-N	51	104	113	27	10	370
NO_3-N	0.6	1.7	0.3	-	1	-
SO_4	132	137	267	-	53	36
PO_4	13.1	7.5	20	44	16	34
Cl-	350	-	1155	1099	200	-
TSS	1290	-	1188	554	-	-

* All data in mg/L; - = No data were given

Which present that Palestinian domestic wastewater is high strength with respect to the .classification shown in Table 2.2

Metcalf and Eddy, 1984) Table 2.2 characteristics of raw wastewater)

Parameter	Weak	Medium	Strong
(BOD5 (mg/l	110	220	400
(TSS (mg/l	100	200	350
(Ntotal (mg/l	20	40	85
(P (mg/l	4	8	15
Fecal coliforms (most probable number per 100 ml)	10^8	10^8	10^8

2.3 SUSTAINABILITY OF WASTEWATER TREATMENT FACILITIES

Conventional mechanical treatment facilities in developing countries have had a sparse record of success. They frequently do not function as expected because of a variety of technical, financial and institutional reasons. Alternative treatment technologies emphasize cost reduction, integrated system management, minimal mechanical operations, water reclamation and nutrient conversion wherever feasible. Technologies include simplified, lower cost wastewater collection infrastructure, anaerobic enhanced primary treatment and

Lagoon-based post-treatment processes that can achieve high effluent quality levels and that can be managed adequately by non-specialists.

2.4 Aerobic treatment process

It is the degradation of organic and inorganic compound in the presence of oxygen as an electron accepter in the redox reaction which is used as secondary treatment process in the treatment of waste water ,as shown in equation 2.1

Aerobic Degradation:

$CH_2O + O_2 \rightarrow CO_2 + H_2O$ + new biomass……………………………………………...2.1

Aerobic treatment is used as secondary treatment process as shown in table 2.3

Table 2.3. Common options for secondary sewage treatment (Parr et al., 2000)

Treatment process	Description	Key features
Activated sludge process (ASP)	**Oxygen is mechanically supplied to bacteria which feed on organic material and provide treatment**	**Sophisticated process with many mechanical and electrical parts, which also needs careful operator control. Produces large quantities of sludge for disposal, but provides high degree of treatment (when working well).**
Aerated lagoons	**Like WSPs but with mechanical aeration**	**Not very common; oxygen requirements mostly from aeration and hence more complicated and higher operation and maintenance costs.**
***Land treatment**	**Sewage is supplied in controlled conditions to the soil.**	**Soil matrix has quite a high capacity for treatment of normal domestic sewage, as long as capacity is not exceeded. Some pollutants, such as phosphorus, are not easily removed.**
Oxidation ditch	**Oval-shaped channel with aeration provided**	**Requires more power than WPS but less land, and easier to control than processes such as ASP.**
***Reed (or constructed wet lands) beds**	**Swage flow through an area of reeds**	**Treatment by action of soil matrix and, particularly, the soil/root interface of the plants. Requires significant land area, but no oxygenation requirement.**
Rotating biological contractor (or biodisk)	**Series of thin vertical plates which provide surface area for bacteria to grow**	**Plates are exposed to air and then the sewage by rotating with about 30 per cent immersion in sewage. Treatment by conventional aerobic process. Used in small-scale applications in Europe.**
Trickling (or 'percolating') filters	**Sewage passes down through a loose bed of stones, and the bacteria on the surface of the stones treats the sewage**	**An aerobic process in which bacteria take oxygen from the atmosphere (no external mechanical aeration). Has moving parts, which often break down in developing county locations.**
***Upflow anaerobic sludge blanket (UASB)**	**Anaerobic process using blanket of bacteria to absorb polluting load**	**Suited to hot climates. Produces little sludge, no oxygen requirement or power requirement, but produces a poorer quality effluent than processes such as ASP. (Note: other anaerobic processes exist, but UASB is the most common at present).**
***Waste-stabilization ponds (WSP) ('lagoons' or 'oxidation ponds')**	**Large surface-area ponds**	**Treatment is essentially by sun light, encouraging algal growth which provides the oxygen requirement for bacteria to oxidize the organic waste. Requires significant land area, but one of the few processes which are effective at treating pathogenic material. Natural process with no power/ oxygen requirement. Often used to provide water of sufficient quality for irrigation, and very suited to hot, sunny climates.**

* Indicates processes more suitable for developing countries.

The basic aerobic treatment process involves providing a suitable oxygen rich environment for organisms that can reduce the organic portion of the waste into carbon dioxide and water in the presence of oxygen. With the ever increasing development of land, both suburban and rural, large central sewerage systems have not always been cost-effective or available. Many homeowners still rely on individual septic tank or other systems to treat and dispose of household wastewater onsite as shown in table 2.3

Table 2.4 Performance of Most Common Aerobic Wastewater Treatment Technologies (Engleman, *et al*, (1993

Treatment Technology	Removal Efficiency BOD_5	 TKN	 N_{total}	 P	Effluent TSS	Sludge production (dry weight)
	(%)				(mg/l)	(kg/kg $BOD_{removed}$)
Primary sedimentation	20-30	15-20	0	-	-	-
Activated sludge						
high load	90	25	30	30	25	0.9-1.0
low load	95	75	55	45	10	0.5-0.7
Oxidation ditch	95-98	80-90	50-70	10-20	10-15	0.3
Trickling filter						
high load	80	20-35	25	-	45	0.6
low load	90	60-80	35	-	25	0.4
Rotating biological contactor	90-95	50-75	-	-	-	0.6
Aerated lagoon	70-80	-	-	-	-	m^3/caput/year 0.03-0.08
Waste stabilization ponds	80-90	-	50-90	-	% 50-75 removal	m^3/caput/year 0.03-0.08

2.5 Anaerobic degradation

2.5.1 General ideas

Anaerobic processes have been used for the treatment of concentrated municipal and industrial wastewaters for well over a century. In the absence of molecular oxygen, these processes convert organic materials into methane, a fuel that can yield a net energy gain from process operations. Because of recent advances in treatment technology and knowledge of process microbiology, applications are now extensive for treatment of dilute industrial wastewaters as well (McCarty and Smith, 1986).

2.5.2 Anaerobic Metabolism and Biochemical Pathways

Degradation of organic matter is a complicated microbial process anaerobic consisting of several interdependent consecutive and parallel reactions. Methanogenesis was initially considered to be a two phase process in which the volatile fatty acid (VFA) and other fermentation end products of hydrolytic fermentative bacteria were directly converted to methane and carbon dioxide by methanogenic species. The multiphase nature of the process was subsequently revealed by the discovery of hydrogen producing acetogenic bacteria and by a better appreciation of the limited substrate capabilities of methanogens (Wilkie and Colleran, 1988).

First Step: Hydrolysis and Fermentation

In these process hydrolytic fermentative organisms hydrolyses and ferment complex organic matter such as proteins, poly carbonates, lipids, etc. to simple organic compounds (formate, acetate, propionate, butyrate and other fatty acids, ethanol etc.), hydrogen and carbon dioxide.

Second Step: Syntrophic Acetogenesis

Syntrophic acetogenic organisms that, in combination with hydrogen utilizing methanogens, convert the metabolic products from the first group mainly into acetate and hydrogen (or formate).

Third Step: Methanogenesis

Methanogens, which carry out the terminal reaction in the anaerobic food chain, are most important in anaerobic digester systems. Methanogens utilize the simple fermentation products formed by trophic group 1 and 2 such as acetate, methanol, methylamines, carbon dioxide and hydrogen or formate. Most methanogens in digesters are very specialized for their growth substrates and can be classified accordingly into acetotrophic methanogens, which disproportionate acetate into methane and carbon dioxide, and unicarbonotrophic methanogens, which oxidize hydrogen gas, methanol or formate and methylamines as electron donors and reduce carbon dioxide and activated methyl group of methane as shown in figure 2.1.

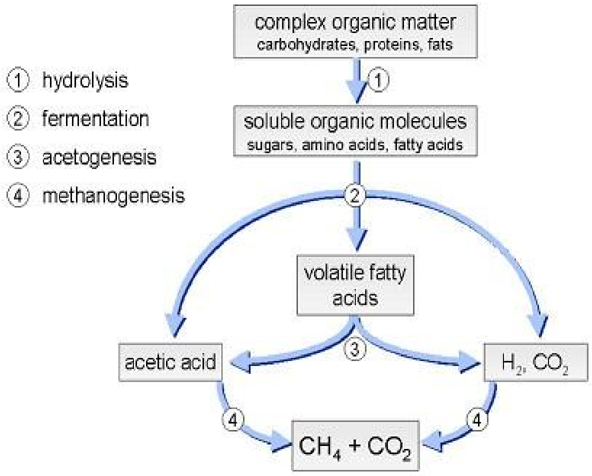


Figure 2.1 anaerobic process of the degradation of organic matter (Prasanna, 1996).

Methane and carbon dioxide are the chief gaseous products of the process. If the composition of the substrate is known and the entire substrate is converted to gas, the theoretical yield of methane can be calculated from the following equation.

$$(C_nH_aO_b + (n - a/4 - b/2)\ H_2O \rightarrow (n/2 + a/8 - b/4)\ CH_4 + (n/2 - a/8 + b/4)\ CO_2\ (2.2$$

.There are many bioreactors for the degradation of organic compound as shown in figure 2.2

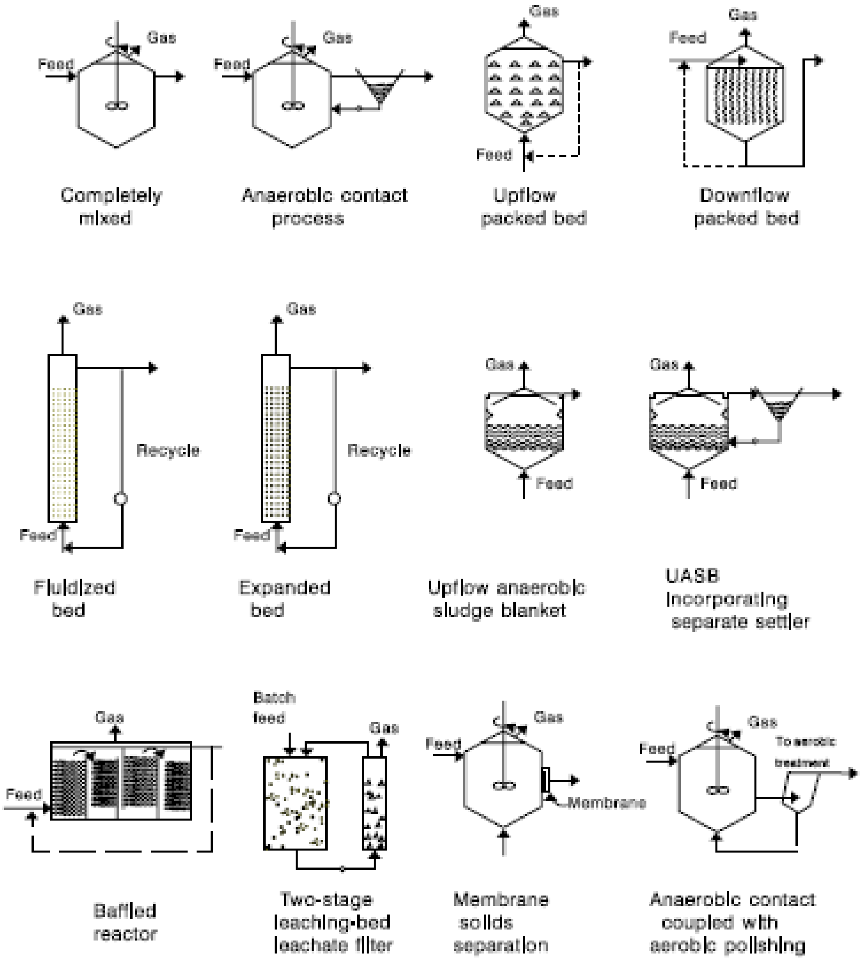


Figure 2.2 Reactor Configurations for Anaerobic Biotechnology (Speece, 1983)

2.5.3 Advantage and limitations of anaerobic treatment

2.5.3.1 Advantage of anaerobic treatment.

Anaerobic treatment of wastewater is an effective enhanced primary treatment option for developing countries, particularly those with mild climates, and has important advantages over aerobic processes:

- Anaerobic reactors are simple to build and operate and have low capital and operating costs.
- Anaerobic digestion is a passive process that can be operated with little or no externally supplied energy.
- High strength waste streams can be treated efficiently at no energy penalty.
- Anaerobic systems withstand shock loads better than aerobic systems.
- Large diurnal flow variations and even prolonged shutdown are not problematic;
- Anaerobic digestion reduces organic nutrients to inorganic forms that are readily available for plant uptake, a feature that makes aquatic farming systems ideal for nutrient removal;
- Low amounts of residual sludge byproduct.
- Sludge has good settling properties and is easily dewatered.
- No need to treat residual sludge.
- Production of methane-rich biogas fuel that may be economical to utilize for large scale facilities (>100,000 population equivalent);
- Anaerobic processes can attenuate or degrade many refractory organic compounds so that they are less toxic, no longer toxic or no longer available to threaten water quality;
- Anaerobic treatment can be managed with relatively less skilled employees than required for conventional treatment plants;
- Anaerobic treatment provides virtually complete stabilization of organic material to CO2 and methane.

2.5.3.2 limitations of anaerobic treatment

Optimal reactor temperature is 20°c and above; (the lower limit of currently applied anaerobic technology in developing countries is influent temperatures above 12° C); Longer startup time because of the slow growth rate of anaerobic bacteria;

- Additional treatment is required to meet secondary quality standards in terms of oxygen consuming substances;
- Odor control measures are more important than for aerobic treatment.
- Methanogenic activity may be inhibited from the toxic effects of high concentrations of heavy metals, toxic organics, free ammonia (> 50 mg/l) and free H2S (> 250 mg/l);Chemical buffering may be required to maintain alkalinity in reactor;

- Corrosion resistant materials, such as plastics and masonry coatings are required for the reactor vessel and pipes. (McCarty, P.L., 1981)

2.6 Unsewered Communities

2.6.1 Issues

The issues that contribute to a re-evaluation of the way sewerage services have been traditionally delivered and which favour decentralized sewerage are:

2.6.1.1 Economics

A greater return on capital expenditure is now required. As the large pipes connecting villages to central treatment plants are a significant proportion of the total cost, lower cost decentralized sewerage systems may provide a solution.

2.6.1.2 Environmental

- More stringent environmental standards for discharge of effluent to waterways may favour local reuse from decentralized plants;
- Government push for ecological sustainable development favours effluent reuse;
- Customers have voiced a preference for effluent reuse instead of ocean and river discharges;
- in striving to limit the use of energy and greenhouse gases, gains can be made through decentralized systems which do not require pumping stations and can incorporate local energy production such as solar power or wind turbines

2.6.1.3 Social

Many rural communities value their independence from surrounding towns and cities, and some favour retaining responsibility for their own sewerage;

2.6.1.4 Technology

The present large centralized systems do not readily accommodate the adoption of new whole-of-plant technologies, whereas more numerous small scales, cost effective systems could be more easily upgraded as advanced technologies become available.

2.6.2 Benefits

The benefits accruing from a decentralized sewerage service are:

2.6.2.1 Economics

- Lower cost than connection to a centralized treatment plant, especially in remote, hilly, rocky or flat areas
- Increased rate of return on investment (Pinkham, 2000).

2.6.2.2 Environmental

- Decentralized schemes can be integrated with water supply and storm water services in a catchments or sub-catchments enabling sustainable yields and usage
- supports total water cycle management
- Opportunity to match water quality to end use ie non-potable quality for toilet flushing; treated effluent containing nutrients to plants.
- Upgrades can be targeted to priority problem areas instead of whole area required for economies of scale with centralized systems
- Local water use decreases the need for inter-basin transfer of water
- Local reuse increases soil moisture, groundwater recharge and stream base flow, decreasing susceptibility of the land to drought, and decreasing flood peaks while increasing environmental flows – the system more closely mimics nature
- facilitates resource recovery - greater control of the influent increases bio-solids use ability and value
- Reduction of point source discharge contributes utility aims to reduce discharge to waterways
- Protection of public and environmental health
- provides opportunities for targeted demand management, benefiting the decentralized treatment plant by reducing loading
- Lower use of energy
- Potential to produce of local ‘green’ energy through solar or wind power
- Flexible small diameter polyethylene pipes can be routed around culturally and environmentally significant sites reducing the cost, construction time and impact of the reticulation
- As there is no need for pipes to follow the creek lines, the health and integrity of the riparian zone and waterway is protected.

2.6.2.3 Social

- Retains sense of local self-sufficiency
- enhances local sense of identity
- Potential for sewerage solutions to be congruent with the needs of the local community and culture
- Potential for a short feedback loop between effluent quality and householders’ use and abuse of water
- Potential for targeted wastewater and water education
- provides an opportunity for customers to have more input in the decision making process and to have choices
- Shorter construction time and rapid land restoration due to small trenches for the small diameter pipes, reduces public inconvenience
- Water conservation measures taken more seriously as the impact is local.

2.6.2.4 Technology

- Expands the range of product and service options which can be tailored to more closely match customers’ needs
- Opportunities for new technologies to be trialed
- Maximizes use of existing infrastructure by not overloading it.
- Expertise in sustainable decentralized sewerage systems can provide an enormous opportunity to export the technology and management skills to developing and developed countries

2.6.2.5 Management

- Facilitates adaptive management.
- Enables integrated catchments management.
- Encourages community and government partnerships.
- Operation and maintenance is simplified.
- Facilitates integration of water, wastewater and storm water services.
- Centralized management utilizing remote monitoring ensures professional and prompt service.

2.6.3 Challenges

When appropriately designed, sited, operated and maintained decentralized sewerage systems will meet public health and water quality goals. However, a number of obstacles exist that may delay the acceptance of decentralized systems:

- Lack of knowledge about the technology
- The need to design new maintenance and management systems
- Negative perceptions of on-site systems and interceptor tanks
- Regulatory barriers
- Community, utility and regulator education of the risks and benefits
- multi-skilling staff
- Institutional barriers
- High level of familiarity and comfort with centralized systems by all stakeholders.

2.7 UASB reactor

2.7.1 UASB removal mechanism.

In a UASB-reactor, the accumulation of influent suspended solids and bacterial activity and growth lead to the formation of a sludge blanket near the reactor bottom, where all biological processes take place.

Two main features decisively influencing the treatment performance are the distribution of the wastewater in the reactor and the "3-phase-separation" of sludge, gas and water, As shown in Figure 2.3 below:-

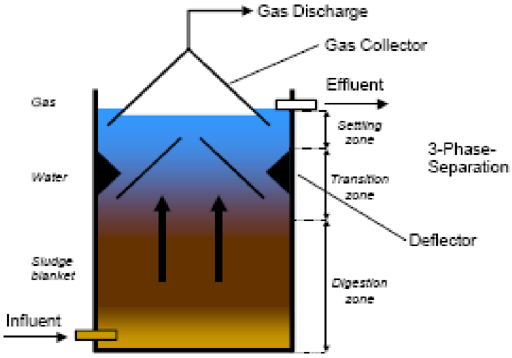


Figure 1: **The UASB-Reactor** (Source: TBW, modified after [6])

Figure 2.3 UASB general compartments (Wirtschaftsberatung TBW GmbH, 2001).

The influent point (sewage) is situated at the reactor bottom, the effluent discharge (treated wastewater) is situated in the upper part of the reactor, thus forcing the entering sewage to follow an upflow regime and to get into contact with the sludge blanket in the reactor. Here, the organic matter in the sewage is subject to anaerobic degradation by the bacteria contained in the sludge blanket, with methanogenic ("methane building") bacteria producing methane gas (CH4) during the degradation processes.

In order to prevent unwanted sludge discharge, separation devices (deflectors) are installed that revent the further upward movement of the sludge and force it to sink back into the bed. The gas is collected in gas holders installed in the upper part of the reactor; for gas rising close to the reactor walls, an additional one may be installed (Wirtschaftsberatung TBW GmbH, 2001)

The UASB reactor traps particles of organic material in a "sludge blanket" and digests them over a long time period, while passing the liquid fraction through in a matter of a few hours. As a result, the volume of the reactor is kept to a minimum and the treatment plant is compact.

The pretreated influent is introduced from the bottom, and gas bubbles form as the organic material is digested. The rising gas bubbles help to mix the substrate with the anaerobic biomass. The biogas, the liquid fraction and the sludge are separated in the gas/liquid/solids (GLS) phase separator, consisting of the gas collector dome and a separate quiescent settling zone. A clarified effluent is collected in gutters at the top of the reactor and removed.. A properly designed UASB reactor eliminates the need for mechanical mixing and has few moving parts. Typically, a UASB treatment plant may need pumps only to remove excess sludge from the reactor (Al-Sa'ed, 2006).

One of the main features of UASB processes certainly is its ability to produce a granular type of anaerobic sludge, which has a high methanogenic activity and good settleability. So that the reactors are able to be operated stable at high volumetric COD loading rate (Lettinga et al., 1983).

2.7.2 Design criteria of UASB

The UASB reactor is designed around two main criteria:

1- hydraulic retention time

The average amount of time that the liquid part of the wastewater stays in the reactor,

2- solids retention time

The average residence time of the solids in the reactor.

Table 2.5: Important average operational parameters for MWWT in UASB (Wirts, 2001).

parameter	Unit	Value
HRT(hydraulic retention time)	**h**	**4-20**
Upflow velocity	**m/hr**	**0.2-1**
Charge per volume	**Kg COD/m3.d**	**0.4-3.6**
Sludge charge	**g COD/g DOM.d**	**0.05-0.5**
Specific energy demand	**Kwh/m3 wastewater**	**0.07-0.2**
Gas production	**Nm3/m3reactor.d**	**0.02-0.3**
Excess sludge	**Kg DM /P.E.D**	**2.5-5**

DOM: Dry organic matter, DM: dry Matter, P.E: population Equivalent.

2.8 Biofilttration

2.8.1 Introduction

The trickling filter is an aerobic attached growth process that distributes settled wastewater or an anaerobic effluent over solid media, such as rock, broken brick or plastic. Attached films of aerobic biomass grow on the media and digest the organic material in the wastewater. Periodically, excess biomass sloughs off the media and is collected for disposal in a secondary clarifier.

Trickling filters are secondary aerobic biological processes which are used for treatment of sewage. Biofilters or biotowers are terms describing trickling filters which use random or stackable modular synthetic media.

Trickling filters enable organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria, fungi, algae, and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film.

The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer (USEPA, 2000).

The BOD_5 removal rates for the trickling filters vary according to the filter type

There are four basic categories of filter design that are based on the organic loading of the trickling filter, which is Low-rate filters:-

2 Intermediate-rate filters
3 High-rate filters
4 Roughing Filters

Table 2.6 classification of trickling filters with respect to organic load (USEPA, 2000).

Filter Type	Loading
Low rate filters	<40 kgBOD per100 m^3 per day
Intermediate-rate filters	UP to 64 kg BOD per 100m^3 per day
High rate filters	64-160 kg BOD per 100m^3 per day
Roughing filters	160-480 kg BOD per 100m^3 per day

This system has received increased attention from wastewater researchers for solving the problem of wastewater in small communities along with its potential for delivering several benefits including (Bakir, 2000):

- It is appropriate for areas where water supplies are intermittent and water consumption is low.
- It involves managing wastewater as close as possible to where it is generated.
- It increases wastewater reuse opportunities by keeping wastewater as close as practical to the potential reuse site.
- It results in significant reduction in wastewater transportation and collection.
- The probability of simultaneous failure of all small systems is significantly lower than that of failure of one system serving the entire community.

2.8.2 General Requirements.

(A) Materials. Crushed rock, slag, or similar material shall not contain more than five percent by weight of pieces whose longest dimension is greater than three times the least dimension. Rock media shall conform to the following size distribution and grading when mechanically

(B) Passive Ventilation. The under drain system or synthetic media support structure, Effluent channels, and effluent pipe shall be designed to permit free passage of air. Naturally-based approaches are also defined in this paper as having one or more of the Following characteristics:

1. Achieving acceptable levels of treatment;

2. Requiring low capital investment;

3. Requiring low ongoing operation and maintenance costs;

4. Requiring less-skilled operator knowledge than many conventional technologies; and,

5. Potentially having longer life-cycles than conventional electro-mechanical technology.

2.8.3 Removal mechanism in biofilter and backing materials

It is an attached-growth process in which many trophic levels of organisms live in and on the filter bed (Figure 2.8), reducing the organic portion of waste into carbon dioxide and water in the presence of oxygen (Venhuizen ,1997).

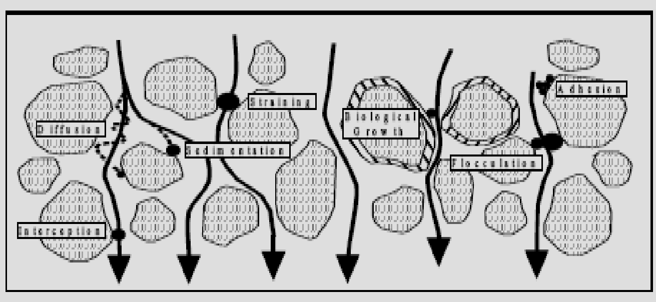


Figure 2.4: Removal Mechanisms of Filtration (Rowe et al. 1995)

:The packing material in a trickling filter must

- have a high specific surface (m^2/ m^3 filter material) - thus maximizing the are available for colonization by the biofilm;

- have a high voidage so that there is an adequate space for the downward movement of liquid and upward movement of air;

- be inert and durable and be able to withstand weathering;

- have mechanical properties so it is resistant to abrasion during transport and handling.(DG Demonstration Project LIFE,2005)

In rapid filter (RF), the packing filter media can be single, dual, or triple layer (Coulsont *et al*., 1991). Beside the type of the packing material, the specific surface area, porosity, and pore size. Also, it will influence the treatment process irrespective of being anaerobic or aerobic, nor the flow direction (Fitzpatrick e*t al*., 1998).

1 In wastewater treatment, the packing materials will get clogged with time, due to the deposition of suspended solids. To achieve prescribed effluent standards, the filter should be cleaned (back washed) when the head loss had increased (Huisman, 1985). Back washing can be achieved by reversing the flow direction, that in case the flow of the water to be treated in down ward direction.

Wastewater is uniformly applied to the media bed by the application system. Uniformity is necessary to ensure that all media is wet. The performance of the process is affected by the application system, which can also be used as control of dosing frequency

2.8.4 Relevance of using biofilters

Despite the advantages the UASB technology has, the effluents produced must be further polished to comply with the environmental standards. Hence, it is of great importance to consider a post-treatment for the UASB effluent. The main objective of post-treatment is to enhance the organic matter removal. In addition, based on the receiving water bodies removal of nutrient and pathogens should be accomplished, as these are barely affected by the anaerobic treatment (Metcalf and Eddy, 1991).

The combination of the two systems (UASB and biofilters) could become very promising alternative for the treatment of domestic sewage, where the removal efficiency in terms of COD for the UASB effluent almost 80%. It had been observed also that both systems (UASB and biofilter) were capable of promoting additional removal, by increasing the removal efficiency to 85-90%, in the combination of UASB/biofilters (Chernicharo *et al*., 1998).

The mechanism of the filtration process for the removal of pollutants is brought about by combination of different mechanisms, the most important of which is the adsorption process. In the case of anaerobic filtration treatment process with a media of the lowest surface area but the largest pore size and porosity, demonstrated the highest chemical oxygen demand (COD) removal efficiencies of 90% and 73% at loading rate of 8 and 16g COD/L.d (Tay *et al.,* 1996). According to(Huisman , 1985) and (Reynolds ,1998), the most important mechanisms taking place in the filter bed are mechanical straining, sedimentation, chemical and biological reactions, where the latter is the main step in pollution load reduction.

The Palestinian community emphasizes the need for simplified treatment systems that could present low investment and running costs operating simplicity, minimum mechanization level, and sustainability of the system. Due to poor maintenance and operation, system design failures and mismanagement in installment, most of the existing small onsite sanitation systems in Palestine are not sustainable (Mubarak and Al-Sa`ed, 2006).

Based on the recommendation made by (Ali *et al.*, 2006), no attempts were made to investigate the efficiency of an integrated two-stage multimedia biofilters as a post-treatment stage of the UASB effluent. However, recent results obtained by Fuqaha and Al-Sa`ed (2006) showed that if the UASB has a proper design, regular operation and maintenance, a two-stage biofilter can achieve an effluent of adequate quality for re-use in agricultural purposes.

2.8.5 Design criteria for biofilters

Design criteria taking two permeters into account as shown in table 2.7, 2.8 below:-

1- organic loading rate
2- hydraulic loading rate.

Table 2.8 design parameters of trickling filters (Al-Saed)

Trickling filter		
Parameter	**Low loaded**	**High loaded**
OSLR	1-7 gBOD/m2/day	4-38 gBOD/m2/day
Hydr. Load	0.1-0.3 m3/m2/h	0.4-2 m3/m2/h
Effl. BOD	< 25 mg/l	> 30 mg/l
BOD removal	80-90%	50-80%
Nitrification	60-80%	0-50%

2.8.6 Design Equations For Using Biofilters

The National Research Council (NRC) formulation to predict BOD removal efficiency was the result of an extensive analysis of operational records from stone-media trickling filter plants at military installations.

The NRC data analysis is based on the fact that the amount of contact between the filter media and organic matter depends on the filter dimensions and the number of passes, and that the greater the effective contact, the greater will be the efficiency. However, the greater the applied load, the lower will be the efficiency. Therefore, the quantity that primarily determines efficiency in a trickling filter is a combination of effective contact and applied load.

The efficiency through the first or single stage (E) and through the second 1 stage (E) can be predicted from equations 2.3 and 2.4.

$$E_1 = \frac{100}{1 + 0.0085\left(\frac{W_1}{VF}\right)^{\frac{1}{2}}}$$ ……………………………………………………………..2.3

$$E_2 = \frac{100}{1 + \frac{0.0085}{1-E_1}\left(\frac{W_2}{VF}\right)^{\frac{1}{2}}}$$ ………………………………………

…………………...2.4

E = percent ROD removal efficiency through the first-stage filter and 1 settling tank

W = BOD loading (lb/day; 1 lb/day = 0.45 Kg/day) to the first- or 1 second-stage filter, not including recycle

V = volume (acre-ft; 1 acre ft = 1,233.5 m3) of the particular filter stage (surface area times depth of media)

F = number of passes of the organic material, equal to (1 + R/I)/ [l + (1 - P) R/I]

where R/I equals the recirculation ratio (recirculated flow/plant influent flow), and P is a weighting factor which, for military trickling filter plants, was found to be approximately 0.9

E = percent BOD removal efficiency through the second-stage filter and 2 settling tank

W = BOD loading (lb/day) to the second-stage filter, not including 2 recycle

Note: Empirical equations, can only be used with English units - to use with metric, must convert to English before putting in Equation.

2.8.7 Advantage and limitation for using Biofilter

Some advantages and disadvantages of TFs are listed in table 2.7 below (Metcalf and Eddy, 1991):

Advantages
• Simple, reliable process.
• Suitable in areas where large tracts of land are not available for a treatment system.
• May qualify for equivalent secondary Discharge standards.
• Effective in treating high concentrations of organics depending on the type of media • Used, and flow configuration.
• Appropriate for small- to medium-sized Communities.
• High degree of performance reliability at lower stable loadings.
• Ability to handle and recover from shock loads.
• Durability of process elements.
• Low power requirements.
• Requires only a moderate level of skill and technical expertise to manage and operate the system.
• Reduction of ammonia-nitrogen concentrations in the wastewater.

Disadvantages
• Additional treatment may be needed to meet more stringent discharge standards.
• Regular operator attention needed.
• Relatively high incidence of clogging.
• Relatively low organic loadings required depending on the media.
• Limited flexibility and control in comparison with activated-sludge processes.
• Potential for vector and odor problems.
• Autotrophic bacteria (nitrifies) are sensitive to changes in the waste stream (e.g. pH , Temperature and organics).
• Autotrophic bacteria (nitrifies) are more Sensitive to “shock loads” than other bacteria.
• Predation (i.e. fly larvae, worms, snails)
• Decreases the nitrifying capacity of the System to changes in the waste stream (e.g. pH, temperature, and organics).
• Autotrophic bacteria (nitrifies) are more sensitive to “shock loads” than other bacteria.
• Predation (i.e. fly larvae, worms, snails)
• decreases the nitrifying capacity of the System.

2.9 Integrated system of UASB Biofilter system.

Collection of domestic wastewater and transport to a distant treatment plant is expensive at low population density (Netter *et al.*, 1993; Paulsrud and Haraldsen, 1993).

The treatment technology for small wastewater streams should be based on locally available and serviceable materials and equipments that are simple and economical to operate. Those low technical skills needed are the most appropriate ones (Odegaard, 1997).

The purpose of our research was to develop a treatment process that will guarantee the technical feasibility in rural areas, taking into consideration factors such as the construction and maintenance costs, the availability of construction materials and equipment, the limitation of land for an individual household.

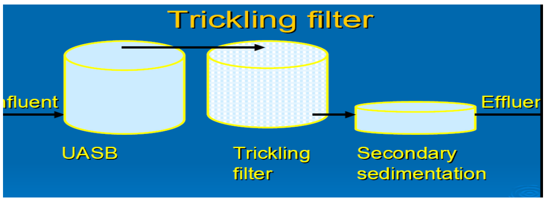


Figure 2.5 integrated system of UASB/TF (Al-Sa'ed,2006)

2.10 Onsite treatment system

For domestic wastewater the suitability of various sanitation technologies must be related appropriately to the type of community, i.e. rural, small town or urban. Typically, in low-income rural and (peri-) urban areas, on-site sanitation systems are most appropriate because:

- They are low-cost (due to the absence of sewerage requirements).
- They allow construction, repair and operation by the local community or plot owner.
- They reduce, effectively, the most pressing public health problems (Hulshoff Pol and Lettinga, 1986).

The potential benefits of a local, small community scale ecologically sustainable small treatment system include:

- □lower construction costs (avoids linking the town to sewage system, reducing the cost of trenching, piping and pumping stations)
- □lower maintenance costs (no long distance pipes to replace, reduced number of pumping stations to service, operational/maintenance can be contracted out to local service providers)
- □□ease of monitoring contaminants

- prompt feedback loop from STS to householders
- □fosters sense of local responsibility for wastewater
- □opportunities for water sensitive urban design
- □community participation in decision making
- □sustainable local solutions.

2.11 Nutrient removal

The five major steps involved in nitrogen cycling are nitrogen fixation, assimilation, mineralization, and nitrification and denitrification (Alexander., 1977; Grady et al., 1980; .Barnes et al., 1983; Atlas et al., 1998) as shown in figure 2.6 below

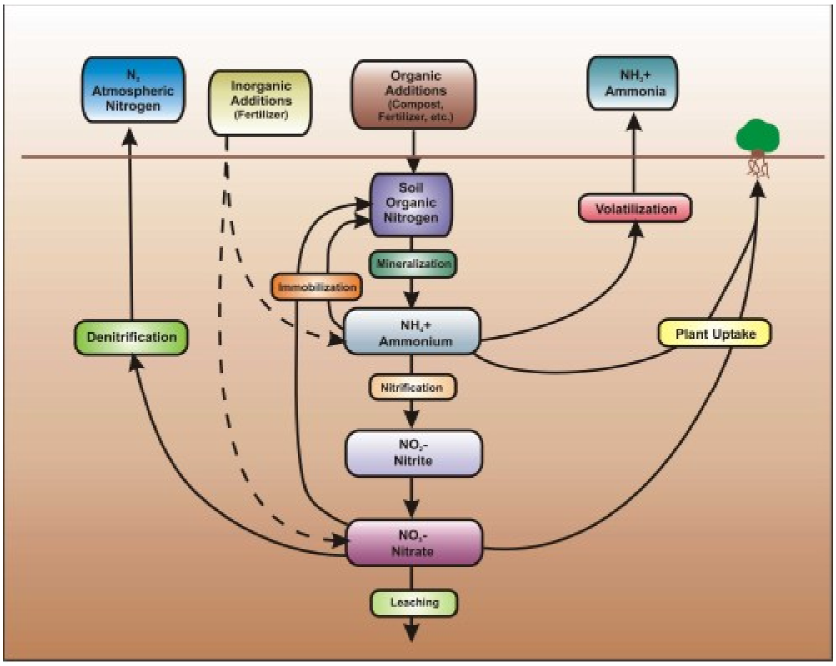


Figure 2.6: Nitrogen Cycle (Source: Coffman et al. 1999)

1
2
3
4 **Nitrification** entails the biological conversion of ammonium to nitrate.

Nitrification can only occur in the presence of oxygen and sufficient alkalinity to neutralize the hydrogen ions produced during the oxidation process. Parker (1975) gives 4.6 mgO_2/mg NH_4^+ as the oxygen requirement oxidized to NO_3^-.

.**Denitrification**, NO^-_3 is reduced to nitrous oxide N2O and nitrogen gas N2

N2 liberation is the predominant output of denitrification and microorganisms involved in .(denitrification are heterotrophic microorganisms (Parker, 1975

2.12 Process

The two principal mechanisms for the removal of nitrogen are assimilation and nitrification-denitrification. In biological nitrogen removal nitrification-denitrification is the dominant mechanism and is accomplished in two conversion steps. The first step, nitrification is achieved in a two stages process involving two genera of microorganisms, *Nitrosomonas* and *Nitrobacter*. In the first stage ammonium is converted to nitrite and in the second stage nitrite is converted to nitrate. The conversion process is described as follows:

First step

$$NH4^+ + 3/2O_2 \xrightarrow{\textit{Nitrosomonas}} NO_2^- + 2H^+ + H_2O \quad ....2.5$$

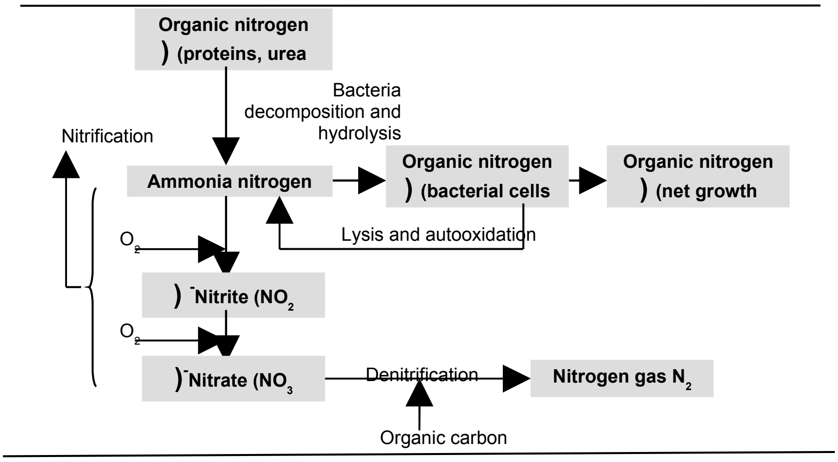
Second step,

$$^-NO_2^- + 1/2O_2 \xrightarrow{\textit{Nitrobacter}} NO_3 \quad ....2.6$$

. In most biological nitrification-denitrification systems, the wastewater denitrified must contain sufficient carbon (organic matter), to provide the energy source for the conversion of nitrate to nitrogen gas by the bacteria. The reactions for nitrate reduction are:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O + N_2 .... \; .... \; ....2.7$$

.The last three compounds are gaseous products and can be released to the atmosphere



(Figure 2.7 Nitrogen transformations in biological treatment processes (Metcalf & Eddy, 2003

2.13 Reuse aspects

The reuse of treated wastewater for fertilizing and irrigating gardens and fields or e.g. Reuse as toilet flushing water. Moreover, produced sludge can also be utilized as fertilizer and soil improver, if local legislation permits land application. Separation of more diluted wastewaters from more concentrated ones adds to the possibility of water recycling. Moreover, consumption of potable water can be minimized simple and low-cost processes suffice, and different scales are applicable (van Lier & Lettinga 1999) as shown in figure2.7.

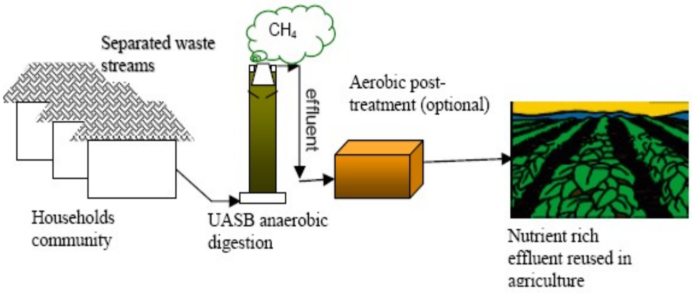
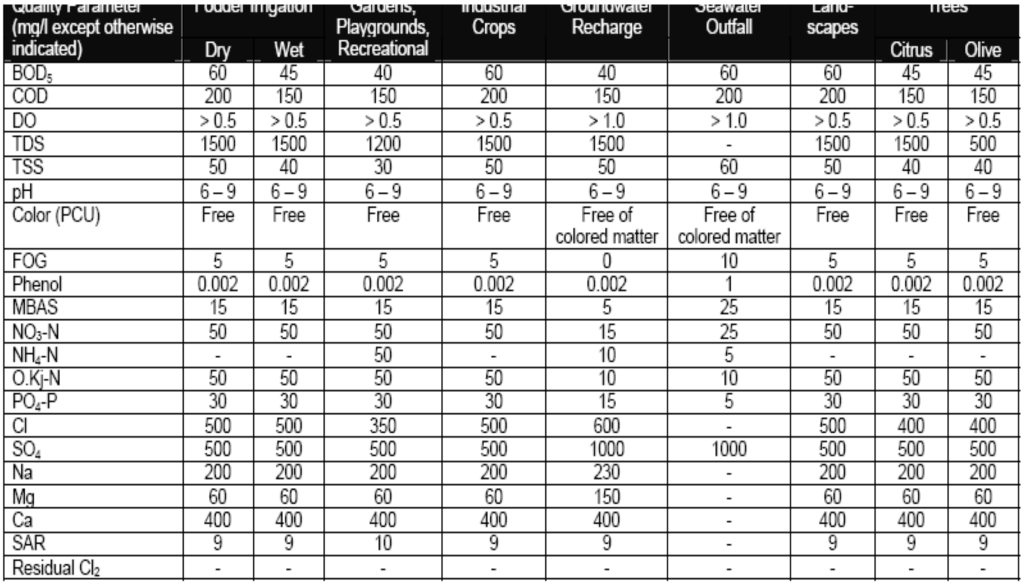


Figure 2.8: An example of onsite application

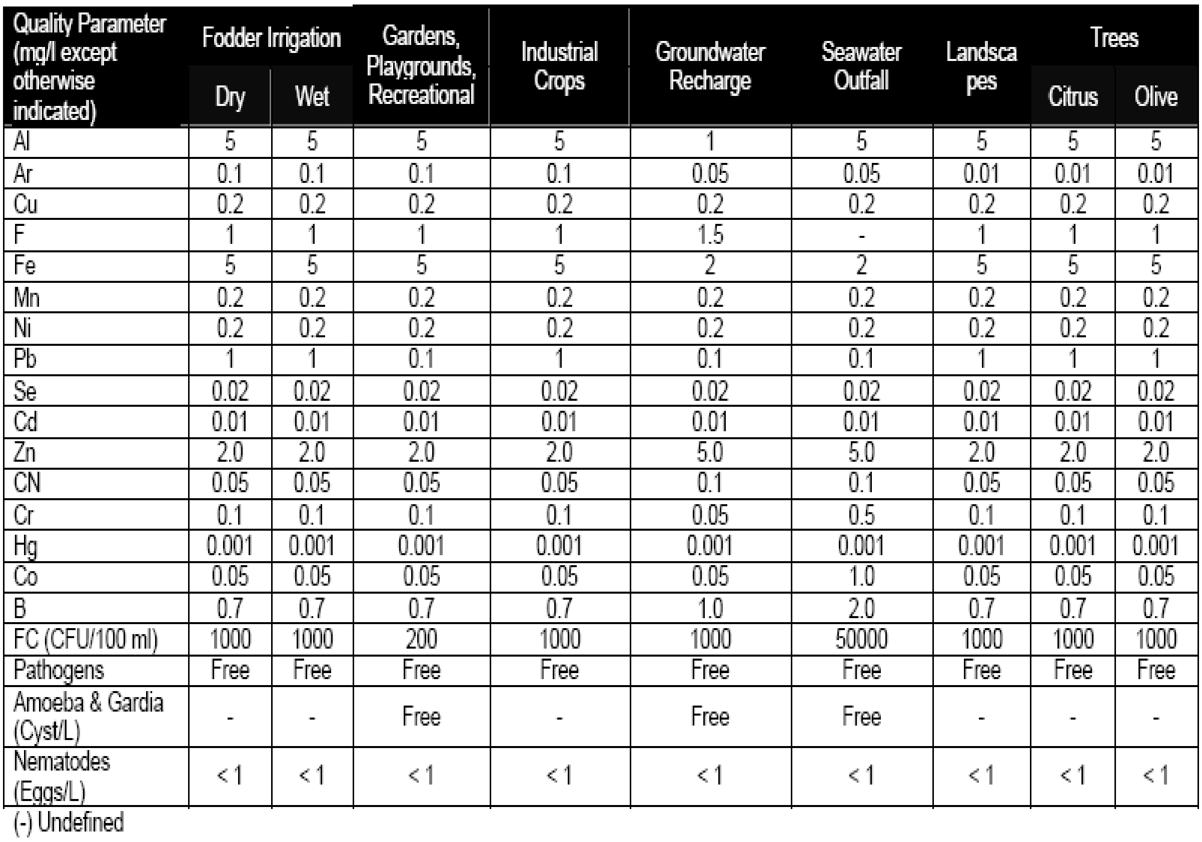
UASB-septic tanks can be applied both for community- and house-on-site treatment of different wastewaters and as opposed to accumulation systems, they are also applicable for more diluted domestic sewage as well as black water from conventional flush toilets and vacuum toilets. Moreover, addition of kitchen waste into the treated wastewater has been reported possible (Kujawa-Roeleveld, et al. 2005).

With respect to reuse aspects of the treated wastewater, wastewater influent must have a minimum characteristic as shown in table 2.7 below:-

Table 2.9 Recommended guideline by the Palestinian standard institute for the treated wastewater characteristics according to the different application



Quality Parameter (mg/l except otherwise indicated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Land-scapes	Trees	
	Dry	Wet						Citrus	Olive
BOD$_5$	60	45	40	60	40	60	60	45	45
COD	200	150	150	200	150	200	200	150	150
DO	> 0.5	> 0.5	> 0.5	> 0.5	> 1.0	> 1.0	> 0.5	> 0.5	> 0.5
TDS	1500	1500	1200	1500	1500	-	1500	1500	500
TSS	50	40	30	50	50	60	50	40	40
pH	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Color (PCU)	Free	Free	Free	Free	Free of colored matter	Free of colored matter	Free	Free	Free
FOG	5	5	5	5	0	10	5	5	5
Phenol	0.002	0.002	0.002	0.002	0.002	1	0.002	0.002	0.002
MBAS	15	15	15	15	5	25	15	15	15
NO$_3$-N	50	50	50	50	15	25	50	50	50
NH$_4$-N	-	-	50	-	10	5	-	-	-
O.Kj-N	50	50	50	50	10	10	50	50	50
PO$_4$-P	30	30	30	30	15	5	30	30	30
Cl	500	500	350	500	600	-	500	400	400
SO$_4$	500	500	500	500	1000	1000	500	500	500
Na	200	200	200	200	230	-	200	200	200
Mg	60	60	60	60	150	-	60	60	60
Ca	400	400	400	400	400	-	400	400	400
SAR	9	9	10	9	9	-	9	9	9
Residual Cl$_2$	-	-	-	-	-	-	-	-	-



Quality Parameter (mg/l except otherwise indicated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	Trees	
	Dry	Wet						Citrus	Olive
Al	5	5	5	5	1	5	5	5	5
Ar	0.1	0.1	0.1	0.1	0.05	0.05	0.01	0.01	0.01
Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
F	1	1	1	1	1.5	-	1	1	1
Fe	5	5	5	5	2	2	5	5	5
Mn	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pb	1	1	0.1	1	0.1	0.1	1	1	1
Se	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	2.0	2.0	2.0	2.0	5.0	5.0	2.0	2.0	2.0
CN	0.05	0.05	0.05	0.05	0.1	0.1	0.05	0.05	0.05
Cr	0.1	0.1	0.1	0.1	0.05	0.5	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Co	0.05	0.05	0.05	0.05	0.05	1.0	0.05	0.05	0.05
B	0.7	0.7	0.7	0.7	1.0	2.0	0.7	0.7	0.7
FC (CFU/100 ml)	1000	1000	200	1000	1000	50000	1000	1000	1000
Pathogens	Free	Free	Free	Free	Free	Free	Free	Free	Free
Amoeba & Gardia (Cyst/L)	-	-	Free	-	Free	Free	-	-	-
Nematodes (Eggs/L)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

(-) Undefined

3 MATERIAL AND METHODS

3.1 Treatment system settings and description

In order to achieve the envisaged research aim, the following methodology will be adopted:

- A comprehensive literature review will be conducted with respect to anaerobic treatment of domestic sewage and post-treatment with special emphasis on biofilter systems.
- Design and installment of the integrated wastewater treatment units as a pilot-scale plant.
- □Running and long-term monitoring for the integrated UASB-biofilter system.

3.2 Design and setup of the onsite treatment system

3.2.1 location of the pilot plant

Pilot plant is located in the albireh wastewater treatment plant.
The City of Albireh and portions of the nearby dwellings of Ramallah city, domestic septage and some commercial and small family owned industrial enterprises generate the wastewater, which enters Albireh Wastewater Treatment Plant (AWWTP).

3.2.2 Feeding system

The sewage first enters the grit chamber where the sand and the grit are removed. The wastewater from the grit chamber was pumped to an equalization tank (250L plastic drum) from which the reactors were fed and the influent sampled. The wastewater was pumped to the drum and the reactors on a continuous basis and was only disturbed due to the occasional blockage of the hoses caused from the accumulated solids in the grit chamber and the distribution tank the drum was however emptied and cleaned on a weekly basis to prevent the accumulation of solids. It should be noted here that due to the accumulated solids in the grit chamber and equalization tank as well as the rapid growth of algae in the hoses, very high COD and solids concentrations were sometimes occurring in the wastewater. This was dealt with by the thorough cleaning of the hoses on a weekly basis to prevent the accumulation, which would also, result in blockage and prevent the continuous operation of the system.

To fulfill the objectives of this research, a post-treatment stage was designed and installed. This stage entailed two passive aerated biofilters operated in series. The complete set-up of the treatment scheme is depicted in Figure 3.1

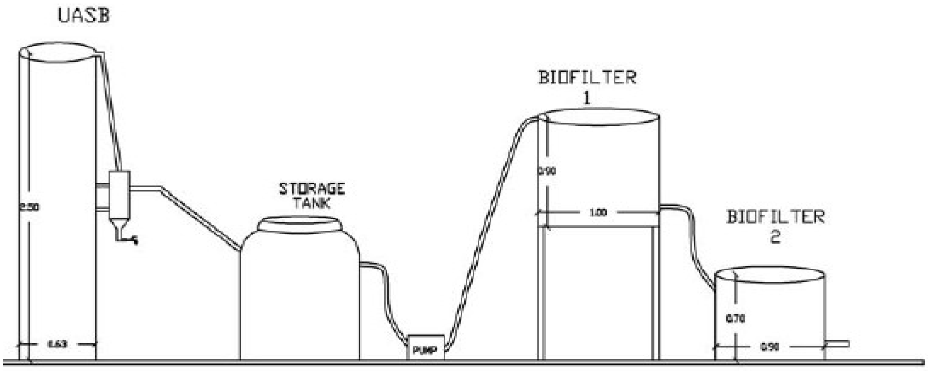


Fig. 3.1: Pilot scale treatment system (UASB and biofilters)

Filter comprised of multilayer fixed film media including sand, small rocks, and aggregate media at specific depths as shown in figure (3.2). In the second filter (Biofilter 2), PVC material was also added in addition to the same filter media as in the first filter with variable heights (Fig. 3.3). Both natural and synthetic fixed film materials were locally available at low-cost price and have stable characteristics. For detailed calculation of specific surface area and other design parameters, Annex 2 can be consulted.

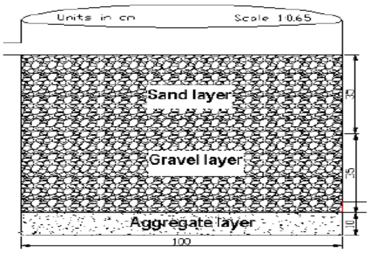


Fig. 3.2: Biofilter 1 with sand and gravel layers

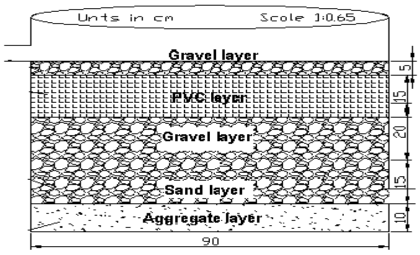


Fig. 3.3: Biofilter 2 with extra PVC media

3.3 Preliminary design

-:They are two types of adjustments

1. Material backfill
2. Flow adjustment.

Table 3.1 shows dimension of biofilters that used for treating wastewater

Dimension	Biofilter 1	Biofilter 2
Diameter	m 1	m 0.9
Effective depth	m 0.7	0.5m

1 Material backfill

First trial

- Operation day for the biofilters in the first trial was on 20/6/2005
- Operation day for the UASB was on 20/6/2005
- profiles shown in table 3.2
- Figures describe this trial indicated in figure 3.4 and figure 3.5 .

Fig. 3.4: Biofilter 1 with sand and gravel layers

Fig. 3.5: Biofilter 2 with extra PVC

Table 3.2 describe biofilters profile for different runs

	Biofilter1		**Biofilter 2**	
Phases	Material	Layer thickness	Material	Layer thickness
Startup phase	Sand	cm 35	Sand	cm 20
	Stones	cm 35	Stones	cm 20
	Aggregates	cm 10	Aggregates	cm 10
	PVC Isolations	----------	PVC Isolations	cm 10
Second phase	Stones	cm 70	Stones	cm 30
	Aggregates	cm 10	Aggregates	cm 10
	PVC Isolations	-------------	PVC Isolations	cm 20

Second trial

In this trial we changed the UASB with another with flow Rate 200 l/d, H.R.T 4 days

During system start-up phase, a constant initial flow rate of 200 L/day was applied to the treatment system for a period of three months (June-September 05).

The treatment system consisted of a pilot-scale UASB reactor, with a volume of 700 liters, followed by a trickling filter (TF) as shown in figure 3.1 above , used for the post-treatment of the anaerobic effluent. The UASB reactor/TF system was fed with domestic sewage taken directly from the sewer.

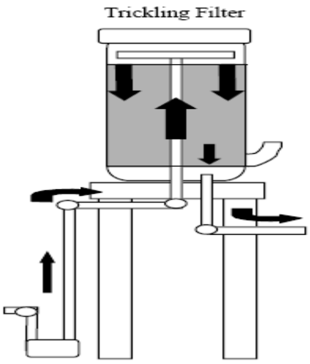


Figure 3.6 shows flow distribution in the bioreactor (Antar Gamble Hall,2003)

The set-up of the UASB reactor is shown in Figure 3.1. A holding tank, preceding the UASB reactor, will serve as a balance tank and as a primary sedimentation tank. The incorporation of the holding tank will provide a partial removal of the solids, which will be accumulated and to the grit chamber. The reactor was inoculated with anaerobic sewage from pilot UASB treating wastewater from ALbireh. Which followed by biofilters.

The experimental runs were conducted as follows:

- Start-up phase: Put into operation in a continuous mode (June 05-August 2005).
- □First run phase under low loading rates (September 05-December 05).
- □Second run phase with increased loading rates (December 05-Feb06).

3.4 Waste Water sampling and lab analysis

The physical-chemical analyses were carried out according to Standard Methods for Examination of Water and Wastewater.

For routine monitoring of VFA concentration in both influent and effluent streams titrimetric method as suggested in the Standard Methods for Examination of Water and Wastewater was adopted.

Lab analysis was conducted in the Water Engineering Lab at the Water Studies Institute according to procedures documented in various sections of Standard Methods (APHA, 1995). Measurement of COD, BOD, TS, TSS, EC, NH_4-N, TKN-N, pH, DO, PO_4-P, Total-P, and volatile fatty acids directly after the sampling process as shown in the table3.5 below , otherwise preserve and stored according to recommendations made in the APHA Standard Methods.

Table 3.3 describe the parameters to tested and the frequency of sampling

Influent - Effluent	Parameters Frequency
Temperature	**Weekly**
pH	**Weekly**
DO	**Weekly**
EC	**Weekly**
COD (total, settled, centrifuged)	**Weekly**
BOD_5	**Weekly**
TSS,	**Weekly**
TS	**Weekly**
VFA, *	**Weekly**
NH4-N, TKN	**Weekly**
PO4-P PTOTAL	**Weekly**
FECAL COLIFORM	**Weekly**

Analytical methods. The methods of analysis used are based on those found in Standard Methods (1998).

3.5 Methodology

The following tasks were accomplished to achieve a successful implementation of the study:

- Detailed technical design multimedia biofilter system
- Lab analysis of the wastewater from Albireh municipality to aid in the concept layout and design of unit operations for the pilot scale system.
- Leakage test conduction and put the system into operation, sample analysis until reaching the treatment system steady state conditions.
- Development of an analysis program for influent, effluent of the UASB effluent and the biofilter system.

Research includes the following phases:-

- Phase I: start-up of the UASB / two sand media biofilter system (UASB reactor had been already previously started-up). Constant inflow.

- Phase II: changing of the media of the two biofilter system (stones and PVC).

- Phase III: Reduction of the Hydraulic Retention Time (HRT) in all units. Constant inflow.

The operating period of 5 months for the latest two phases .

3.6 Work Program Deviations and Justifications

Sand filters were clogged on a regular basis. Hence, without affecting the goal and objectives of this research study, the following minor deviations from the original submitted proposal are listed with justifications:

- Keeping the hydraulic flow and the determined pollution loads (COD and TKN) the multimedia biofilter was accordingly designed. An adequate surface loading rate (15-20 $gBOD/m^2.d$) is expected to deliver reliable effluent quality (EPA, 2004). The erection of the pilot scale treatment system was made at the site of Albireh wastewater treatment plant which represents the real characteristics of waste water in Palestinians territories.

3.7 Planned Activities

- Based on the operational results obtained, the design variables will be changed to validate the optimal design parameter and environmental factors achieving the best effective treatment and stable operation.

3.8 Feeding system

The UASB reactor and the trickling filter (TF) were fed with wastewater taken directly from Albireh waste water treatment plant, through an automated pumping system. Before feeding the reactors, the wastewaters passed through a preliminary treatment system, composed of coarse material and grit removal units, and then directed to an accumulation/distribution tank used to feed the UASB reactor.

After the preliminary treatment, the raw sewage was pumped into the UASB reactor through a peristaltic pump (Masterflex, two heads, 6 to 600 rpm). The effluent of the UASB reactor was directed to a splitting box, which to avoid solids sedimentation, and then pumped into the trickling filter by means of other peristaltic pump (Masterflex, one head, 6 to 600 rpm).

The experimental units were controlled by an automated system that allowed the continuous variation of the flowrate and on-line measurement of temperature, pH and turbidity.

The control allowed all feeding pumps to operate at variable speed throughout the day, in order to simulate a transient hydraulic regime.

3.9 Pilot units

The main characteristics of the pilot-scale UASB reactor and TF used in the experiments are presented in Figures 2 . 3 illustrate the configuration of these reactors.

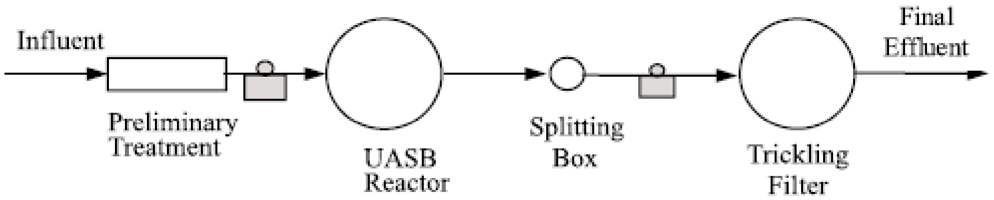


Figure 3.7 Conceptual diagram of the integrated system (PLAN)

The effluent from the UASB reactor is pumped onto the rock bed of the trickling filter, according to the flow variation controlled by the automation system. The effluent then has a downward flow, through the reaction compartment that contains the packing material, and is finally collected on the settler compartment that is located at the bottom part of the trickling filter. In the settler, the solids released from the biofilm, or non-retained onto the packing media by filtration or adsorption, are removed from the final effluent which leaves the settler from its upper part.

3.10 Process start up and operational strategy

The pilot UASB reactor had been in operation for about 2 years hence was already adapted to the wastewater to be treated. In relation to the start up of the trickling filter, a stepwise increase in the hydraulic and organic load was adopted. The thesis comprised the investigation of 2 different operational phases, each one testing different hydraulic and organic loads in the TF. The operational characteristics of the UASB reactor were kept constant throughout the experiment, being operated at an average hydraulic retention time of

2days. According to the hydraulic loading rates presented in Table 2, it can be seen that the TF was operated as a low rate filter in the two Phases

3.11 Process monitoring

The UASB/biofilter system was monitored for a period of almost 5 months, through the evaluation of the following physical-chemical parameters: temperature, pH, alkalinity, volatile acids, total COD, total BOD, suspended solids. All analysis were carried out according to the Standard Methods for the Examination of Water and Wastewater, 20th ed. (AWWA/APHA/WEF, 1998).

3.12 . **Operation**

To achieve maximum efficiency of the filter the water should be distributed as evenly as possible to avoid channeling and poor horizontal mixing. The trickling filters also have constraints on the hydraulic load. Too high a load may cause biofilm sloughing and a too low load cause poor wetting and, hence, in both cases poor biofilm cover and a reduced capacity. Sometimes it is therefore necessary to have recirculation over the filter to ensure complete biofilm wetting. Further, to avoid clogging as well as channeling it is also favourable to distribute intermittently.

3.13 **(Operation and maintenance procedures).**

To keep the integrated UASB/biofilter system functioning properly, the following must be done:

3.13.1 Operation activities

- Maintain proper ventilation.
- Keep the location accessible.

Remove solids and scum as needed. Solids should be removed from equalization tank, hoses and from distributors.

3.13.2 Maintenance Activities:

- Seal tanks to prevent infiltration.

- Remove solids from tank as needed.

4 RESULTS AND DISSCUSSION

The treatment performances of the laboratory integrated systems were monitored by determining the removal of (1) suspended solid; (2) organic materials (COD_t);

(3) Nutrients (N and P); (4) pathogenic organisms (FC); and (5) physical parameters.

4.1. Erection of the pilot-plant and results of the start-up phase

The unit operations of individual treatment units of the pilot-scale onsite treatment system were designed and schematic diagrams were drafted for the implementation at Albireh sewage works in Albireh city, West Bank, Palestine. After erection natural and synthetic media were transported and installed by a local firm with the assistant of the new hired research assistant. The system was put into operation to treat domestic wastewater pumped from the aerated grit chamber of the central sewage works of Albireh city, where the pilot plant was situated. The start-up phase (June – August 05) encountered some operational problems, where the sand was washed out from the biofilter units (figure 4.1). The first sample was taken during the last week of June 05. Despite pre-wetting of the filter bed in both units, it seemed that the large pore size of the distributing laterals (figure4.2) placed on the filter surface caused channeling and short circuiting.

Figure 4.1: Distributing laterals with large pore size Figure 4.2: Biofilters with sand layer prior washout

The main results obtained during August 05 on removal efficiency of major parameters are summarized in Table4.1. Despite sand washout from the biofilters, the performance of the treatment system was satisfactory. The overall treatment efficiency was 79% for COD removal and about 29% for ammonia oxidation. For more details on the results obtained during this phase see Annex 2.

Table 4.1: Performance of the onsite system during the start-up phase (Al-Saed, 2006)

Aug-05		Removal Efficiency (%)			
Parameter	**Influent**	**UASB**	**Biofilter 1**	**Biofilter 2**	**Overall Efficiency**
TSS (mg/l)	836.7	34.9	28.6	-19.4	48.4
COD (mg/l)	1392.6	59.6	33.1	20.5	79.4
BOD (mg/l)	965.9	55.6	18.3	36.5	74.3
NH4-N (mg/l)	50.5	15.3	5.8	9.6	28.6
PO4-P (mg/l)	14.9	-3.8	0.2	9.6	5.9
VFA (mg COD/l)	124.7	22.8	41.1	67.9	75.3

The overall TSS removal percentage during this phase was below 50% indicating a clear evidence for the wash out of sand media from the biofilters, especially from biofilter 2.

The two filters under study were designed to have different design criteria, media type's specifications, and corresponding organic loading rates. The biofilm media used in the filters, and the microorganisms that colonize and reside in them, were responsible for the wastewater treatment. Filter media quality was crucial to the operation and efficacy of the biofilters. To prevent clocking of distributing laterals and ensure good wastewater treatment, applied biofilm media were washed out to free fine particles. Intermittent hydraulic loading rate was applied due to low daily flow rate (200 L) and to ensure equal surface loading rates.

4.2 Performance evaluation during the first and second run phases

4.2.1 First run phase (September-December 05)

The first run phase elapsed over a period of three months. During this phase, sand was removed from the biofilters and replaced by gravel in the first filter; where as gravel and PVC material of variable heights were increased in the second biofilter. Table 3 illustrates the various design and operational parameters of UASB-Biofilter system. The daily flow rate was kept constant (200 L) as in the start-up phase, while the organic and surface loading rates were changed. This change was caused by increased surface area obtained when sand layers in both filters were exchanged with other filter media as mentioned above.

Table 4.2: Design parameters applied during the first run (September-December 05)

PARAMETER	UNIT	UASB	BIOFILTER 1	BIOFILTER 2	Typical data	COMMENT
Flow rate	L/d	200	200	200	(-)	-
HRT	Hr	4days	26	20	(-)	-
SRT	D	(-)	(-)	(-)	(-)	(-)
Upflow velocity	m/hr	0.026	-	-	(-)	(-)
LV	(KG(BOD)/M3)	157.	0.11	0.114	0.1-0.2	(OK (1
OSLR	gBOD/m2.day	-	1.4	1.65	2>	(OK (1
HLR	(M/HR)	0.026	0.013	0.01	0.05-0.3	Wetting problem
Volume	m3	0.78	0.55	0.32	(-)	(-)
Surface area	**M2**	**-**	**44**	**22**	(-)	(-)

4.2.2 . Second run phase (January-February 06)

To find out the proper design and operational mode, a change in the design parameters of the treatment system was made during the second run phase (January-February 06). The daily flow rate was increased from 200 to 400 liters, implied a change in all design parameter of the onsite treatment system. In both run phases the performance of the UASB-biofilter system was monitored for thirteen weeks. Table 4.3 lists the changes in design parameters during the run phase 2. Detailed calculations for the determination of these design parameters can be found in Annex 1.

Table 4.3: Design parameters applied during the second run phase (January-march 06)

PARAMETER	UNIT	UASB	BIOFILTER 1	BIOFILTER 2	Typical data	COMMENT
Flow rate	L/d	400	400	400	-	-
HRT	Hr	2days	13	10	-	-
SRT	D	(-)	(-)	(-)	-	-
Upflow velocity	m/hr	1.28	-	-	-	-
LV	(Kg(BOD)/m^3)	0.314	0.22	0.228	0.1-0.2	(OK (1

OSLR	gBOD/m^2.day	-	2.8	3.3	2>	(OK (1
HLR	(M/HR)	0.052	0.026	0.022	0.05-0.3	Wetting problem
Volume	m^3	0.78	0.55	0.32	(-)	(-)
Surface area	M^2	-	44	22	(-)	(-)

PARAMETER	OVERALL	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
BOD	87.5%	52.0%	38.4%	57.6%
AMONIA	46.1%	8.6%	20.8%	25.6%
TKN	47.2%	19.1%	22.4%	15.9%
TS	32.5%	17.5%	7.9%	11.2%
TSS	81.8%	25.7%	44.2%	56.1%
COD	85.2%	50.1%	53.7%	35.9%
P	34.2%	5.9%	13.4%	19.3%
PO4	24.0%	3.9%	9.2%	13.0%
FCOL/100ML	11%	8%	5.5%	4%

The main results obtained over a 22 weeks period of monitoring during the two phases are Presented and discussed below.

Results and discussion the summary statistics of the results from each operational phase are presented in Table 4.3 for the two stages.

Table 4. 4 shows the results of the each operational phase of the waste water treatment process.

- We recommend this value in spite of its higher value than the recommend ones because there is a second biofilter can adjust these values.
- These values according to (EPA, 1998).

4.3 physical parameters

- **Temperature and Dissolved Oxygen**

Raw wastewater temperature were recorded during the first trial and second run with the highest temperatures recorded during summer (September 2005 to February 2006) with average temperature 17.6 c^0.

Installing perforated venting tubes within the biofilters ensured sufficient oxygen content necessary for aerobic microbial communities. Optimal average values for pH and temperature (7.5 and 25 C respectively) of raw wastewater should have positive impacts on the microbial enzymatic activities in the UASB and biofilters.

An average DO concentration of 0.1 mg/L was measured in the raw wastewater, 0.1mg/l out from the UASB , 3.1 and 3.2 out from biofilter1,2 respectively during the two phases)..

- **Electrical conductivity and PH**

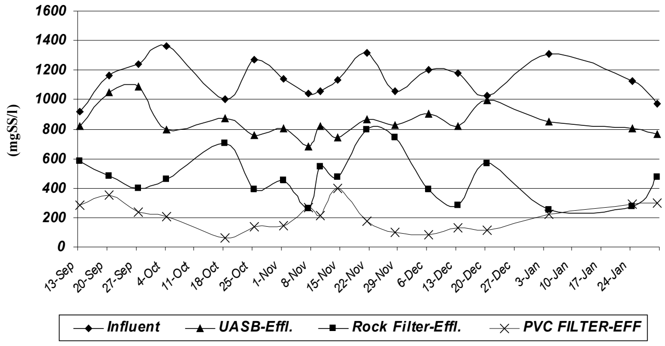
An average EC is 2070MS was measured in the raw wastewater, 1962MS out from the UASB, 1982 and 1967 out from biofilter1, 2 respectively during the two phases).
An average PH is 7.5was measured in the raw wastewater, 7.4 out from the UASB, 7.4 and 7.5 out from biofilter1, 2 respectively during the two phases).

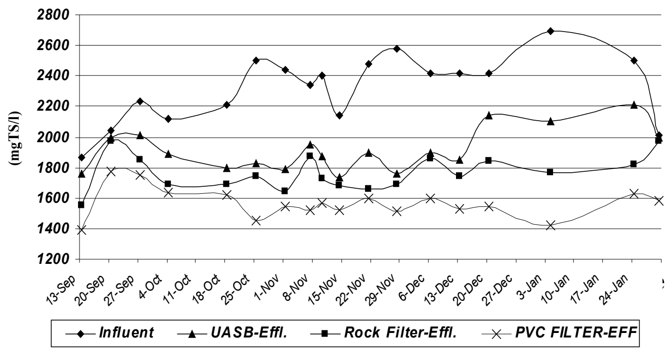
4.4 System efficiency for the removal of TSS and organic (COD,BOD)

4.4.1 TSS removal efficiency

During this run phase the performance of the UASB septic tank reactor was depending on wastewater characteristics, Pell and Nyberg, 1989a reported that septic tanks-sand filters when adequately designed, installed, and operated in will provide effluent BOD5 and TSS levels of less than 10 mg/l. As a post-treatment stage, sand filters were found to be efficient in nutrient removals, and can reduce septic tank effluent ammonia and phosphate by passage through a single pass sand filter (Pell and Nyberg, 1989).

The overall removal efficiency for the total suspended solids (TSS) was around 81% while the bio t. Figure 4.1 shows an influent with sl verloading of the UASB reactor. The U content.





m for TSS removal

While the overall removal efficiency for the total solid (TS) was around 32% while the biofilters removed only 17% of the influent TS content. Figure 4.2 shows an influent with sharp variable TS concentrations that might lead to overloading of the UASB reactor. The UASB was able to remove only 17.5% of inflow TS content.

Fig. 4.4: Treatment efficiency of the onsite system for TS removal

4.4.2 BOD removal efficiency

In contrast to published literature on wastewater characteristics, Albireh wastewater revealed a high strength type of wastewater based on TSS, COD, and nutrient content. This can be explained by low water consumption rates and discharge of industrial effluent without prior pre-treatment (A-Sa`ed, 2005). What exacerbated the performance of the onsite treatment system was the current septage disposal of unknown quality in the aerated grit chamber. This is reflected in the gradual increase of influent BOD Concentration as shown in Figure 4.3.

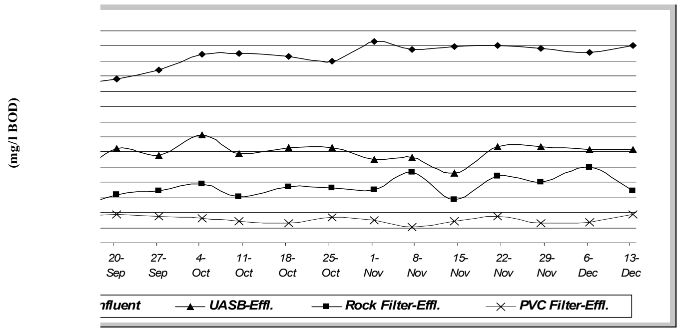


Fig. 4.5: Treatment efficiency of the onsite system for BOD removal

Under aerobic conditions prevailed within the biofilters, about 88% of the BOD influent to the biofilters was removed, compared with 50% reduction achieved by the UASB septic tank system. Despite the high removal efficiency of the onsite treatment system developed, the concentration of BOD in the final effluent was below 100 mg/l. This is a relatively high value compared to published data on single pass slow sand filters treating septic tank effluent. However, this might lead to miss-interpretation when compared with our developed system. One should know and acknowledge the various design, operational and wastewater characteristics of each individual treatment scheme. The developed biofilters under study received an influent with BOD concentration ranged between 215-360 mg/l compared low strength wastewater (100-230 mg/l) treated in single pass sand filters (Pell and Nyberg, 1989a,b,c) applied in developed countries.

4.4.3 **COD removal efficiency**

COD values ranging between 155 and 241.5 mg/L were recorded (average of 190mg/L) in biofilter effluent. An overall COD reduction of 85.2% was obtained figure 4.4.

COD values ranging between 912 and 1543.2 mg/L were recorded (average of 1283.2mg/L) in raw wastewater influent. An overall COD reduction of 85.2% was obtained figure 4.8.

Odegaard c matter is truly soluble and its removal is ng 75% of the organic matter in a wastewa d form. It is argued that most biological the removal of organic matter either as p smaller than 50 µm in diameter, agglomeration through physical, chemical or biological means is necessary in order to facilitate their settling.

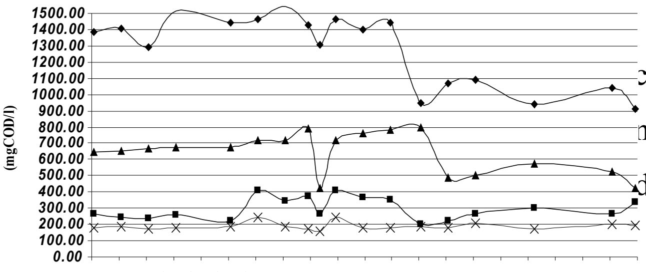


Fig. 4.6: Treatment efficiency of the onsite system for COD removal

4.5 Nutrient removal

4.5.1 Nitrogen removal

It is well known that anaerobic wastewater treatment has a minor role in nutrient removal. On the contrary the ammonium and phosphate concentration in anaerobically pre-treated domestic wastewater might exceed slightly the influent concentrations. Under anaerobic processes organic matter is hydrolyzed into amino acids and ammonium as well as free dissolve ortho-phosphate from protein and organic compounds are released.

It is well known that anaerobic treatment technologies as the UASB system achieve poor nutrient reduction (Fuqaha and Al-Sa`ed, 2006). Hence, it was envisaged to develop and apply multi-media biofilters to achieve nitrification processes where ammonium is oxidized in two-steps mediated microbial action into nitrite and further to nitrate. The UASB septic tank has achieved only 8.5 % for ammonium removal, compared with the overall removal efficiency of both biofilters (26%). These results are depicted in Figure 4.5, which also shows a wide range of ammonium concentration in raw wastewater (55-75 mg NH_4-N/l) at the inlet of the onsite treatment system. The overall removal efficiency of the UASB-biofilters was 46%, which is in accordance with published data on nitrification process achieved by biofilters preceded by a pre-treatment unit.

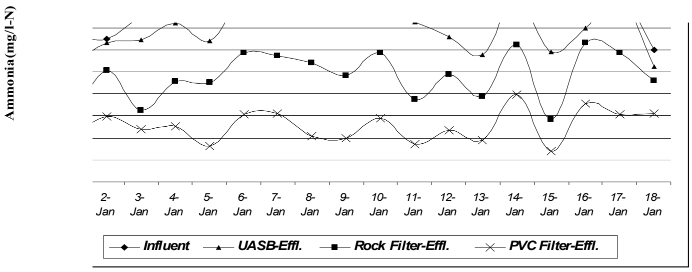


Fig 4.7: Treatment efficiency of the onsite system for NH_4-N removal

An average TKN 73.1 mg/l -N was measured in the raw wastewater, 59 mg/l -N out from the UASB , 46 and 39 mg/l -N out from biofilter1,2 respectively during the two phases) as shown in figure 4.8.

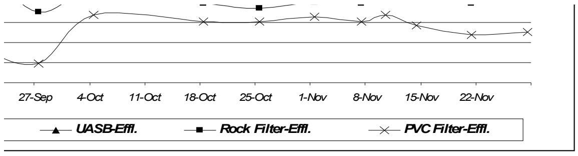
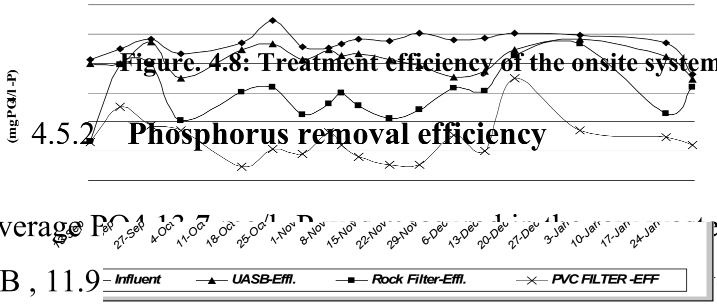
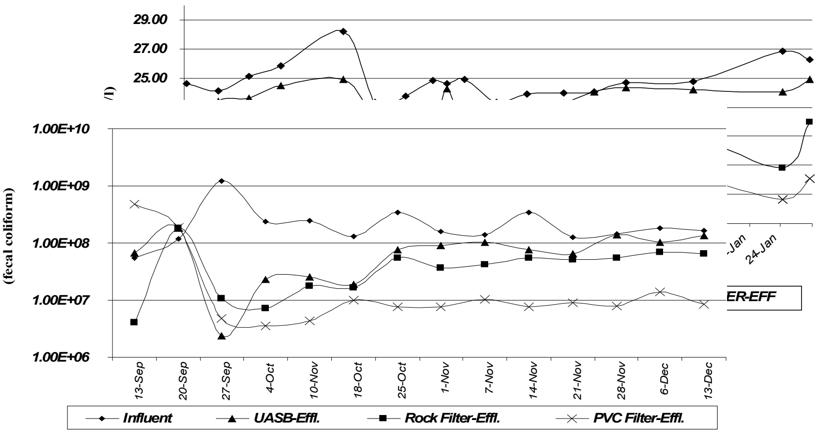


Figure. 4.8: Treatment efficiency of the onsite system for TKN-N removal

4.5.2 Phosphorus removal efficiency



An average P [illegible] water, 13.2 mg/l -P out from the UASB , 11.9 [illegible] ely during the two phases) as shown in figure 4.9.



for po4-p removal

water, 23.4 mg/l -P out from the

ly during the two phases) as

Figure.4.10: Treatment efficiency of the onsite system for po4-p removal

4.6 Microbiological Analysis

Fecal coliforms and E. coli tests were carried out to indicate potential pathogen levels in the greywater and outlet locations of the aerobic biofilters; and hence measure the effectiveness of the wastewater treatment system. The analysis was conducted during the latest two phases 3log reductions were attained from an influent average of 2.59 x 10^8 faecal coliforms (FC)/100 ml as shown in figure 4.11.

Figure.4.11: Treatment efficiency for pathogens removal

5. CONCLUSIONS AND RECOMINDATIONS

Based on a thorough revision of the collected literature, design, operation and overall assessment of the developed UASB-biofilter system within this study, which is the main focus of the report, the following conclusions emerge:

5.1 Conclusions

- Good removal efficiencies were achieved for BOD and nitrogen implied a good effluent quality for agricultural irrigation, however less TSS removal percentages were noticed.

Based on the tables, figures and additional analysis, the following comments are made:

- The average final effluent COD concentrations in Phases II, III were around 155 mg/l.
- The variable inflow did not affect the performance of the UASB-Biofilter process.

- The cost-effectiveness of the system will lead to a more rapid implementation of environmental technologies, particularly in the less prosperous countries that, so far, lack adequate environmental protection. In addition, the immediate reuse of the recovered resources will even give a positive economic incentive to actually implement adequate measures to protect the environment.
- Decentralized treatment concepts offer big potentials for an integrated development of sustainable environmental protection and resource

conservation concepts. Decentralisation leads to huge cost reductions in the construction and maintenance of the sewer network including the required pumping stations. Moreover, particularly in those areas where water is scarce, the abuse of huge amounts of safe drinking water for transport purposes (human excreta and industrial wastes) can be prevented.

5.2 Recommendation

The following recommendations can be made:

- Adequate design of distributing laterals and installment of under drain for the biofilters are essential elements for proper operation and stable treatment process.

- The circular geometry of the multi-media filters should be avoided and choose a rectangular shape to achieve long hydraulic retention time and equal flow distribution.
- More research should be conducted to explore the potential of practical uses of advanced molecular methods to understand the engineering design of wastewater treatment systems, process failure of unit operations as well as maintenance activities. Because flow is too small then any thing cause clogging of the system (distributors ,pipes ,etc) farther monitoring is needed because and any thing can stop the system suddenly .

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ANNEX 1

DATA COLLECTION

	Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
BOD				
AVG	616.0	295.4	182.0	77.2
min	525.0	214.0	107.0	51.0
max	664.5	357.0	249.2	95.0
std	42.9	36.8	37.2	12.7
AMONIA				
AVG	60.7	55.4	43.9	32.7
min	50.0	46.2	34.2	27.1
max	69.7	62.6	51.5	39.9
std	5.1	5.7	5.6	3.6
TKN				
AVG	73.0	59.1	45.8	38.5
min	54.3	52.1	42.6	29.7
max	78.4	67.2	51.5	42.0
std	7.0	4.3	2.3	3.8
TS				
AVG	2322.6	1916.2	1765.0	1567.0
min	1868.0	1733.0	1552.0	1392.0
max	2690.0	2210.0	1972.0	1772.0
std	218.7	138.1	113.8	98.0
TSS				
AVG	1139.8	847.1	472.8	207.5
min	917.0	680.0	254.0	63.0
max	1366.0	1090.0	800.0	400.0
std	128.0	105.0	162.2	95.6
COD				
AVG	1283.2	640.4	296.6	190.0
min	912.1	420.7	204.4	155.0
max	1543.8	793.5	409.8	241.5
std	217.3	123.6	66.2	22.2
P				
AVG	24.8	23.4	20.3	16.3
min	23.3	21.1	17.6	15.1
max	28.2	24.9	22.7	18.3
std	1.3	1.1	1.5	1.0
PO4				
AVG	13.7	13.2	11.9	10.4
min	12.6	12.4	10.4	9.5
max	14.5	13.8	13.6	12.5
std	0.4	0.4	0.9	0.7
PH				
AVG	7.1	7.0	7.0	7.1
TC				
AVG	18	18	17.5	17.5
DO				
AVG	0.1	0.8	3.1	3.2
Fecal coliform				
AVG	2.59E+08	7.91E+07	4.79E+07	5.44E+07
min	5.40E+07	2.40E+06	4.12E+06	3.60E+06
max	1.23E+09	1.80E+08	1.84E+08	4.80E+08
std	290890893	51277933	45082163	131377257

READING DURING MONITORING PERIOD

BOD(mg-O2/l)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	525	214	107	83
20-Sep		540	312	158	94
27-Sep		570	288	171	89
4-Oct		622.5	357	196	81
10-Oct		625.5	295	153	71
18-Oct		617.25	315.6	185.6	65.8
25-Oct		598.5	313.96	183	85.8
1-Nov		664.5	276.55	176.5	76
7-Nov		637.5	282	233	51
14-Nov		648	230	142	72
21-Nov		652.5	318	219	86
28-Nov		641.25	317.5	201.8	64
6-Dec	2ND RUN	628.5	307.5	249.2	67
13-Dec		652.5	309	173	95

AMONIA(mg-N/l)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	66.6	58.4	42.7	37.6
20-Sep		65.5	64.4	56.6	43.5
27-Sep		71.6	65.3	45.3	39.9
4-Oct		73.1	70.0	53.4	40.7
10-Nov		78.1	65.1	53.2	35.0
18-Oct		79.4	78.2	61.7	44.3
25-Oct		80.7	76.7	60.7	44.3
1-Nov		82.1	76.5	58.8	38.0
7-Nov		79.8	76.8	55.1	37.5
14-Nov		87.2	75.3	61.6	43.0
21-Nov		72.1	70.3	48.5	35.7
28-Nov		73.0	66.1	55.4	39.6
6-Dec	2ND RUN	79.0	61.1	49.2	36.7
13-Dec		79.7	77.2	63.8	49.9
20-Dec		79.3	61.9	42.8	33.8
4-Jan		76.7	68.5	64.3	47.2
24-Jan		79.4	78.2	61.7	44.3
30-Jan		62.5	57.7	53.6	44.5

TKN-N(mg-N/L)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	54.32	53.20	47.60	39.76
20-Sep		65.52	53.76	51.52	33.04
27-Sep		68.88	52.08	42.56	29.68
4-Oct		76.72	63.28	47.60	42.00
10-Nov		72.80	61.60	45.36	42.00
18-Oct		76.16	59.36	44.80	40.32
25-Oct		76.72	59.36	43.68	40.32
1-Nov		76.72	59.92	45.05	41.44

7-Nov		77.28	60.48	44.80	40.32
14-Nov		78.40	58.24	45.92	39.20
21-Nov		76.72	60.48	44.80	36.96
28-Nov		75.60	67.20	46.48	37.52

ORTHO PHOSPHATE (mg/l-P)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	13.14	13.00	10.36	10.30
20-Sep		13.48	12.99	12.96	11.51
27-Sep		13.83	13.74	12.96	10.87
4-Oct		13.32	12.48	11.06	10.73
10-Nov		13.64	13.26	11.99	10.22
18-Oct		13.69	13.45	12.03	9.47
25-Oct		14.47	13.67	12.18	10.09
1-Nov		13.56	13.13	11.24	9.90
7-Nov		13.52	13.46	11.61	10.66
14-Nov		13.84	13.34	11.55	9.82
21-Nov		13.77	13.13	11.12	9.55
28-Nov		14.04	12.93	11.41	9.54
6-Dec	2ND RUN	13.79	12.53	12.16	10.54
13-Dec		13.86	12.71	12.04	10.02
20-Dec		14.03	13.46	13.25	12.50
4-Jan		13.97	13.83	13.65	10.72
24-Jan		13.70	13.24	11.29	10.48
30-Jan		12.62	12.44	12.20	10.20

TOTAL P(mg -p/l)

Date	**FIRST RUN**	Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep		**24.64**	**21.10**	**18.61**	**15.09**
20-Sep		**24.14**	**23.43**	**21.85**	**16.25**
27-Sep		**25.14**	**23.61**	**22.53**	**16.02**
4-Oct		**25.85**	**24.49**	**22.70**	**16.14**
10-Nov		**24.59**	**24.25**	**22.45**	**18.31**

18-Oct		**28.21**	**24.92**	**19.06**	**17.68**
25-Oct		**23.31**	**22.40**	**19.83**	**17.12**
1-Nov		**23.79**	**22.54**	**18.97**	**15.96**
7-Nov		**24.86**	**21.79**	**20.08**	**15.72**
14-Nov		**24.90**	**21.69**	**19.11**	**15.22**
21-Nov		**23.30**	**23.17**	**17.60**	**15.56**
28-Nov		**23.91**	**22.76**	**19.70**	**15.57**
6-Dec	**SECOND RUN**	**23.96**	**23.25**	**19.18**	**15.90**
13-Dec		**24.07**	**24.03**	**19.97**	**15.20**
20-Dec		**24.67**	**24.34**	**21.13**	**15.66**
4-Jan		**24.74**	**24.19**	**21.04**	**17.90**
24-Jan		**26.85**	**24.04**	**18.80**	**16.68**
30-Jan		**26.25**	**24.92**	**21.93**	**18.09**

T SS (mg/l)

Date		**Influent**	**UASB-Effl.**	**Rock Filter-Effl.**	**PVC Filter-Effl.**
13-Sep	FIRT RUN	917	820	580	280
20-Sep		1160	1050	480	354
27-Sep		1239.5	1090	398	240
4-Oct		1366	797	458	210
10-Nov		1055	815.5	541	214.5
18-Oct		1005	870.1	702	63
25-Oct		1270	755	389	140
1-Nov		1142.5	801.5	451	147
7-Nov		1040	680	257	270
14-Nov		1135	745	475	400
21-Nov		1317.5	868	800	174
28-Nov		1055	825	739	100
6-Dec	2ND RUN	1202	900	390	88
13-Dec		1177	818.5	280	130
20-Dec		1026	992	570	114
4-Jan		1312	846.1	254	220
24-Jan		1125	806	275	290
30-Jan		972	767.5	471	301

TOTAL SOLID(mg/l)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	1868	1756	1552	1392
20-Sep		2040	2000	1972	1772
27-Sep		2230	2012	1850	1750
4-Oct		2120	1890	1690	1640
10-Nov		2400	1870	1730	1570.5
18-Oct		2214	1800	1690	1621
25-Oct		2500	1830	1745	1450
1-Nov		2438	1789	1641	1547
7-Nov		2344	1950	1870	1522
14-Nov		2140	1733	1680	1524
21-Nov		2478	1900	1658	1600

28-Nov		2580	1760	1690	1512
6-Dec	2ND RUN	2420	1900	1860	1600
13-Dec		2415	1852	1740	1530
20-Dec		2414	2145	1845	1547
4-Jan		2690	2100	1765	1424
24-Jan		2503	2210	1822	1625
30-Jan		2012	1995	1970	1580

COD(mgo2/l)

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	1382.75	645.00	262.25	177.50
20-Sep		1410.00	652.50	245.00	190.00
27-Sep		1292.50	665.00	235.00	175.00
4-Oct		1512.50	677.50	260.00	181.75
10-Nov		1305.00	421.00	265.00	155.00
18-Oct		1441.25	675.25	223.25	187.50
25-Oct		1462.75	718.50	409.75	241.50
1-Nov		1543.75	720.50	344.00	185.50
7-Nov		1431.25	788.25	373.75	175.65
14-Nov		1462.75	718.50	409.75	241.50
21-Nov		1400.00	758.75	364.77	179.37
28-Nov		1445.00	785.50	351.50	182.90
6-Dec	2ND RUN	950.40	793.50	204.44	183.98
13-Dec		1070.38	485.62	222.68	181.25
20-Dec		1089.52	502.37	264.04	210.88
4-Jan		943.31	573.87	301.29	173.10
24-Jan		1042.84	524.27	264.99	202.18
30-Jan		912.07	420.72	336.65	195.25

TC

Date		Influent	UASB-Effl.	Rock Filter-Effl.	PVC Filter-Effl.
13-Sep	FIRT RUN	25.7	25.7	25.2	25.2
20-Sep		26.3	26.3	26.1	26.1
27-Sep		23.3	23.3	23.1	23.1
4-Oct		23.7	23.7	22.5	22.5
10-Nov		21	21	20.6	20.6
18-Oct		18.6	18.6	18.3	18.3
25-Oct		19.5	19.5	19	19
1-Nov		17	17	16.5	16.5
7-Nov		17.5	17.5	17.3	17.3
14-Nov		14.2	14.2	14	14
21-Nov		16.9	16.9	16.2	16.2
28-Nov		16.5	16.5	16	16

6-Dec	2ND RUN	14.5	14.5	14	14
13-Dec		13.5	13.5	13	13
20-Dec		14.2	14.2	14	14
4-Jan		13	13	12.4	12.4
24-Jan		15.5	15.5	15	15
30-Jan		13.2	13.2	13	13

EC(MS)					
Date		**Influent**	**UASB-Effl.**	**Rock Filter-Effl.**	**PVC Filter-Effl.**
13-Sep	FIRT RUN	2003	1980	1966	1960
20-Sep		1895	1991	1982	1869
27-Sep		2035	1991	1982	1869
4-Oct		2290	1974	1960	1967
10-Nov		2003	1870	1850	1830
18-Oct		2045	1880	1843	1821
25-Oct		2210	2030	1911	1870
1-Nov		2140	2001	1870	1889
7-Nov		1998	1800	1746	1700
14-Nov		2230	1990	1880	1820
21-Nov		2280	2140	1900	1820
28-Nov		2125	1920	1893	1883
6-Dec	2ND RUN	2003	1990	1866	1827
13-Dec		1836	2007	1911	1905
20-Dec		1930	2005	1911	1739
4-Jan		1943	1857	1838	1828
24-Jan		2250	1980	1911	1874
30-Jan		2034	1920	1890	1840

PH					
Date		**Influent**	**UASB-Effl.**	**Rock Filter-Effl.**	**PVC Filter-Effl.**
13-Sep	FIRT RUN	7.36	7.57	7.63	7.89
20-Sep		7.51	7.61	7.64	7.96
27-Sep		7.78	7.21	7.43	7.80
4-Oct		7.10	7.32	6.56	7.76
10-Nov		7.60	7.45	7.24	7.41
18-Oct		7.70	7.54	7.41	7.32
25-Oct		7.90	7.42	7.60	7.47
1-Nov		7.80	7.32	7.54	7.23
7-Nov		7.63	7.50	7.70	7.30
14-Nov		7.50	7.30	7.42	7.25
21-Nov		7.25	7.60	7.30	7.50
28-Nov		7.45	7.60	7.30	7.38
6-Dec	2ND RUN	7.26	7.30	7.36	7.45
13-Dec		7.10	7.21	7.27	7.40
20-Dec		7.01	6.62	7.36	7.38
4-Jan		7.13	6.92	7.45	7.63
24-Jan		7.45	7.60	7.25	7.12
30-Jan		7.65	7.35	7.25	7.10

DO mg/l					
Date		**Influent**	**UASB-Effl.**	**Rock Filter-Effl.**	**PVC Filter-Effl.**
13-Sep	FIRT RUN	0.1	1.5	3.1	4.3
20-Sep		0.1	1.6	2.5	4.4
27-Sep		0.1	1.6	2.5	4.4
4-Oct		0.1	0.5	3.2	2.5
10-Nov		0.1	1.2	4.3	3.5
18-Oct		0	1.2	2.7	3.8
25-Oct		0.3	1.7	5.1	4.5
1-Nov		0.3	1.7	5.1	4.5
7-Nov		0	0.9	3.25	2.5
14-Nov		0.1	1.3	2.8	3.7
21-Nov		0.1	0.4	3.5	2.7
28-Nov		0.2	0.25	3.5	2.4
6-Dec	2ND RUN	0.14	0.1	3.5	1.2
13-Dec		0.11	0	0.5	1.25
20-Dec		0.1	0.1	3.21	5.61
4-Jan		0.23	0	1.5	2.5
24-Jan		0.1	0.45	3.5	2.4
30-Jan		0.1	0.23	2.4	1.4

FC					
Date		**Influent**	**UASB-Effl.**	**Rock Filter-Effl.**	**PVC Filter-Effl.**
13-Sep	FIRT RUN	5.40E+07	6.80E+07	4.12E+06	4.80E+08
20-Sep		1.20E+08	1.80E+08	1.84E+08	1.86E+08
27-Sep		1.23E+09	2.40E+06	1.08E+07	4.80E+06
4-Oct		2.40E+08	2.28E+07	7.20E+06	3.60E+06
10-Nov		2.46E+08	2.55E+07	1.76E+07	4.40E+06
18-Oct		1.31E+08	1.87E+07	1.66E+07	1.01E+07
25-Oct		3.45E+08	7.70E+07	5.50E+07	7.70E+06
1-Nov		1.58E+08	8.90E+07	3.70E+07	7.70E+06
7-Nov		1.40E+08	1.02E+08	4.20E+07	1.04E+07
14-Nov		3.45E+08	7.70E+07	5.50E+07	7.70E+06
21-Nov		1.26E+08	6.58E+07	5.19E+07	9.00E+06
28-Nov		1.45E+08	1.41E+08	5.57E+07	8.00E+06
6-Dec	2ND RUN	1.82E+08	1.04E+08	6.95E+07	1.40E+07
13-Dec		1.65E+08	1.34E+08	6.38E+07	8.60E+06

ANNEX 2

DESIGN CALCULATION

CALCULATIONS

1 DETERMINE SURFACE AREA FOR THE MEDIA USED IN BIOFILTERS

First biofilter

We used two samples of stones

-:First sample

H.R.T=19hr

-:Second sample*

H.R.T=220/200=26.4 HRS

AVG for two samples=(26.4+19)/2=22.7 hrs

Total surface area for 10 layers =0.0744*60*10

<u>44.354m2</u>=

Surface area for 1m3 of this stones =80 m2/m3

Second biofilter

FOR PVC

H.R.T=0.6DAY =14 HRS

(Surface area for pvc =(12*4*10-4*4/20

Total surface area=6.5m2

FOR STONES*

H.R.T=0.05/0.2=6HRS

.Surface area =15.2m2 for stones

Total surface area =6.5+15.2=22m2

Total H.R.T=6+14=<u>20 HRS</u>

Picture 1. Examples of Media Filters: Peat Filter (top-left), Single-Pass Sand Filter (top-right), Foam Filter (bottom-left), and Textile Filter (bottom-right)

DESIGN CALCULATIONS-2

avg(BOD)=310mg/l=0.31kg(BOD)/M3

- avg(BOD)=310mg/l=0.31kg(BOD)/M3
- THEN $E_{Required}$ =(310-30)/310=90%

TOTAL VOLUME =0.55M3

- USING NRC EQUATION ,R=0,F=1

(($E_{REQUIRED}$=100/(1+a*sqrt (lv

sqrt(0.11))=90%*1+036)/100=

FIRST RUN

- **HSLR**=0.2/(24*Π(1/4)=0.013M/HR
- **LV**=0.2*(310/1000)/0.55=0.11kg(BOD)/M3
- **OSLR**=0.2*0.31*1000/44=1.4 gBOD/m2.day

SECOND RUN

- **HSLR**=0.4/(24*Π(1/4)=0.026M/HR
- **LV**=0.4*(310/1000)/0.55=0.22kg(BOD)/M3
- **OSLR**=0.4*0.31*1000/44=2.8 gBOD/m2.day

USING NRC EQUATION, R=0,F=1

(($E_{REQUIRED}$=100/(1+a*sqrt (lv

sqrt(0.22))=86%*1+036)/100=

Table 1 present physical properties for various proposed media as a backfill for biofilter.

Filter media	Natural rock (lava)	Plastic
Diameter	4-8 cm	-
Specific surface area	60-90 m2/m3	150-200 m2/m3
Porosity	40-60%	80-90%

تطوير نظام لاهوائي – مرشح حيوي لمعالجة المياه العادمة المنزلية

الخلاصة :-

إن من ايجابيات المعالجة اللاهوائية التكلفة المتدنية وسهولة التشغيل وانخفاض الكمية المنتجة نسبيا من المواد العضوية الصلبة و من أهم الطرق الشائعة للمعالجة اللاهوائية (up flow an aerobic sludge blanket) و المصممة لمعالجة المياه العادمة , وبالرغم من هذه الايجابيات , إلا أن هذه التكنولوجيا تواجه صعوبات في إنتاج مياه معالجة ذات مواصفات تتوافق مع المقاييس المطلوبة ,لذا من الضروري تطبيق معالجة متقدمة (post treatment) لإزالة المواد العضوية المتبقية , وللتخفيف من نسبة "الغذاء " (Nutrient) , والميكروبات الضارة ((pathogens . في هذه الدراسة تم اقتراح طريقة مستحدثة للمعالجة المتقدمة , حيث إنها تتألف من مرحلتي "فترة بيولوجية".

تتلخص هذه الطريقة بإنشاء فلترين هوائيين (two passive aerated filters) لتخفيض المواد الصلبة العالقة من المياه العادمة مسبقة المعالجة بواسطة UASB و لإزالة (Nutrient) .

إن النتائج التي تم الحصول عليها للفلاتر الهوائية أثبتت إمكانية إزالة المواد العضوية تحت الحمل العضوي المنخفض , لذا إن استخدام الفلاتر في مرحلة المعالجة الهوائية كأسلوب للمعالجة المتقدمة أثبتت نجاعتها بحيث أن المواد التي تم استخدامها كمادة لتعبئة الفلتر هي الرمل,حجر الوادي,PVC.

لقد تم تشغيل النظام وفق طريقتين:- بتغيير مادة تعبئة الفلتر أو بتغيير الحمل الهيدروليكي .خلال مراحل البحث حيث تمت معالجة 400 لتر يوميا .

وبلغ الحمل الهيدروليكي لسلسلة وحدات المعالجة على مدار المراحل الثلاث (96,26,20), (96,26,20 ساعة) و(48,13,10.0 ساعة). بينما بلغ الحمل العضوي بوحدة g BOD/m^3.d للمراحل الثلاث (157,110,114),(157,110,114),(314,220,228).

أما بالنسبة للكفاءة الكلية لإزالة الأكسجين الكلي المستهلك كيميائيا (CODtot) لسلسلة وحدات المعالجة فقد بلغت (%81,88%,79%) مقارنة بالكفاءة الكلية لإزالة CODtot بواسطة UASB منفردا والتي بلغت (59%,52%,45%) في نفس الوقت فإن كفاءة إزالة المواد الصلبة العالقة لسلسلة وحدات المعالجة على أحمال هيدروليكية وعضوية مختلفة بلغت (48%,88%,83%) مقارنة بكفاءة ال UASBوالتي بلغت (35%,26%,25%)للمراحل الثلاث .

أما معدل إزالة الامونيا في المرحلة الاولى فكان 28% والفسفور كان 6% خلال مرحلة المعالجة الأولى بينما في المرحلة الثانية فكان 47% والفسفور كان 34% بينما المرحلة الثالثة 44% والفسفور كان 34% .

. وبناء على النتائج التي تم الحصول عليها فان أفضل الظروف التي من لممكن استخدام المرشح الهوائي ذو حجم 0.55 م ^{3} للفلتر الأول و 0.35 م ^{3} للفلتر الثاني بحمل عضوي 2.8 g COD/m^2.day للفلتر الأول و 3.3 g COD/m^2.day للفلتر الثاني .