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Characterization and treatment of Al-Menya Landfill leachate Using Biological and Physical Methods

Ala' Ibrahim IssaAbuayyash

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Prepared By :

Ala' Ibrahim Issa Abuayyash

B.Sc. Applied Physics. Palestine Polytechnic University.
Hebron-Palestine.

Supervisor: Dr. Mohannad Qurie.

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Prepared By: Ala' Ibrahim Issa Abuayyash.
Registration No: 21210046.

Supervisor: Dr. Mohannad Qurie.

Master thesis submitted and accepted, Date: 28/5/2016
The names and signatures of the committee members are as follows:

Head of Committee: Dr. Mohannad Qurie. Signature…………..

Internal Examiner: Dr. Amer Kanan. Signature…………..

External Examiner: Dr. Tahseen Sayaara Signature:…………..

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Dedication

To My lovely hometown Palestine, and to the soul of martyrs.

Ala' Ibrahim Abuayyash

Declaration

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

Signed……….…

Ala’ Ibrahim Abuayyash

Date: 28/5/2016

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Abstract

Sanitary landfill is the most common way to eliminate solid urban wastes, Al-Menya is Palestinian sanitary landfill located in south West Bank. The most disadvantages of Al-Menya sanitary land fill is leachate production as results of solid waste compacted. Leachate is a complex liquid that contains many contaminants and excessive concentrations of biodegradable and non biodegradable products including organic matter, phenols, ammonia nitrogen, phosphate, heavy metals, and sulfide. If not properly treated and safely disposed, landfill leachate could be an impending source of surface and ground water contamination as it may percolate throughout soils and sub soils, causing adverse impacts to receive waters.

The Leachate physical, chemical and biological characteristics were studied and performance of Sequencing Batch Reactor (SBR) system as biological treatment process after primary treatment stage (settling for the leachate sample for 3hours) was investigated for leachate treatment. Advanced membrane technology including UF and RO were applied for biological effluent.

Al-Menya landfill leachate is classified as young leachate according to BOD, COD and solids analysis. The BOD/COD ratio (< 0.5) indicated the possibility of biological treatment. The heavy metals concentrations varied in leachate samples because there different solid waste types as metal electroplating, as stabilizers or pigments in plastics, batteries and alloys as a result of no complete waste separation stage. The concentration of Cr and Ni is the highest concentration with higher than 5 ppm whereas the Ag and Pb below the detection limit.

The primary treatment and biological treatment using SBR shows 88% ,95%,100% and 96% removal for COD, TSS, Ammonia nitrogen and phosphate respectively. The final stage of treatment included the advanced membrane technology (UF and RO). The treatment of SBR effluent using UF unit shows highly efficient of UF unit for TSS, Nitrate, and phosphate, Al, Zn, removal with (100%), (98 %), (95%), (100%), (82%), respectively. The heavy metals were partially removed; the Al was completely removed where as Cr concentration shows no different concentration. An efficient removal ranging between 97-100% was observed for COD, Ammonia-Nitrogen, TSS, Al, K and Na using RO unit whereas Cr and Cd still have high concentration.

دراسة خصائص عصارة مكب نفايات المنيا والبحث عن إيجاد طرق فعالة بيولوجية وفيزيائية لمعالجة العصارة

إعداد: آلاء إبراهيم عيسى أبوعياش.
المشرف: د. مهند قريع.

الملخص

تعد مكبات معالجة النفايات الصحية بالطمر الصحي، إحدى طرق التخلص من النفايات الصلبة. و يعتبر مكب المنيا احد المكبات الفلسطينية الذي يعالج النفايات الصلبة المتدفقة من جنوب الضفة الغربية بطريقة الطمر الصحي. و تعتبر إنتاج العصارة من اكبر سلبيات معالجة النفايات الصلبة الطمر الصحي حيث يتم تجميعه في برك خاصة و يؤثر هذا السائل سلبا على البيئة بأنواعها. يكون هذا السائل معقد و يحتوي العديد من الملوثات وعلى تراكيز عالية من المواد المتحللة وغير المتحللة، بما فيها المواد العضوية، الفينول، الأمونيا-النيتروجين، الفوسفات، العناصر الثقيلة، والسلفات. إذا لم يتم معالجتها والتخلص الآمن لها، فتتشكل احتمالية وصولها إلى المياه السطحية والجوفية وبالتالي تلوثها، كما ويمكن تسربها الى التربة محدثة آثار سلبية.

هذه الدراسة فحصت آداء طريقتين، المفاعل الدفعي المتتابع في إزالة المواد العالقة الصلبة، العكارة، المواد العضوية المتحللة كيميائيا، الأمونيا- نيتروجين، النيترات، النيترات - نيتروجين، و الفوسفات. والطريقة الفيزيائية باستخدام كلا من تكنولوجيا غشاء الخاصية الإسموزية العكسية والترشيح الفائق؛ حيث تعتبر هذه الطريقة في الآونة الأخيرة ، واحدة من أهم الطرق التكنولوجية المتطورة المستخدمة في علاج العصارة.

لقد تم دراسة الخصائص الفيزيائية, الكيميائية و البيولوجية للعصارة الناتجة من مكب المنيا و كذلك تم تجربة المعالجة الفيزيائية أولا بالترسيب الأولي تم المعالجة البيولوجية باستخدام المفاعل الدفعي المتتابع (SBR) للتخلص من المواد العضوية القابلة للتحلل بيولوجيا و أخيرا تم تجربة استخدام طريقة الفلترة المتقدمة باستخدام فلتر الأغشية الدقيقة (UF) و خاصية التناضح العكسي (RO) للمساهمة في تحسين مواصفات المياه.

لقد بينت نتائج خصائص عصارة مكب المنيا أن يتميز بناءا على نتائج الطلب البيولوجي و الكيميائي للأكسجين و مجموع المواد الصلبة بان العصارة ذات عمر صغر و كذلك يمكن معالجتها بيولوجيا نظرا لمعدل BOD_5/COD الذي يساوي 0.36 و الذي يقع ضمن المعدل الذي يسمح بالمعالجة البيولوجية. أن وجود تراكيز مختلفة من العناصر الثقيلة في العصارة يبين وجود مصادر لهذه العناصر من الصناعات المختلفة مثل الدباغة و البطاريات و صناعة البلاستيك

حيث انه لا يوجد فصل كامل للنفايات الصلبة في المكب. المعالجة الاولية و البيولوجية بينت مقدرة على ازالت 88%, 95%, 100% و 96% من الطلب الكيميائي للاكسجين, المواد العالقة, الامونيا و الفوسفات. المرحلة النهائية من المعالجة الفيزيائية باستخدام الفلترة المتقدمة باستخدام الاغشية المتقدمة)(UF و التناضح العكسي (RO) حيث بينت النتائج مقدرة الاغشية المتقدمة على ازالة المواد بالصلبة العالقة, النترات, و الفوسفات بنسبة 100%, 98%, 95%, 100% و 82% على التوالي. مع ازلة جزئية للعناصر الثقيلة. و كانت فاعلية التناضح العكسي عالية جدا في ازالة المواد العضوية , النيتروجين و الامونيا و بنسبة تتراوح ما بين 97-100% بينما كان تركيز الكادميوم و الكروم عالي.

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List of Abbreviation

Abbreviation	Full Name
mg/ l	Milligram per Liter
mS/cm	milli-Siemens per centimeter
RO	Reverse Osmosis
MSWW	Municipal Solid Wastewater
TDS	Total Dissolved Solids
EC	Electrical Conductivity
SWM	Solid Waste Management
TSS	Total Suspended Solids
BOD	Biological Oxygen Demand
USEPA	United States Environmental Protection Agency
COD	Chemical Oxygen Demand
SW	Solid Waste
KC/m^2	KilloCalori per meter square
UF	Ultrafiltration
NTU	Nephelometric Turbidity Unit
AS	Activated Sludge
SBR	Sequence Batch Reactor
PSTWW	Palestinian Standards for Treated Wastewater
Rpm	Round per minute
AOP	Advanced Oxidation Process
HDPE	High-Density PolyEthylene
MCM	Million Cubic Meter
MWWTP	Municipal Wastewater Treatment Plant

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Chapter One: INTRODUCTION

1.1 Back Ground

There is a lot of factors increasing the waste production, the exponential generation of municipal solid waste (MSW) over the years related to the expanding of industrial activities, population growth, and lifestyle changes (Ahmed and Lan, 2012). As the world faces a lot of obstacles towards its urban future, the amount of municipal solid waste (MSW) are one of the most important by-products of an urban lifestyle, that growing faster than the rate of urbanization. More than ten years ago there were 2.9 billion urban citizens who generated about 0.64 kg of MSW per person per day (0.68 billion tons per year). But in 2012, these amounts have increased to about 3 billion citizens generating 1.2 kg per person per day (1.3 billion tons per year). By 2025, this will likely increase to 4.3 billion urban citizen generating about 1.42 kg/capita/day of municipal solid waste (2.2 billion tons per year) (Hoornweg and Bhada-Tata., 2012).

1.2 Solid Waste Management (SWM)

The waste management sector follows a generally accepted hierarchy. The earliest known usage of the 'waste management hierarchy' appears to be Ontario's Pollution Probe in the early 1970s. The hierarchy started as the 'three Rs', reduce, reuse, and recycle but now the fourth R is frequently added which represents recovery. The hierarchy put with respond to financial, environmental, social and management considerations. Figure 1representedthe waste hierarchy.

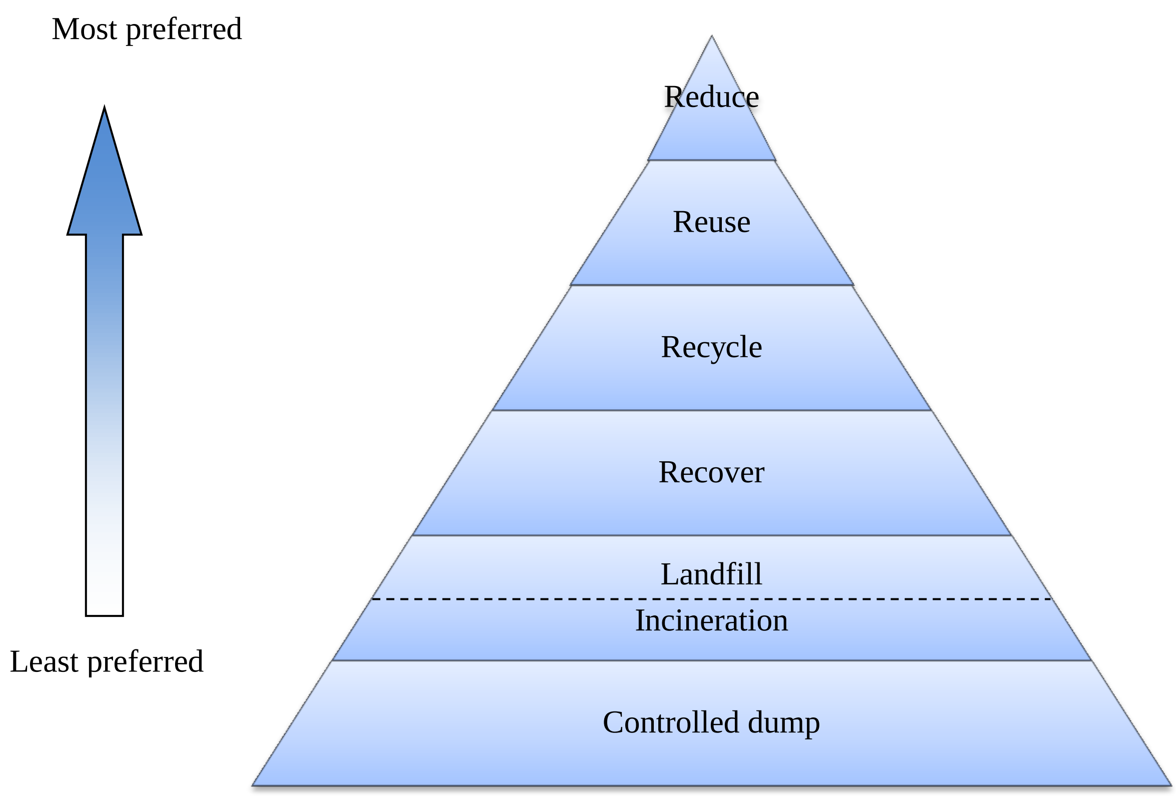

Fig.1: Waste Management Hierarchy

Nowadays, landfilling is the most common option to eliminate municipal solid waste (MSW), although waste management hierarchy considers landfilling as a last option for disposing both municipal and some solid industrial waste (Chen et al., 2008; Cordente-Rodriguez et al., 2010; Schiopu&Gavrilescu, 2010).

1.2.1 Solid Waste Definition

Any waste that is not gaseous and is not a liquid waste as determined by EPA (EPA Guideline, liquid waste classification test, 2003). It is generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its contents (glass, organic material, metal, plastic paper etc); according to its origin (domestic, industrial, construction, commercial or institutional); or according to hazard potential (toxic, non-toxin, radioactive, flammable, infectious etc).

1.2.2 Types And Quantities Of Solid Waste

There are many factors which affect solid types and their quantity, these factors can be summarized as following:

- Seasonal variation (affects the availability of food types);
- The state of emergency (volume and waste content may change with time);
- Packaging of food;
- Socio –cultural practices and material levels among affected population;
- The geographical region (developed or less developed).

In general, the volume of waste generated differs in rural areas than in urban areas. In rural areas, the volume of waste generated is likely to be small and largely degradable. But in urban areas, they are more likely to generate larger volumes of non - degradable waste, especially when there is a packaging food.

1.2.3 Sanitary Landfill

The "Municipal solid waste" (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas. The characteristics and quantity of the solid waste generated in a region is a function of the living standard and lifestyle of the region's inhabitants, also of the abundance and type of the region's natural resources (Diaz et al., 2005).Urban wastes can be subdivided into two major components, organic and inorganic. In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable. Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odors and visual unpleasantness. Fermentable wastes tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non-fermentable wastes tend to resist decomposition and, therefore, break down very slowly (Diaz et al., 2005).

In a MSWL, the waste is enclosed by cover material at the top and by a liner system at the bottom. A typical landfill has two forms of cover consisting of soil and geosynthetic materials: a daily cover placed over the waste at the close of each day's operations; and a final cover, which is the material placed over the completed landfill to control infiltration of water, gas emission to the atmosphere, and erosion. It also protects the waste from long-term contact with the environment, so less bad impacts to environment. The liner is a system of clay layers and/or geosynthetic membranes used to collect leachate and reduce or prevent contaminant flow to groundwater. A properly designed MSWL should include a leachate collection system, a gas control and a recovery system: (USEPA, 1995).

Solid waste disposal ways contain open dump, sanitary landfill, incineration, composting, grinding and discharge to sewer, compaction, milling, reduction, and anaerobic digestion. Sanitary landfill is the most general urban solid waste (Aziz et al., 2010) because it is easy to use and efficient economically. Solid waste landfill sites are often defined as hazardous and heavily polluted wastewaters with considerable variations in both composition and volumetric flow (ESIA Al – Menya landfill, 2009). Sanitary landfill is the most common (MSW) disposal method due to such advantages as simple disposal procedure, and low cost (Bashir et al., 2010; Davis and Cornwell, 2008). On the other hand, the production of highly contaminated leachate is the major drawback of this method (Wiszniowski et al., 2007; Kurniawanet al., 2006), in addition to air pollution if there is no methane gas collector, and the ability to explosion occurrence.

1.2.3.1 Sanitary Landfill Advantages and Disadvantages

The sanitary landfill as the most common method used for solid waste treatment has several advantages and disadvantage as described below:

- **Advantages:**
    - Filled land can be reused for other community purposes.
    - The lowest cost method for solid waste disposal.
    - Methane recovery can be collected and used for power generation (Jaramillo, 2003).
- **Disadvantages:**
    - Impedes waste minimization and recycling.
    - Needs proper planning, designing, and operation.
    - Methane which is a greenhouse gas produced will participate in climate change.
    - Leachate production that cause soil and water pollution.
    - The properties or lands surrounding the sanitary landfill may be devalued (Jaramillo, 2003).

1.2.4 Leachate

Leachate is any liquid passing through matter. When rain water passes through waste in the landfill, the percolating water becomes contaminated (Rowe et al., 1997), also when there is an exceeding of the field capacity of the compacted cells. It varies according to the composition depending on the landfill age and on the waste type. It contains suspended and dissolved solids. Leachate can be collected and carried out to a storage tank by pipes placed at the low areas of the liner over which a drainage blanket of soil or plastic netting is placed to facilitate the flow of leachate over the liner to the pipes. The generated leachate must be periodically removed from the storage tank for treatment and/or recirculation back into the landfill. Recirculated leachate over waste in landfills has been shown an increasing in the quantity (by nearly a factor of 10) and the quality of methane gas for recovery. This will possibly reduce the concentration of contaminants in leachate and enhance the settling of the waste.

1.2.4.1 Leachate Characteristics

Leachate is generated as a consequence of rainwater percolation through wastes, chemical biological processes in waste and the inherent water content of wastes themselves (Rivas et al., 2004). Leachate is a very dark colored liquid formed primarily by the percolation of precipitation through open landfill. The decomposition of organic matter such as humic acid may cause the water to be yellow, brown or black (Zouboulis et al., 2004). (Bengtsson et al., 1994; Capelo and de Castro, 2007) concluded that, the percolation of leachate through the landfill is very heterogeneous due to channels or macro pores with much higher hydraulic conductivity than the surrounding matrix. (Lema et al., 1988) investigated the production of leachate is generally greater whenever the waste is less compacted, since compaction reduces the filtration rate. Leachate contains large amounts of organic contaminants measured as chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonia, suspended solid, significant concentration of heavy metals (Aziz et al., 2009).

1.2.4.2 Leachate Bad Effects

The leachate has bad effect on environment. Basically, an estimation of health risk due to the exposure to a specific constituent can be calculated by determining an estimation of the concentration of the constituent in an environmental medium, an estimation of the level of exposure to that medium over a determined time frame, and an estimation of the toxicity of the constituent by that route of exposure. (Bradley et al., 2011)

Thus: Risk = [Constituent concentration] x [Exposure] x [Toxicity]

The effect of leachate in different environment constituents can be described in the following sections:

1.2.4.2.1 Effects on Environment

The leachate from MSW landfills is a highly concentrated "chemical soup," so small amount of leachate can pollute large amounts of groundwater causing unsuitable useage for domestic water supply and undesirable due to tastes and odors. Furthermore, leachate from MSW landfills contain many organic matter. It contains a lot of "non-conventional pollutants" which represents more than 95% of the organics in MSW leachate (Lee et al., 1994). (Wang et al., 2002) indicated that the municipal landfill leachate has been one of the major problems for environment because of high organic, inorganic, heavy metal contents, and toxicity characteristics.

1.2.4.2.2 Impact on Groundwater

Contamination of groundwater by landfill leachate is considered to be one of the major environmental concerns. A sanitary MSW landfill in Greece shows that the most commonly documented evidence of groundwater is the pollution in Cl, P, metals, NH_4, NO_3 and hardness (Loizidou and Kapetanios, 1993). Landfill leachate could be a potential source of surface and ground water contamination, as it may percolate through soils and subsoils, causing pollution to receiving waters (Aziz et al., 2011).

1.2.4.2.3 Impact on Hydraulic Conductivity (HC) of Clay

HC defines the capacity of a porous medium to conduct a particular fluid, and is a function of both the medium and the fluid. Landfill leachate in form of water- soluble organic liquids could result in raising the hydraulic conductivity of water-compacted clay. Leachate can cause a little bit increase in the permeability, which maybe an effect on HC of the clay (Ozcoban et al., 2006). After permeating leachate through the clay, the structure of the clay was changed from hexagonal to needle like crystal structure, caused by the chemical content of leachate (Ozcoban et al., 2006).

1.2.4.2.4 Impacts on Human Health

Different studies show impacts of leachate in human living close to sanitary landfill. (Jarup et al., 2007) reported that there is no excess risk of cancer in the population living close to landfill sites. Another study by (Porta et al., 2009) concluded that there was inadequate evidence for increasing cancer to who lives near landfills.

A cancer risk analysis in the US which focused mainly on leachate indicated that 60% of MSW landfills posed a cancer risk of less than one in 10 billion, another 6% posed a risk of less than one in a billion and 17% presented a risk of less than one in a million (Chilton and Chilton, 1992).

Health effects from leachates are not limited to drinking water but may also occur through the food chain due to the ingestion of other organisms (fish, aquatic plants) that locate in an environment contaminated by leachates (James, 1977).

Organic halogen (AOX) compounds, humic acids and chloride compounds that remain in stabilized leachate, ammonia nitrogen (NH_3–N) has been identified as one of the major toxicants to living organisms (Kurniawan et al., 2006).

1.3 History of Leachate Treatment Methods

There are different studies concerning leachate characterizations and treatment. (Renou, et al., 2008) studied the removal of organic material indicated as chemical oxygen demand (COD), Biological oxygen demand (BOD) and ammonium from leachate is the usual prerequisite before discharging leachate into the natural water. Pre-treatment is required prior to landfilling unless it is unnecessary. Landfill leachate treatment usually involves a multistage system of chemical, physical and biological processes and their treatment cost is higher than that of municipal and industrial wastewater (Kjeldsen et al., 2002; Renou et al., 2008). Mechanical and Biological Treatment have several aims: to save landfill space, recover useful materials and stabilize biodegradable waste prior to landfilling in order to improve leachate quality and reduce the risk of settlement, landfill gas production and the need for aftercare (Read et al., 2001; Binner, 2002; Robinson et al., 2005). Initially leachate contains high concentrations of BOD, COD and toxic chemicals. However the characteristics of the leachate differ from landfill to landfill and over the life span of the same landfill (it becomes less biodegradable with time). As a result, a combination of biological and Physic-chemical treatment processes is required to achieve complete and efficient leachate treatment over the life span of a landfill (Qasim and Chiang,1994).

The municipal landfill leachate has been one of the major problems for environment because of high organic, inorganic, heavy metals content and toxicity characteristics (Wang et al., 2002).

There are different leachate treatment methods among the time including the following;

1.3.1 Physical-Chemical Treatment

Physical/chemical treatment methods are non-biological methods used in leachate treatment as a pre-treatment and a post-treatment method. Below, there are some physical-chemical methods, e.g. Combined treatment with domestic sewage, flotation, coagulation-flocculation, chemical precipitation (adsorption, ammonium stripping, ion exchange, electronic chemical treatment and chemical oxidation, advanced oxidation process (AOP)), and membrane filtration.

Combined treatment with domestic sewage, it was preferred for its easily maintenance and low operational costs (Ahn et al., 2002), but due to the organic compounds with low biodegradability and heavy metals, there will be a reduction in the treatment efficiency and increasing in the effluent concentrations (Ceçen et al., 2004). Flotation, for many years flotation has been used and focused on the decrease of colloids, macromolecules, ions, microorganisms, and fibers. Until now, there are very few studies on the application of flotation for the treatment of landfill leachate. (Zoubouliset al., 2003) investigated the usage of flotation in column, as a post-treatment step for removing residual humic acids (non-biodegradable compounds) from landfill leachates. Coagulation-flocculation used successfully in treating stabilized and old landfill leachates (Silva et al., 2004). It is widely used as a pretreatment (Zamora et al., 2000; Amokrane et al., 1997) to biological or reverse osmosis step, or as a final polishing treatment step in order to remove non-biodegradable organic matter. Chemical precipitation is widely used as leachate pre-treatment in order to remove high strength of ammonium nitrogen (NH_3-N), this method have many processes as adsorption, chemical oxidation, ammonium stripping, ion exchange, electrochemical treatment. Adsorption process is used as a stage of integrated chemical-physical-biological process for landfill leachate treatment (Geenens et al., 2001), or along with biological process (Kargi et al., 2003). The most frequently adsorbent is granular or Powdered Activated Carbon (PAC). Carbon adsorption permits 50-70% removal of both COD and ammonia nitrogen (Amokrane et al., 1997). Activated carbon adsorption aim is to ensure final polishing level by removing toxic heavy metals or organics and support microorganisms. Chemical oxidation is required for wastewater treatment containing soluble organic, non-biodegradable and/or toxic substance (Marco and Saum, 1997). (Amokrane et al., 1997) reviewed the commonly used oxidants such as chlorine, ozone, calcium hydrochloride and potassium permanganate for landfill leachate treatment resulted in COD removal of around 20-50%. Common disadvantages of Advanced Oxidation Process (AOP) is the high demand of electrical energy for devices such as ozonizers, ultrasounds, UV lamps, which results in high treatment costs (Lopez et al., 2004). Ammonium stripping, due to its effectiveness, it is the most widely employed treatment for the removal NH_3-N from landfill leachate. But a major concern about this process is the release of NH_3 into the atmosphere, so this leads to severe air pollution if ammonia cannot be properly absorbed with either H_2SO_4 or HCl. Other drawbacks are the calcium carbonate scaling of the stripping tower, when lime is used for pH adjustment and the problem of foaming which imposes to use a large stripping tower (Li et al., 1999). Ion exchange is a reversible interchange of ions between the solid and liquid phases where there is no permanent change in the structure of the solid. Prior to ion exchange, the leachate should first be subjected to a biological treatment. Its application is not economically effective due to the high operational cost. Other limitation is that, prior to ion exchange, appropriate pre-treatment system such as the removal of suspended solids from leachate is required (Abbas et al., 2009). Electrochemical treatment, in Rio Claro- Brazil, the electro degradation of stabilized landfill leachate was investigated by using a flow electro-chemical reactor (Moraes &Bertazzoli, 2005). The results suggested that electro degradation was an alternative means to breakdown recalcitrant organic compounds in landfill leachate. But due to the high energy consumption, this technology is more expensive than other treatment methods. As a result, this treatment technique has been investigated less widely for the treatment of stabilized leachate. Membrane filtration; Microfiltration is a low pressure membrane process for separating colloidal and suspended particles in the range of 0.05- 10 microns (i.e., Fat). It was used as a pre-treatment for another membrane process, Ultrafiltration (UF), Nanofiltration (NF) or Reverse Osmosis (RO) or in along with chemical treatments. But, it cannot be used alone (Abbas et al., 2009). (NF), due to its unique properties between (UF) and (RO) membranes, it has found a place in the removal of recalcitrant organic compounds and heavy metals from landfill leachate (Ozturk et al., 2003). A wide spectrum of constituents may lead to membrane fouling in leachates (NF) (Trebouet et al., 2001).

1.3.2 Biological Treatment

It is a natural process using organisms that available within the environment. (Salem et al., 2008) concluded that there is a number of leachate treatment techniques have been applied with varying degrees of success, including: Aerobic biological treatment (attached growth or non-attached growth), Anaerobic biological treatment, Spray irrigation to land, Reed bed treatment, Ammonia stripping, Reverse osmosis, and Ozonation.

Biodegradation which carried out by microorganisms can degrade organic compounds to carbon dioxide and sludge under aerobic conditions and to biogas (a mixture comprising chiefly CO_2 and CH_4) under anaerobic conditions (Lema, 1988). These processes have been the lowest cost and successfully applied for MSW landfill leachate. This type of treatment when applied for the treatment of landfill leachates may be only partially effective in removing COD, but not effective in salinity reduction. Also, it's very effective in removing nitrogenous matter from leachate when the BOD_5/COD ratio has a high value (> 0.5) (Renou et al., 2008). Biological treatment is a very effective method in removing organic and nitrogenous matter from leachate (Abbas et al., 2009).

(Ehrig, 1984) concluded that this method generally considered as an efficient treatment and it is very similar to domestic wastewater treatment except for some unique issues. These issues include high ammonium concentrations, low BOD/N-ratio, precipitation of inorganics and foaming which could cause clogging of aerators and other operational problems.

The primary purpose of biological wastewater treatment was to remove organic compounds, colloidal and suspended solids and also to reduce the concentration of pathogenic organisms released to receiving waters.

It has a good removal ability of the biodegradable substrates from wastewater treatment industry and this method can reduce cost of treatment residues with respect to ecological and economical requirements (Puig,2007;Renou, 2008). The biological organic matter removal requires sufficient time between wastewater and heterotrophic microorganisms, sufficient oxygen and nutrients, the organic compounds (Carbon, Oxygen, Hydrogen, Nitrogen and Sulphur) serves as the electron donor while the oxygen serves as the electron acceptor (Metcalf & Eddy, 2007; Puig 2007; Vives2005). Although, young leachate can be treated easily by biological treatment, COD removal efficiency are usually low due to high ammonium ion content and the presence of toxic compounds such as metal ions (Sletten et al., 1995; Amokrane et al., 1997; Chiang et al., 2001).

In the last few years, biological treatment has attracted more interests due to its many advantages which includes variety of sources, the ease, and the speed which the microorganisms can be cultured and produced (Zhao et al., 2010). Biological treatment has been shown very efficient in removing organic and nitrogenous matter (Abbas et al., 2009). Other method is the Recycling, it's a widespread technique which depends on recycling leachate back through the tip, so it was one of the least expensive options (Lema et al., 1988), it increased the moisture content in a controlled reactor system and provided the distribution of nutrients and enzymes between methanogens and solid/liquids (Bae et al., 1998). Ledakowicz and Kaczorek, (2004) observed that leachate recirculation may cause high concentrations of organic acids ($pH<5$) which are toxic for the methanogens. Furthermore, if the volume of leachate recirculated is very large, problems may occur such as saturation, ponding and acidic conditions. Biological treatment classified as aerobic and anaerobic. In aerobicprocess organic pollutants transformed into CO_2 and biological solid products (sludge) by using the atmospheric O_2 which transferred to the wastewater. In anaerobic treatment organic matter is converted into biogas, moisture comprising basically to CO_2 and CH_4 and in a minor part into biological sludge. Aerobic biological processes based on suspended-growth biomass, such as aerated lagoons, conventional activated sludge processes and Sequencing Batch Reactors (SBR) (Bae et al., 1999). So, one of the common biological treatment methods are aerated lagoons, which are relatively simple leachate treatment system. Its advantages appear in an effective and low-cost method for removing pathogens, organic and inorganic matters. Also, their low operational and maintenance costs have made them a popular choice for wastewater treatment, particularly in developing countries since there is a little need for specialized skills to run the system (Zaloum& Abbott, 1997). But its disadvantages presented in the inadequate sludge settleability, the need for longer aeration times (Loukidou&Zouboulis, 2001), high energy demand, excess sludge production (Hoilijoki et al., 2000), and microbial inhibition due to high ammonium-nitrogen strength (Lema et al., 1988). In last decades, the performance improvement of the anaerobic process was believed to be a promising option and so, high rate reactors have been designed to reduce long digestion time (Lin et al., 2000).

1.3.2.1 Activated - sludge

The activated-sludge is a biological treatment process that uses aerobic micro-organisms to biodegrade organic contaminants in leachate. Leachate is aerated in a SBR using aerator pump. After that, the mixed liquor (the mixture of microorganisms and the treated water) was settled out the microorganisms. A high percentage of the settled biomass was recycled through the aeration phase to maintain the design mixed-liquor suspended solids level and the excess sludge is wasted.

1.3.2.2 Sequence Batch Reactor

The treatment of wastewater or leachate using activated sludge one of the common methods as biological treatment methods. (EPA, 1982) concluded the variations in the conventional activated-sludge process have been developed to provide greater tolerance for shock loadings, to improve sludge settling characteristics, and to achieve higher BOD_7 removals, Process modifications include complete mixing, step aeration, modified aeration, extended aeration, contact stabilization, and the use of pure oxygen needed.(Lin et al., 2000) concluded the activated sludge process is expensively applied for the treatment of domestic wastewater or for the co-treatment of leachate and sewage. However, this method has been shown in the more recent decades to be inadequate for handling landfill leachate treatment. (Ellouze et al., 2008) investigated leachate treatability by utilizing sludge from a waste water treatment plant.

SBR process is efficient in removal of pollutants from different types of wastewaters and operational parameters such as cycle time, aeration rate, volume of reactor, hydraulic retention time (HRT), that have a great role on performance of SBR method (Aziz et al., 2013). (Madu, 2008) demonstrated that the use of the (SBR) technology for primary biological treatment of landfill leachate has proved to be a reliable and robust strategy, and concluded that the combination of the SBR biological technique with the membrane reverse osmosis technique has proven to be very effective in leachate treatment. (Mohamad et al., 2014) shows that biological treatments are still one of the acceptable means in treating leachate because these offers low capital and operating cost to the operators. In addition, the application of biological treatment has been proven as a total destruction of organic, sulfides, organic compounds, and toxicity. According to (Andreottola et al., 2001), SBR systems applied to nitrogen removal from industrial wastewater offer various benefits such as minimal space requirements, ease of management and possibility of modifications during trial phases through on-line control of the treatment strategy.

The average performance of SBR effluent as the following, BOD removal (89-98%), TSS removal (85-97%), Nitrification removal (91-97%), Total Nitrogen Removal (>75%), Biological Phosphorus Removal (57-69%) (USEPA, 1992). (Lo, 1996) observed that a removal by 99% of NH_4^+-N using aerobic treatment of domestic leachates in a SBR achieved with a 20-40 days residence time. (Dollerer and Wilderer, 1996) observed the COD value was 5295 $g.l^{-1}$, the volume of reactor used is 10-20 L, pH is 9.1, temperature recorded 25˚C, and HRT is 0.5 day. (Mahvi et al., 2005) investigated feasibility of continuous flow sequencing batch reactor in synthetic wastewater treatment, the results showed that the removal efficiency that has been achieved by the system were 97.7, 94.9, 71.4 and 55.9% for BOD_5, COD, Total N and Total P, respectively could be achieved by the system. (Janczukowicz et al., 2001) investigated settling properties of activated sludge from a SBR, the study showed very well settling properties of the sludge, low sludge volume index (SVI) (30 — 60 ml g^{-1} SS) was responsible for an intensive and quick sedimentation which shortened the settle phase to less than one hour.

SBR is an activated sludge, biological nutrient removal (nitrification/denitrification) process, based on a cycle of operation. The SBR performs all operations (flow, activated-sludge systems, settling, aeration and clarification) in a single tank.

In general, any typical SBR should include the phases mentioned as in figure 2, but the time cycle on the figure is related to this study. The cycle time reaches 8hrs, each cycle include five phases within the same system, the number of cycles can implemented each day.

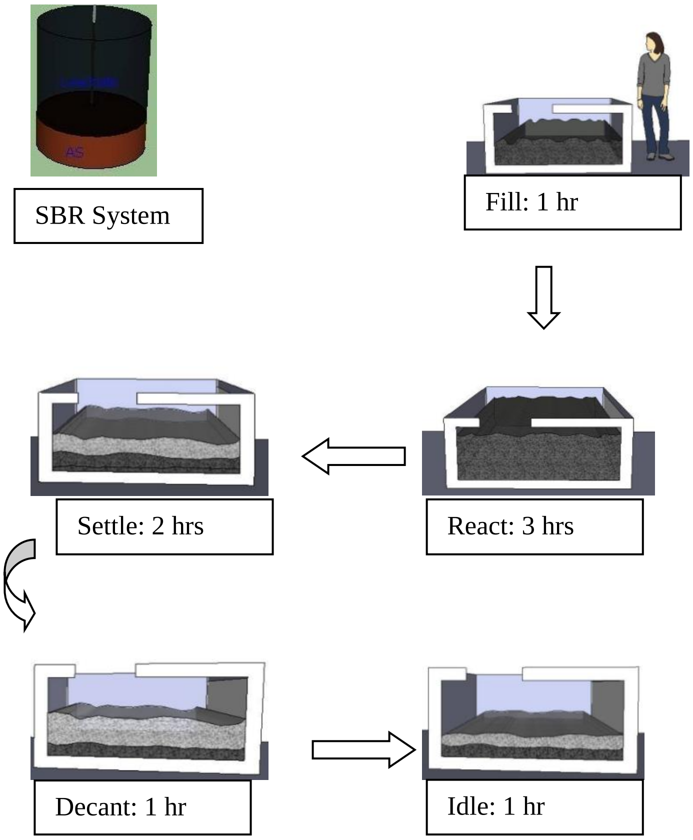

Fig.2: Typical cycles in SBRs (Aziz et al., 2011; Mahvi, 2008)

1.3.2.2.1 Advantages and Disadvantages of SBR

The application of SBR technology in wastewater or leachate treatment has advantages and disadvantages, the following described both sectors.

Advantages of SBR

The primary advantages of SBR are (Washington Department of Ecology, 1998., USEPA, 1999)

1. Primary clarification (on most cases), secondary clarification and biological treatment can be achieved in a single reactor vessel**.**
2. Common wall construction for rectangular tanks.
3. Require small spaces.
4. Elimination of return sludge pumping.

5. Controllable react time and perfect settling.
6. Capital cost savings when eliminate clarifiers.
7. Operation is control and flexible.

Disadvantages of SBR

The most disadvantages of SBR are the of need high level of complicity which requires more daily maintenance (more timers, valves etc.) also, there is some of the disadvantages: (Washington Department of Ecology, 1998, USEPA, 1999; Mace & Alvarez, 2002).

1. Require technical problems (e.g., pump break) that could lead to complete failure of the process;
2. This process is less suitable for treatment of high amount of wastewater.

1.3.3 Physical Treatment

Physical methods are most commonly used in leachate treatment as a combination with biological methods for further polishing of the treated leachate and removal of specific contaminants, though UF and RO these could be used as the main removal step. Physical treatment is either required to remove other pollutants such as heavy metals, organic matter, or to enhance biological degradability as a pre-treatment before biological treatment.

1.3.3.1 Membrane Treatment

Membrane filtration can be defined as the separation of solid immiscible particles from a liquid or gaseous stream primarily based on size differences. The classifications of membrane separation processes are based on particle and molecular size. The processes such as RO, NF, UF, and MF do not generally require aggressive chemicals and can be operated at ambient temperature making these processes both are considered to be environmentally friendly and economically attractive to conventional operational units.

1.3.3.2 Advantages and Disadvantages of Membrane Technology

In general, Membrane process has become more attractive for wastewater treatment, despite this, it has advantages that enables this method to be reliable as a treatment technology and some disadvantages related to its small pore size, so this method needs more attention when use.

Advantages

Advanced membrane technology has a lot of advantages, some of them mentioned here (Furukawa & Burton, 1997):

1) Small footprint.
2) Remove bacteria and viruses.
3) Membrane processes don’t require any start-up time, as biological processes.
4) High automation of the process.

Disadvantages

The primary disadvantages of advanced membrane technology are (Furukawa & Burton, 1997):

1) Clogging of membranes causing fouling;
2) Chemicals are required for membrane cleaning;
3) Uses more electricity;
4) The brine generation that concentrated with inorganic and salts.

1.3.3.3 Reverse Osmosis (RO)

RO is one of the most promising and efficient method among the new processes for landfill leachate treatment. In the past, several studies have already demonstrated RO performances on the separation of 36 pollutants from landfill leachate (Linde et al., 1995; Bilstad et al., 1992). Values of the rejection coefficient referred to COD parameter and heavy metal concentrations higher than 98 and 99%.

It is also known as a hyper filtration, due to its separation technique which operates at high pressure, it is applied for the purification of water (Bhattacharyya and Williams, 1992; Li et al., 2009; Williams, 2003; Wiszniowski et al., 2006). This method is able to concentrate all solutions and solids in suspension and able to separate ions, organic compounds containing oxygen and nitrogen, pesticides, colloids with sizes below 3.10 μm (Lee et al., 2011).

RO seems to be one of the most promising methods among the new processes for landfill leachate treatment (Linde et al., 1995; Bilstad et al., 1992).

(Anand& Singh, 2014) studied the removal efficiency of COD and heavy metals using RO membrane, the removal efficiency of both parameters are higher than 98 and 99%, respectively. (Abbas et al., 2009) observed high percentage removal of dissolved solids and metals using RO membrane, the elimination rates can sometimes reach to 99%. (Şchiopu et al., 2012) investigated RO efficiency in leachate treatment and concluded a removal efficiency of contaminants (COD, $NH4^+$, electrical conductivity) exceeding 90% was achieved. (Cartwright, 1985) investigated the efficient removal of RO process in the treatment and recovery of wastewater containing nickel, acid copper, zinc, copper cyanide, chromium, aluminum, and gold.

1.3.3.4 Ultrafiltration (UF)

The UF is effective to eliminate macromolecules and particles that tend to foul reverse osmosis membrane. The elimination of polluting substances reached values within the range of COD between 10 and 75%. UF has been applied to biological post-treatment of landfill leachate (Bohdziewicz et al., 2001).

(Amy et al., 1987) concluded the rate of UF depends on the area of the membrane, the concentration gradient, molecular diffusion, and temperature. (Bohdziewicz et al., 2001) concluded that UF is effective to eliminate the macromolecules and particles, but it is strongly dependant on the type of material constituting the membrane. UF is used for fractionation of the organic compounds in leachate based on their molecular weight or size. In this technique, the migration of the molecules through the membrane is usually a combination of molecular diffusion and advective flow.

More recently, UF has been applied to biological post-treatment of landfill leachate.

1.4 Palestinian Experiences in Solid Waste Management

The Palestinian territories are divided into two parts; the West Bank and Gaza Strip. West Bank is divided into three regions which are Northern, Middle and Southern regions. The targeted areas of this project are Hebron and Bethlehem Governorates which they located in the southern region. Both targeted areas include touristic activities within their main cities and have nearly important agricultural areas.

In recent years, the management of solid wastes has become a greater concern. Disposing waste in any open dumping ground may create environmental pollution problems (soil contamination, ground water contamination, health problems etc). When solid wastes are incinerated they reduce the waste to ash and release potentially hazardous gases into the air causing public health risks. The best possible option is the biological conversion of solid wastes that contain higher percentage of organic matter and moisture content (i.e. about 45-50%).

The open dumping sites were considered as point sources of pollution over the groundwater basins. Chloride was used as the pollutant and its concentration in the generated leachate was obtained from the results of the laboratory analysis that was conducted for leachate samples collected from Dura sanitary landfill in the Hebron District, table 1 summarizes the characteristic of Dura sanitary landfill leachate. The samples were collected in October 2003 and analyzed at the Center for Environmental & Occupational Health Sciences in BirZeit University. Values of the chloride concentrations in the groundwater were 151 extracted for each year over a time period of 20 years. The extracted values were compared to the standards set by the (USEPA) for drinking water which recommends an upper limit for chloride concentrations of 250 mg/L. (Isaac et al., 2005).

Table 1. Leachate Analysis Results For Dura Landfill,(Isaac et al., 2005)

Parameter	Dura Landfill
BOD (ppm)	315
TSS (ppm)	3392
Chloride (ppm)	35040
Nitrate (ppm)	132
Nickel (ppm)	0.144
Cadmium (ppm)	0.287
Chromium (ppm)	0.008
Lead (ppm)	0.049
Zinc (ppm)	0.485
PH	8.145

In addition to the 85 sites that were rehabilitated and closed between 2001 and 2007 in northern governorates in the west Bank 15 sites were rehabilitated in since 2010 in the northern and southern west Bank (Isaac et al., 2005).

1.4.1 Solid Waste Management (SWM) Status in Palestine

SWM was faced many obstacles at deferent levels; either legislative, organizational, environmental, financial, and technical levels. Mismanagement appears in the lack of accurate national statistics in the amount of SW produced, the source of waste, and it’s composition. So, a lot of difficulties found in planning and decision making in this sector. Another big challenge for Palestinian Territory is the political reality. The limited control for Palestinians in their areas, especially the full Israeli control over the “C” areas, and the lack of available land, lead to a big prohibitive factor in implementing several projects, such as sanitary landfills. A general description for solid waste in Palestine is illustrated in table 2.

Waste entering the landfill undergoes biological, chemical and physical transformations. In the landfill, there are three physical phases are present which is solid phase (waste), liquid phase (leachate), and gaseous phase (CO_2, CH_4). Solid waste disposed in landfills will go through several stages of decomposition, are eventually result in the liquid at the bottom of the landfill leachate.

Table 2. General Description for Solid Waste in Palestine, (Country Report, 2014)

Population	4.421 million (mid, 2013)
Municipal Solid Waste (MSW) Generation	1.387 million tons/year (2012)
Per Capita MSW Generation - Urban Areas - Rural Areas	0.94 kg/day (2012) 0.9-2.05 kg/day (2012) 0.35-0.6 kg/day
MSW Generation Growth	4 % per year; 1% per capita per year
Medical Waste Generation	3,226 tons/year (2011)
Industrial Waste	131,344 tons/year (2011)
Hazardous Waste	62,621 tons/year
Waste Tyres	5,550 tons/year (as rubber)

MSW resulted from things we commonly used and then throw away. These materials range from food scraps, packaging and grass clippings, to old sofas, computers, tires, and refrigerators. MSW does not include industrial, hazardous, or construction waste.

SWM in Palestine has extremely deteriorated since Intifada, that started in 2000, emergency open dump sites has found and SWM problems were resulted as the following:

- Accumulation of solid waste in the streets and outside the solid waste containers.
- Using alternative dumping sites which resulted in increasing the number of uncontrolled open dumping sites.
- frequent open burning of waste accumulated in MSW dumps within city boundaries, primarily to reduce waste volume.

Nowadays, the construction of the Segregation Wall has significant effect on the Palestinian environment and natural resources. The existence of these dumping sites that are located outside the Wall have become inaccessible to the localities that are enclosed inside the Wall, so the emergency disposal sites inside the localities found. The Wall will also hinder the implementation of solid waste management projects such as sanitary landfills that aim at serving the cluster of districts (Ghonim et al., 2010).

1.4.2 Solid Waste within the Political Situation

Waste is a complex mixture of different substances; some of which is hazardous to health (Ghonim et al., 2010). The West Bank still suffers from the shortage of sanitary landfills. Until September 2000, there were 100 random unsanitary MSW dumpsites in the West Bank (Talahmeh, 2005). These dumpsites were ‘‘random’’. When the second Palestinian Uprising (Intifada) started in 2000, reaching the locations of these dumpsites has become harder than ever, due to military roadblocks, which has led to the establishment of emergency open dumps within the boundaries of Palestinian cities and villages. This situation has been further worsened by the rapid retrogradation of MSW transfer trucks, which were forced to use unpaved side roads (avoiding roadblocks) to reach the MSW dumpsites. As a result, the number of random dumpsites in the West Bank surged to about 190 by the year 2003 (Abu Thaher, 2005). Another negative phenomenon that developed during the uprising is the frequent open burning of waste accumulated in MSW dumps within city boundaries, primarily to reduce waste volume. Additionally, frequent closures and roadblocks have resulted in a shortage of pesticides and insecticides needed to overcome the negative effects of MSW accumulation within residential areas (Abu Thaher, 2005). Limited recycling initiatives have been put into practice in the West Bank in the past. These initiatives were mostly privately owned and focused mainly on metals, paper, and glass recycling. Metals and glass were locally utilized, whereas other items such as automobile scrap were sold to Israeli firms for utilization in Israel

(Environmental Quality Authority, 2005). The Israeli practices of disposing their waste, including hazardous waste in Palestinian areas are aggravated the health and environmental impacts of the SW problem, from here Palestinians are faced Mismanagement in SW.

1.4.3 Solid Waste Types and Composition

There are different types of solid wastes. Domestic, industrial, commercial, and agricultural wastes. These are obvious in the table below.

Table 3. Different types of solid wastes, (Al - Sa'di, 2009)

Type of waste	Source	Percentage of the total waste
Domestic waste	Households	45-50%
Industrial Waste	processing and non processing industries	20-25%
Commercial waste	offices, restaurants, hotels, and public services	25-30%.
Agricultural waste	agricultural activities such as leaves, plants, plastic pipes and the hazardous waste; rom fertilizers or pesticides.	15-20%.

All types of solid waste in Palestine consists mostly from papers, metals, plastics and glasses as shown in figure 3. The amount of solid waste produced are varies according to the prevailing lifestyles, consumption patterns, and according to the type of locality (city, village, refugee camps). Generation rate per capita was estimated to be 1.045kg/day in Gaza Strip nearly, and in the West Bank 0.939kg/day. It is estimated that waste generation rate increases 4% per year; where 3% is increased due to natural population growth, and 1% is due to increase in generation rate per capita. Waste Generation Per capita in rural communities (very small villages) was observed to be between 0.35kg/day and 0.6 kg/day; in the big urban areas it observed in the ranges between 0.9 and 2.05kg/day, while in the middle size towns, this value between 0.6kg/day and 0.9kg/day (Country Report, 2014).

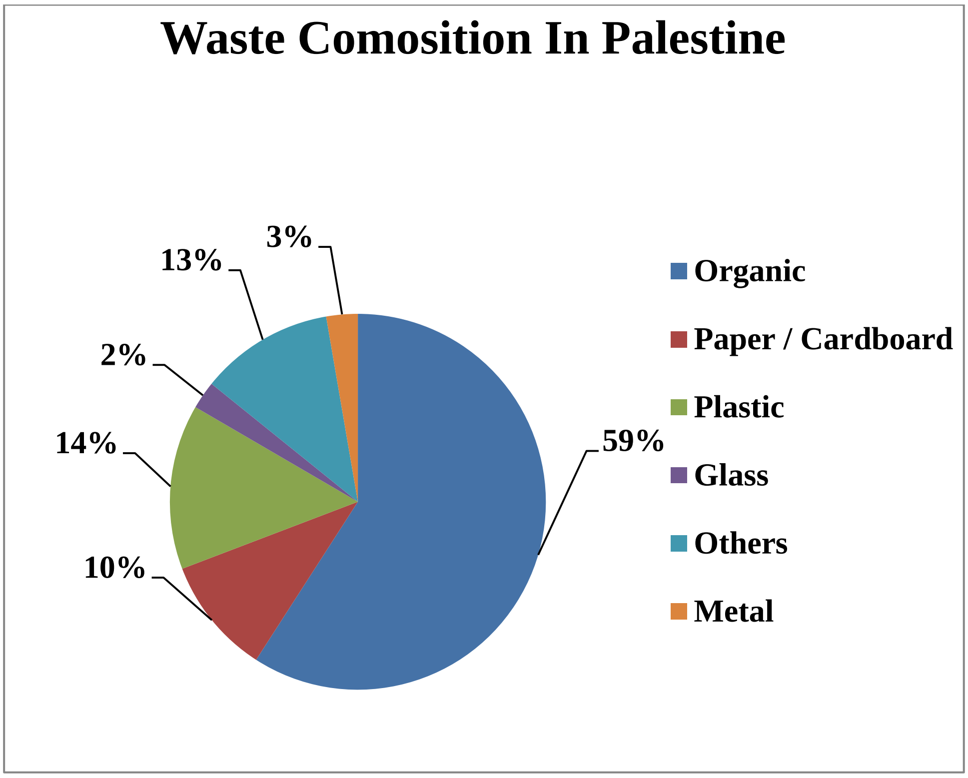

Fig.3: Waste composition in Palestine (PCBS, 2005).

The high fraction of organic wastes (59%) is not unusual for areas with a low level of economic activity. This high fraction of organic components will be reduced at the landfill by composting. Waste density estimated by 0.30 ton/m^3, which give the large quantity of organic content.

1.4.4 Solid Waste Collection and Disposal

Waste collection is the collection of solid waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal.

The collection of solid waste in West Bank is done by the municipalities or the village councils. The solid waste is gathered from the buildings by the employees of the local communities. Some local communities are far from the public services; therefore people dump their solid waste outside their houses with no concern to how it will be removed. There are 166 local communities that do not have any solid waste collection services, which represent around 27.8% from the total local communities where as 78.5% of the local communities have collection service. There are 129 local and 32 communities in the West Bank collect their solid waste daily. For the 266 of the local communities the solid waste is collected more than once a week (PCBS, 2005). The solid waste is collected in the West Bank in different ways:

- Direct collection: the waste vehicles collect the waste from containers, there size 1.1 m^3 or barrels. This is found in most of the local communities in the West Bank.
- Skip lift containers: which are commercial container in size of 5- 6 m^3 collected by skip-lift vehicles.
- Manual door to door collection: The people used the plastic bins to dispose the waste, and then the waste is collected by trucks.

Many environmental and health impacts may result due to the random disposal such as surface and groundwater pollution by waste leachate, air pollution due to burning, and the public health due to misquotes and insects (UNEP, 2003).

There is four sanitary landfills in Palestine, table 4. Zahrat Al Finjan, Al Menya Landfill, Deir El Balah, and Jericho Sanitary Landfill.

Table 4. Existing sanitary landfills in Palestine, (ReemMusleh, 2010)

Name	City	Composition	Open Year	Closure Year	Area in hectares built	Design capacity built (million m3)	Amount of waste already disposed	Population served
Zahrat Al Finjan	wadi Ali – between Arrabeh and AjA	Lining and leachate systems	2007	2017	9.5	2.9	532	968,877
Al-Menya Landfill	Al Menya	Lining and leachate systems	2013	2033	10	2.65	0	905,113
Deir El Balah	Deir El Balah	Built on impermeable ground outside the aquifer watershed without lining and leachate system	1997	Should be closed no alternative yet far bryond capacity	NA	0.7725	1600	NA
Jericho sanitary	Jericho		2007	2014	1.03	0.0685	64	40,805

1.5 Palestinian Laws and Regulations Relevant to all Kinds of Waste

The major laws issued by the Palestinian National Authority (PNA) related to SWM are: Basic Law (2003) the Environmental Law (1999), the Local Authorities Law (1997), and the Public health Law (2004). The Basic Palestinian Law (2003) identifies the right to a clean and a balanced environment as a basic right of every Palestinian and that preservation of the Palestinian environment for the sake of both present and future generations is a national duty. Defining clean and balanced environment as a human right in the basic law is essential for the further laws issued on the environment, and for the protection of the environmental systems. Also this article indicates the importance of sustainable development, as the environment has to be preserved and protected for the sake of not only present but also future generations.

- **Basic Palestinian Law**

“The enjoyment of a balanced and clean environment is a human right. The preservation and protection of the Palestinian environment from pollution for the sake of present and future generations is a national duty”.

- **Environmental Law: Law No. 7 for the year 1999 regarding the Environment**

This law identifies waste, hazardous materials, and hazardous waste. It is also based on the polluter pays principle. The definition of hazardous waste based on this law is: any waste generated by the various activities and operation or the ash thereof which preserve the characteristics of hazardous substance, where hazardous substance is defined as any substance of combination of substances, which because of its hazardous characteristics poses a danger on the environment as toxic, radioactive, biologically infectious, explosive or flammable substances.

- **Local Authorities Law**

Local Government Units (LGUs) responsibilities include collection, transfer, and disposal of solid waste. According to this law, municipalities can provide their services directly, through private sector, or jointly with other municipalities through a Joint Service Council (JSC). In 2010, the Ministry of Local Government (MoLG) has issued a strategy to further support joint councils' development, however the strategy excluded (JSC) for solid waste management.

- **Public Health Law**

According to the Public health Law, the Ministry of Health (MoH) is the responsible institution to issue a license to waste facilities. Furthermore, the (MoH) in coordination with competent bodies shall determine the health hazards that negatively affect public health or the environmental health in any way possible. The (MoH) in coordination with the relevant bodies shall issue specifications and instructions with regards to the transport, storage, treatment or disposal of hazardous materials and wastes.

- **Medical Waste by law (2012)**

The Medical waste bylaw identifies roles and responsibilities in medical waste management, definition of waste management, procedures and specifications for medical waste separation, storage, collection, transport, treatment as well as waste tracking.

1.6 Problem Statement

Our research problem concentrated in one of sanitary landfill disadvantages. The production of leachate as part of solid waste treatment , The leachate which has the possibility of soil, groundwater and surface water contamination. The leachate composed of mixture of degradable and non biodegradable substances that expected to persist in their original form for many years, even for centuries. Also, its environmental bad effects which represents in deterioration of water quality, shoreline and marine pollution, air pollution, and deterioration of nature.

1.7 Objectives

The major objective for this study is to investigate an effective methods of Al-Manya leachate treatment.

The sub-goals of our study:

1. Investigate physical, chemical and biological characteristics of Al-Menya leachate,
2. Investigate the SBR system as biological method in leachate treatment
3. Investigate the use of physical treatment method including RO and UF for removing toxic organic compounds.

1.8 Thesis Outline

The thesis consists of four chapters. Chapter one included general introduction, the problem of leachate treatment as well as aims and scope of this study, history of leachate treatment, in addition to literature review. In chapter two , the study area, also research methodology, the existing leachate treatment system for Al - Menya landfill leachate and focusing on the various aspects of lab-scale SBR process. In chapter three is the results and discussion were presented, begin with Al-Menya leachate characteristics, the calculations of SBR facility for Al-Menya landfill Leachate, based on the data, obtained during laboratory experiments, in addition to UF and RO effluents. The conclusions of our study, recommendations and references are listed in chapter four.

1.9 Thesis Flowchart

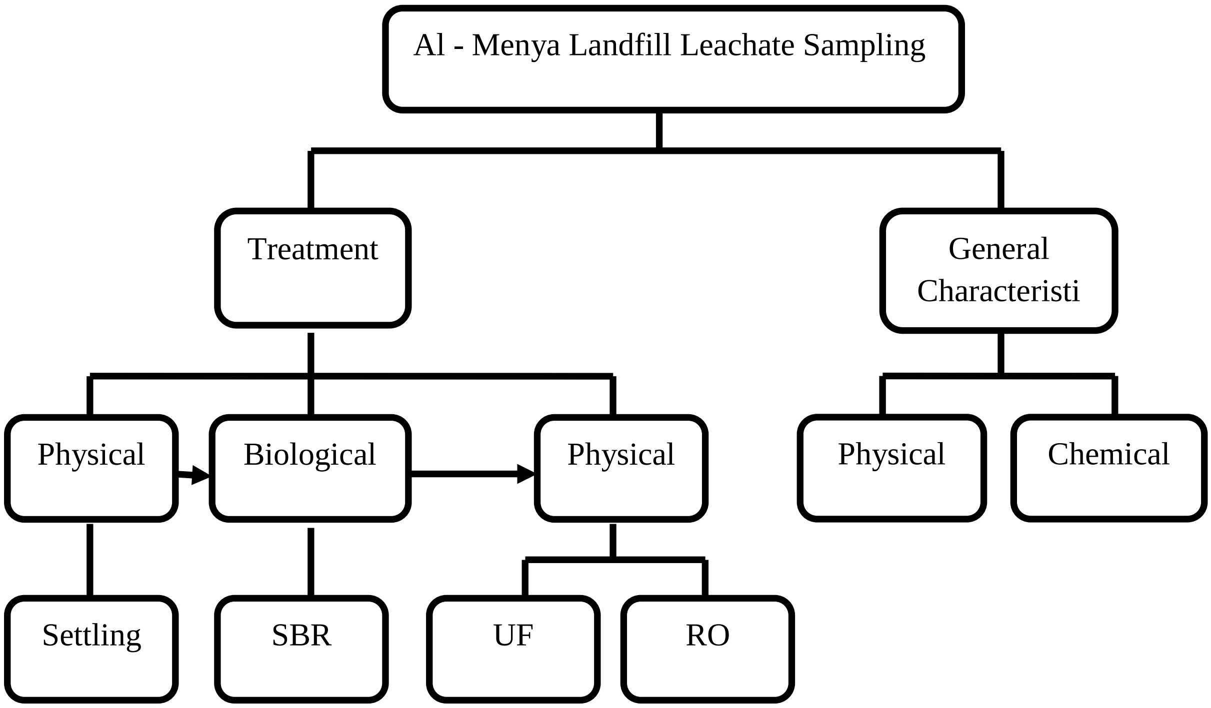

Fig.4: A flow chart diagram of the laboratory scale of SBR

Chapter Tow: METHODOLOGY

2.1 Study Area

It locates between 2-3 km to the south and western south of Al-Menya village in Bethlehem. Figure 5 shows the map of study area location. The area of the landfill is 20.5 ha (540X490m). It's highest about 690-730m above the sea level. The average yearly rainfall about 200-300ml and the average yearly temperature is about 19-20^{0}C. The average yearly sunrise is about 189-195Kilo Calorie/ Cm^2.

The waste that is received at Al-Menya landfill is municipal solid waste, and the daily quantity is 600 ton. Normally, there is specific pollutants in the textile waste water including suspended solids, biodegradable organic matter, toxic organic compounds and heavy metals, these what the researcher want to analyze and try to treat.

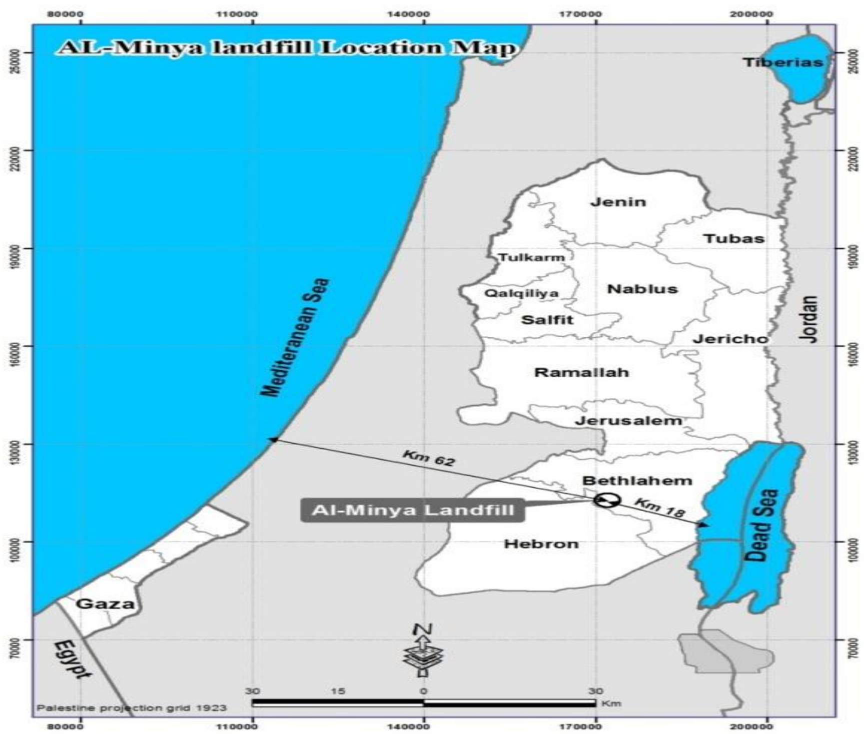

Fig.5: Map for the study area location.

2.2 Geology of the Area

The geology of the area almost consist of gravels, deposits of clay from the mountains and hills around. Most of the well appeared that all of the contents are almost of alluvial, sand and a little of gravels, as in figure 6. The rock caps consist of a strong and white lime (<0.5 and its maximum value 1.5 m). The lime stone reach to more than 10 m down, the ratio for preventing leakage/permeability is slim because the ability of forming another forms of stones (Chert, Flint, Marl, Marl stone and Dolomite) within forming lime stone that little in formations but large and different quantities. The design of the landfill access to achieve high levels to contain the leachate with least leakage inside the landfill, the depth of the groundwater have a big depth under the surface around 200m, the ability of these leakages to reach from the landfill to depth more than 10-20 m, is small and too far.

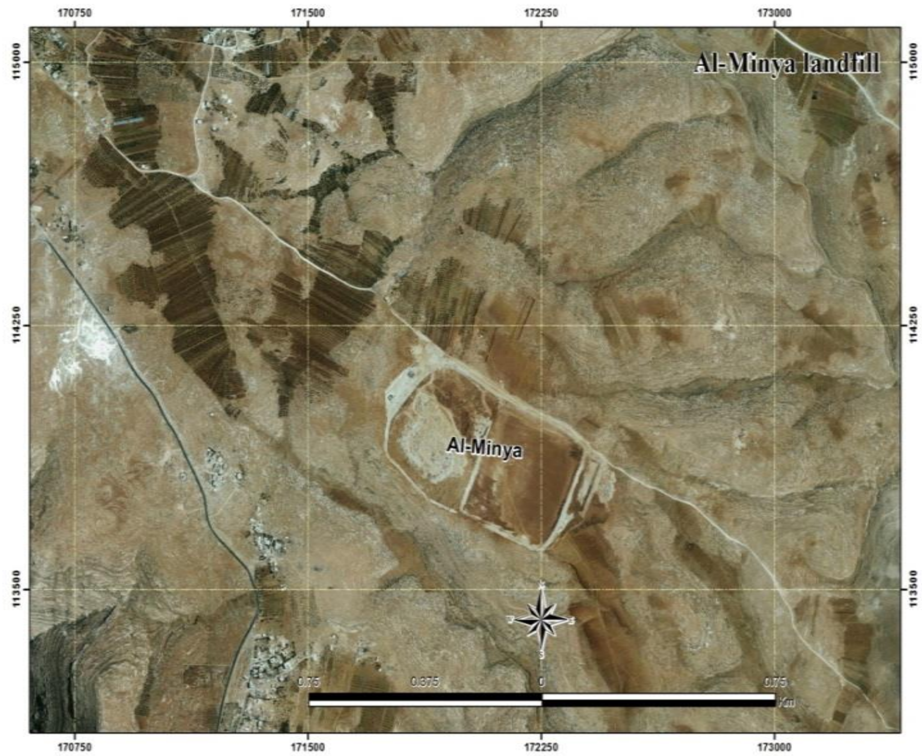

Fig.6: Map for the geological area location

2.3 Al-Menya Landfill Components

The design of Al-Menya sanitary landfill included the following components:

landfill cell division, base lining system, leachate collection and evaporation pond, internal roads, fence and gate, weighing bridge, buildings (administration building, reception building, vehicle and maintenance shop), parking area, water storage, rain water drainage system, recycling and composting plant (optional), gas collection and energy recovery system, storage of materials, and vegetation plan (ESIA Al-Menya Landfill, 2009)

2.3.1 Base Lining System

The base of the landfill was lined so that leachate generated retained inside the landfill and collected for safe disposal. Ideally the natural subsoil underneath and surrounding a landfill would constitute a geological barrier. Because there was none of the proposed site in the Hebron / Bethlehem governorates have suitable soil, so an integrated base lining system using a high-density polyethylene (HDPE) geo-membrane used. The integrated liner consists of an upper (primary) geo-membrane liner to collect the leachate, and a lower (secondary) geosynthetic clay liner (GCL) as a backup to the primary liner (ESIA Al-Menya Landfill, 2009).

2.3.2 Leachate Collection

Leachate is generated due to biochemical processes in the landfill, the water content of the waste deposited at the site and the inevitable infiltration of rainwater during operation of the site. It contains several organic and inorganic pollutants as chemical reaction in compacted cell and need to be collected and treated.

The HDPE pipes are used for leachate collection. A main leachate collecting pipe will be located in the deepest point of the landfill area running nearly from north-west to south-east. Leachate drain pipes placed at right angles or less to the main pipe. All leachate flow drained to the lowest points (for each main pipe). At those points, a pumping pit arranged and a pumping system installed to transfer the leachate to a collection pond (ESIA Al-Menya Landfill, 2009). Figure 7 shows the barriers used and the leachate collection system.

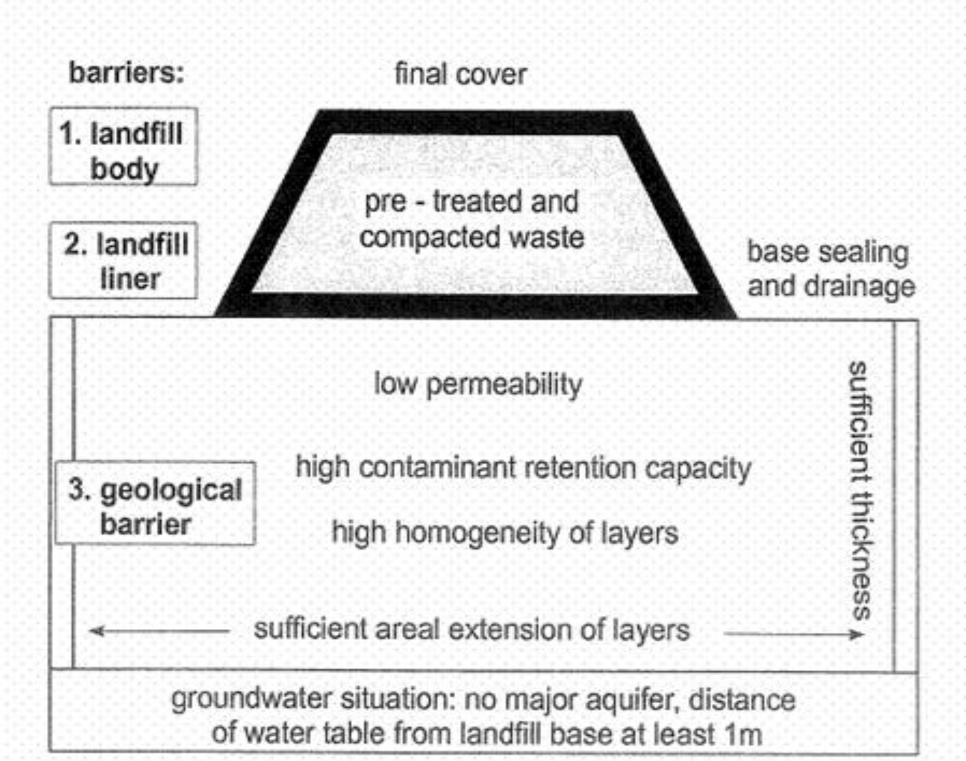

Fig.7: barriers used and the leachate collection system.

2.3.3 Leachate Treatment

The leachate pond was excavated in the ground, at a slope of 1:2. In the collection pond, primary treatment of the leachate occurs naturally (sedimentation, natural biological degradation of organic pollutants and evaporation). Whenever necessary, (when the leachate volume exceeds the capacity of the pond due to precipitation events) the leachate will be re-circulated by spraying over the surface of already lined cells of the landfill. The design does not initially include secondary leachate treatment because the low rainfall and high evaporation characteristics of the project area indicate that it will not be necessary.

The dimensions of the leachate pond were calculated using the HELP model for leachate generation. Results suggest the following:

Area: top - 4900 m^2, bottom - 3500 m^2, Depth: 2 m and Volume: 8,400 m^3(ESIA Al-Menya Landfill, 2009).

2.3.4 Surface Water Collection

The volume of rainwater or surface run-off that comes into contact with the waste in the landfill, or leachate, should be minimized to reduce the potential for contamination. The surface of the waste body covered intermediately during operation of the landfill and finally after closure of the landfill. The rainwater that flows from the surrounding areas and (after filling) from the surface seal of the landfill, will be captured by ditches around the landfill body and directed to the lowest point of the landfill, located to the south. The ditches along the landfill berms will be lined to avoid erosion of the cover layers of the closed cells. From this low point, the run-off water will be led by gravity to the wadi that drains away to the south-east direction. A rainwater retention pond is not necessary (ESIA Al-Menya Landfill, 2009).

2.3.5 Waste Filling

The vehicles delivering waste have to unload the waste at a distance of about 10 m from the actual waste filling area. The waste is transferred to filling area using a compactor and filled into the cell by the compactor in layers with a maximum thickness of 50 cm. The waste filling area are dimensioning in such a way that after approximately 3 days the next waste layer can be started. In this way odour is minimized and waste incorporation by the compactor prevents the production of wind-blown debris. Immediately after waste filling, the active disposal area will be covered with a soil layer of about 20 cm in thickness (ESIA Al-Menya Landfill, 2009).

2.3.6 Landfill Cap

In order to achieve a total disposal volume of about 4.9 MCM, in the area of the site, the waste has shaped into a pile with an inclination of 1:3, and the height of the final structure reaches up to about 40 m. When the cells are filled, to prevent the infiltration of rainwater into the waste body, as well as to avoid the spread of waste to the surrounding area (caused by wind) the final waste body covered by a surface sealing system. This will comprise the following

- A "compensation layer", to protecting the sealing layer from the rough structured waste body, and to provide a space within which landfill gas can accumulate and be extracted.
- A "sealing layer", which forms an impermeable barrier, keeping landfill gas inside and rainwater out of the body of waste.
- A "drainage layer", above the sealing layer through which rainwater falling on to the surface of the landfill can flow off, into the surface drainage channels.
- A "recultivation layer" on which vegetation is grown to cover the structure and integrate it back into the natural surrounding environment (ESIA Al-Menya Landfill, 2009).

2.4 Research Methodology

Water tension has become a significant problem all over the world. According to numbers given by WHO (2012), 1.1 billion people of the world do not have improved water and 2.4 billion people do not have any type of improved sanitation facilities. Landfill leachate can be either treated locally at the landfill site, that can be physio-chemical, biological or a combination of both (Reinhart and Al-Yousfi, 1996; Cheng and Chu, 2007; Schiopu et al., 2010 ;Martten et al., 2002).

2.4.1 Leachate Samples

Al-Menya Sanitary Landfill was constructed in March, 2014. The leachate were collected from Al - Menya landfill about six times in Summer Seasons. The activated sludge was collected from Oasis Hotel in Jericho, at the beginning the sludge activation and adaptation using leachate dilution samples in SBR system. Leachate was preserved at $4^{\circ}C$ in refrigerator at the Center for Chemical and Biological Analysis Laboratory, Al-Quds University, to prevent the occurrence of chemical and biological activities. Sample was removed and left at room temperature prior to analysis and further treatment.

2.4.2 Instrumentations

Autoclave (Tuttnauer Autoclave, steam sterilizer, Model 2340M, USA)., UV/VIS spectrophotometer, (Perkin elmer, Germany). Water bath, (Type JBL, England). Analytical balance (Type D0422601283, Japan) Evaporation dishes. Microprocessor Oximeter. (OXI 196 from WTW) was used to measure the dissolved oxygen in BOD samples .pH – EC- TDS meter (HI 9811 portable HANNA instrument”) Portable data logging spectrophotometer (DR/2010, HACH),Flame photometer (Jenway). Atomic absorption (AA6200. Shimadzu). ICP optical emission spectrometer (HORIBA Scientific ,JobinYvon technology. Japan)

In biological treatment the equipments used was laboratory-scale SBR which was designed as shown in the schematic diagram; figure 8, dosing pump, mixer, air pump, timer, and beakers.

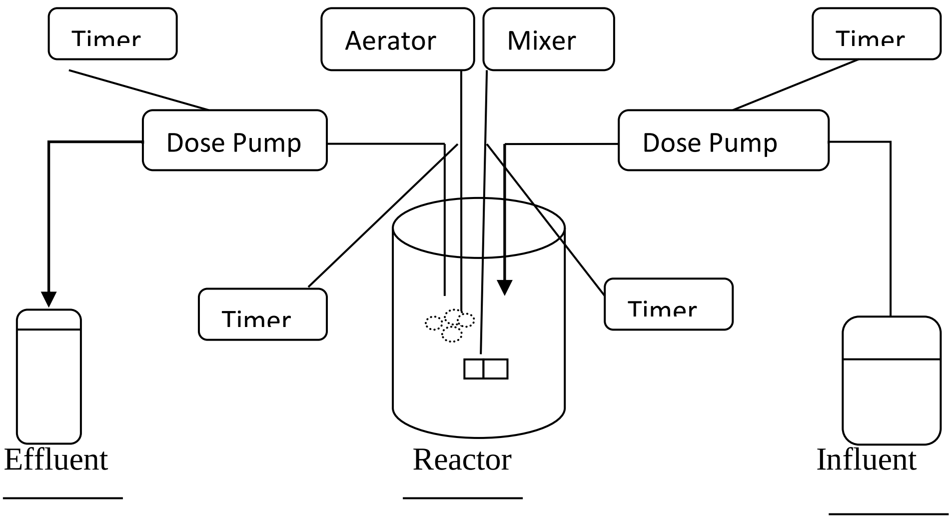

Fig.8: The layout of laboratory SBR installation.

2.4.3 Chemicals and Reagents

Potassium Dichromate ($K_2Cr_2O_7$) (SIGMA – ALDRICH, catalogue No. P5271. USA), was used to oxidize the organic and nonorganic meter. Sulphric Acid 96 % (H_2SO_4) ((CARLO ERBA, catalogue No. CASNr 7664-93-9,), Silver Sulphate (Ag_2SO_4), (SIGMA- ALDRICH, catalogue No. 497266), Sodium phosphate ($Na_3PO_4.12H_2O$), Sodium citrate ($C_6H_5Na_3O_7.2H_2O$), EDTA, phenol crystals, Sodium nitroprusside $Na_2FeCN_5NO.2H_2O$ were used for Phenol measurement. For Phosphate measurement we used, Ammonium hypochlorite $(NH_4)_6Mo_7O_{24}.4H_2O$, antimomy potassium tartarate ($Ksbo.C_4H_4O_6.1/2\ H_2O$).

2.4.4 Sampling and Standard Preparation

A standard stock solutions for COD, NH_4^+, PO_4^{-2}, Na^{+2}, K^{+1}, Mg^{+2}, Ca^{+2}, were prepared then different concentrations were prepared. Concentrations for the sample measured were calculated from the standards calibration curve were prepared.

2.4.5 Methods

At first we analyzed leachate sample from the Al-Menya landfill, nearly all collected samples among the whole study were analyzed. Then we start treatment by making dilution for the samples with tab water in the biological treatment part through using SBR to make sure the sludge used is effective enough for organic decreasing, then started working with concentrated samples. After that the effluent from biological treatment were transferred to physical treatment using UF and RO .

The UF process consists of two small-scale membrane treatment plants with a capacity of 12 $m^3.\ d^{-1}$. The first UF unit is equipped with two 2 × 4 inch pressure vessels with a pressure resistance up to 150 psi. The second unit is equipped with two pressure vessels made by Vendor (AST Technologies model number 8000 WW 1000-2M, Israel) that houses the HF membranes with 100 kDa cut-off.

The RO system consists of a 1 × 4 inch pressure vessel constructed with composite material having a pressure resistance up to 400 psi. The vessel holds two 4 inch special separation membranes (thin polyamide film with pH range 1–11, model BW30-4040 by DOW Film tec, USA). A membrane anti scaler (product NCS-106-FG) solution of phosphoric acid disodium salt is continuously dosed to the RO feed at a concentration of 4 $mg.\ L^{-1}$ in order to prevent deposition of divalent ions. The system is designed to remove major ions and heavy metals. The designed RO permeate capacity of the system is 0.45–0.50 $m^3.\ h^{-1}$.

The leachate samples were collected in plastic bottles, labeled and divided according to the required analysis. Standard method was used for all analysis we used the standard methods for examination of water and wastewater (Andrew, 1998). A comparison between the biological effluents and physical effluents were analyzed.

The working volume up to 5 L was used as the sequencing batch reactor (SBR). Experiment on laboratory scale of SBR was carried out to investigate the removal efficiency of organic matter measured as Chemical Oxygen Demand (COD), Suspended Solid (SS), Phosphate (PO_4^{-3}), Nitrate (NO_3- N, NO_3^-), Sodium (Na), Potassium (K^+), and ammonia-nitrogen (NH_3^+- N/NH_4^+/NH_3).

The operating of the experiment were performed following the order: Filling, Reaction, Aeration, Settling and Decantation. Before starting SBR operation, the reactor was filled with leachate using a dosing pump then mixed with activated sludge for several days to obtain a dense culture to start with. First, primary treatment we started by settling for 2hrs, then filling 3.5 L of leachate occur for about 1hr using the dosing pump that pumped on a 1.5 L of activated sludge, after that reaction occurred using mixer and aerator for 2hrs, then the sample settled for 2hrs, decantation occur for 1hr, and finally 1L of the clear supernatant was removed for analysis, then stored at 4˚C in the refrigerator. A friction of the culture was removed from the reactor before sedimentation everyday to adjust the mixed liquor suspended solids (MLSS) to the desired level.

Chapter Three: RESULTS AND DISCUSION

The results and discussion chapter included the leachate physical, chemical and biological properties, the biological treatment result using SBR and finally the biological effluent samples were injected in advanced membrane technology system using ultrafiltration unit (UF) and reverse osmosis unit (RO). The results described in following sections.

3.1 Al-Menya Leachate Characteristics

Al-Manya leachate samples were taken during the years 2014 and 2015. The samples were taken directly from the pool influent. This pool was prepared for leachate collections. The samples were divided into two types, one fresh samples group which analysis directly as microbiology and BOD whereas the other samples group were stored in refrigerator under 4C° until other chemical and physical analysis. Three samples were taken for triplication and reproducibility for each test. Table 5 summarizes the average concentration and measurement of physical, chemical and biological characteristics of Al-Menya leachate during research study.

Table 5. Chemical and physical characteristics of Al-Menya Landfill leachate.

Characteristic	Measurement	Standard Deviation (SD)
PH	6.1	0.3
Electrical Conductivity	5.96 mS/cm	1.1
Total Dissolved Solids	2000 mg/l	550
Turbidity	3000 NTU	5.8
Total Suspended Solids	2500 mg/l	5.3
Chemical Oxygen Demand (COD)	11000 mg/l	400.0
Biological Oxygen Demand (BOD)	4000 mg/l	250.0
BOD/COD	0. 36	
Ammonium (NH_4^+)	105.00 mg/l	4.1

Ammonia-Nitrogen : NH_3^+-N/NH_4^+/NH_3	0.48 mg/l/0.62 mg/l/0.58 mg/l	0.1
Ca	3500 mg/l	0.1
Mg	300 mg/l	0.0
Na	5700 mg/l	0.1
K	1000 mg/l	0.0
Nitrate/NO_3¯N/NO_3^-	19.57 mg/l / 4.4 mg/l	0.0
Phosphate	8.00 mg/l	0.0
Ag	***	0.0
Al	3.86 mg/l	0.0
Cd	3.66 mg/l	0.0
Cr	5.22 mg/l	0.0
Cu	0.643 mg/l	0.0
Ni	5.15 mg/l	3.4
Pb	***	0.2
Zn	3.37 mg/l	3.1

***: below limit.

The EC in mS/cmvalues shows that inorganic ions such as Na^+ , K^+ , Mg^{2+}, Ca^{2+}, Cl^- , SO_4^{2-}, HCO_3^- are present in reasonable concentrations in leachate; such ions have major influence on the leachate conductivity . Existing elements, agricultural activities, Algae that grow with nourishment from nutrients entering the stream through leaf decomposition or other naturally occurring decomposition processes can also be a source of turbidity and bottom sediments. Conductivity is important in determining the relative degree of solid waste decomposition and detection of contamination migration. (James, 1977). The EC in Gaza and Dear Al Balah leachate range was 32200 µS/cm – 55400 µS/cm. (Alslaibi, 2009). Demonstrated that leachate conductivity in Palestinian areas are high in spite of low value in Al-Menya leachate. This mean there is a lot of contamination and solid waste decomposition in it.

Chemicaloxygen demand (COD) is the measure of the total quantity of oxygen required to oxidize all organic and some inorganic materials into carbon dioxide and water. COD values are always greater than BOD values, COD is an important parameter for its usefulness in determining the relative degree of solid waste decomposition, leachate treatment technique, detection of contaminant migration, and organic contamination. (James, 1977). The COD concentration in Al-Menya leachate was within the range 11000 and 11500 mg/l, this value considered as typical concentration rangeas in table 6. According to (Ehrig, 1990), COD for leachate from MSW were 6000 – 60000 mg/l. Also (Kruse, 1994), demonstrated that COD ranges for MSW leachate is 950 – 40000 mg/l. Related to (Alslaibi, 2009), COD ranges in Gaza leachate were 40000- 450000 mg/l, and in Dear Al Balah were 12840 – 46500 mg/l. So, Al-Menya leachate related to Palestinian areas was within the range.

Microorganisms such as bacteria are responsible for decomposing organic waste. And the existence of organic matter such as dead plants, leaves, grass clippings, manure, sewage, and food waste is present in leachate let bacteria begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria to live. BOD is the measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high. As the waste is consumed or dispersed through the leachate, BOD levels will begin to decline. The measure of biodegradable organic mass of leachate and that indicates the maturity of the landfill which typically decreases with time (Qasim et al., 1994). The BOD_5 is consistent with those recorded by other researchers (Jedrczak&Haziak, 1994).

Human and animal waste in the leachate is a significant contributor to elevate BOD levels. Fertilizers from farms and other sources contributes to accelerate eutrophication, in which contributes to the carbonaceous (organic) content of leachate as these plants die and decompose.

The chemical analysis of leachate shows that higher COD values, this indicated a high concentration of organic matter. The increased in dissolved heavy metals concentrations will be toxic to bacteria and inhibit BOD and COD reduction in leachate.

If we compare this tested value of BOD (4000 mg/l) with a study for (Ehrig, 1990), this value is within the range 4000 – 40000 mg/l. And within the range related to (Kruse, 1994) , 600 mg/l – 27000 mg/l (Alslaibi, 2009). BOD in Gaza leachate 887.5 mg/l – 28500 mg/l , and in Dear Al Balah between 800 mg/l and 11200 mg/l.

The BOD_5 to COD ratio in Al-Menya is 0.36 .Organics in leachate are characterized by different levels of biodegradability. The BOD_5/COD ratio is consistent with those recorded by other researchers (Koliopoulos&Koliopoulou, 2003; Alslaibi, 2009). Generally, the BOD_5/COD ratio describes the degree of biodegradation and gives information on the age of a landfill. The low BOD_5/COD ratio shows the high concentration of non-biodegradable organic compounds and thus the difficulty to be biologically degraded (Ntampou et al., 2006). In the study for (Alslaibi, 2009), this ratio is within the range in Gaza leachate 0.02 – 0.713 and within the range in Dear Al Balah leachate 0.017 – 0.441.

TheSodium (Na)is 5700 mg/l of Al-Menya leachate **,** this concentration value acceptable related to (Kruse, 1994) studied which ranging between 1 – 6800 mg/l, and belongs to (Ehrig, 1990),whereas this value exceeded the range 50 – 4000mg/l (UNEP, 2005).

The term “heavy metals” refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech, 2004). (Battarbee et al., 1988; Nriagu and Pacyna 1988; Nriagu, 1989; Garbarino et al., 1995, Hawkes, 1997). Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), mercury

(Hg), arsenic (As), silver (Ag) chromium (Cr), copper (Cu) iron (Fe), and the platinum group elements.

Cadmium (Cd)It is registered 3.66 mg/l more slightly than in Gaza 3.2 mg/l, and below the highest value in Dear Al Balah which is between 0.01 and 22.5 mg/l. (Alslaibi, 2009). But it is more than what recorded in a study that includes the values 0.0005 – 0.14 mg/l (Ehrig,1990). And this value recorded much more than another study that recorded concentration values within the range 0.0007 – 0.525 mg/l, (Kurse, 1994). This value for Al – Menya leachate related to cadmium compounds that used in metal electroplating, as stabilizers or pigments in plastics, batteries and alloys as a result of not separated wastes.

Zinc (Zn)concentration in the leachate sample is 3.37 mg/l.By comparing this value with the concentration in Gaza leachate, this metal recorded values within the range 5.6 – 65.5 mg/l. Dear Al Balah recorded values of 0.01 – 64 mg/l. (Alslaibi, 2009), and this value within the limit of the tow landfills. A study for (Ehrig, 1990) recorded different values for this metal, 0.1 – 120 mg/l, and the leachate sample concentration is within the range belongs to this study. The concentration of Zn from the leachate sample also within the range according to (Kurse,1994), 0.05 – 16 mg/l. The value 3.37 mg/l also as a result of not separated waste in the landfill.

Copper (Cu)is 0.643 mg/l in Al – Menya leachate.Gaza leachate recorded values from low detected limits to 6 mg/l. Also, Dear Al Balah leachate recorded small values, below detected values to 0.01 mg/l. (Alslaibi, 2009). A study for (Ehrig, 1990) represented range values for the concentration of Cu, 0.004 – 1.4 mg/l, and the concentration of this metal in the sample is within the range. Another study for (Kruse,1994) the Cu locates within this range 0.005 – 0.56 mg/l, this metal concentration in the sample is over this range. This type of heavy metal presents in the leachate due to the agricultural activities as a result of no separated waste stage in landfill.

Table 6 identifies and presents average concentrations ranges for some of hazardous and "conventional" pollutants characteristic of conventional municipal solid waste leachate of the early to mid-1980's. It indicates the presence of many known chemicals in concentrations that can readily render a groundwater unusable for domestic water supply purposes.

Table 6. Concentration Ranges for Components of Municipal Landfill Leachate (Jones-Lee & Lee, 1993)

Parameter	Typical Concentration Range
BOD	1,000 - 30,000 mg/l
COD	1,000 - 50,000 mg/l
Nitrate (as N)	0.1 – 10 mg/l
Ammonia (as N)	100 – 400 mg/l
Total Phosphate (PO_4)	0.5 – 50 mg/l
Total solids	3,000 - 50,000 mg/l
Total dissolved solids	1,000 - 20,000 mg/l
Calcium	100 - 3,000 mg/l
Magnesium	30 – 500 mg/l
Sodium	200 - 1,500 mg/l
Chromium (total)	0.05 – 1 mg/l
Cadmium	0.001 - 0.1 mg/l
Copper	0.02 – 1 mg/l
Lead	0.1 – 1 mg/l

Nickel	0.1 – 1 mg/l
Zinc	0.5 – 30 mg/l

Related to table 6 all parameters except Nitrate (as N) which is more than the limit value, Ammonia (as N) it is below the typical range, Ca is more little abet than the typical range, Na is too far than the typical range, also, Cd is too high than the limited range, Cu is within the range, Pb below the limited range, Ni is over the typical range, Zn is within the range.

The quantity of chemicals in the waste is finite and, therefore, leachate quality reaches a peak after approximately two to three years followed by a gradual decline in the following years (McBean et al., 1995). Table 7 and table 8, summaries the concentration changes of the most common of leachate pollutants with time.

Table 7. Landfill leachate composition vs. landfill age (Renou, 2008; Chian&Dewalle, 1976).

	Recent	Intermediate	Old
Age (years)	<5	5-10	>10
PH	6.5	6.5-7.5	>7.5
COD (mg/l)	>10000	4000 -10000	<4000
BOD5/COD	>0.3	0.1- 0.3	<0.1
Organic compounds	80% Volatile fat acids (VFA)	5-30% VFA+humic and fulvic acids	Humic and fulvic acids
Heavy metals	Low – medium	Low – medium	Low
Biodegradability	High	Medium	Low

According (Renou, 2008, Chian&Dewalle, 1976) landfills leachate are classified into three different stages, recent, intermediate, and old one according to different parameters as illustrated in table 8. With increasing the landfill age, PH of leachate tends to increase, while COD concentration decreases.

Table 8. Leachate characteristics with time (Koliopoulos and Koliopoulou, 2007)

Parameter	0 – 5 yr	5 – 10 yr	10 – 20 yr	>20 yr
BOD5 (mg/l)	4,000-30,000	1,000-4,000	50-1,000	<50
COD (mg/l)	10,000-60,000	10,000-20,000	1,000-5,000	<100
Ammonia (mg/l)	100-1,500	300-500	50-200	<30
pH	3-6	6-7	7-7.5	6.5-7.5
Chloride (mg/l)	500-3,000	500-2,000	100-500	<100
Sulphate (mg/l)	50-2,000	200-1,000	50-200	<50

BOD and COD concentration in Al-Menya leachate is 11000 and 4500 mg/l respectively. The concentration of both test is highly concentration this due to that the Al-Menya leachate was classified as young leachate which characterized with higher concentration of BOD and COD,.

Generally, leachate from new landfills will be high in BOD and COD and will then steadily decline, leveling off after about 10 years (Akyurek, 1995). Due to their initially biodegradable nature, organic compounds decrease more rapidly than inorganic with increasing age of the landfill (Chian&DeWalle, 1977). Inorganic is only removed as a result of washout by infiltrating rainwater (Qasim& Chiang, 1994).

In other hand the BOD/COD ratios 0.5 which enhancement that Al-Menya leachate is young landfill leachate and its possible for biological treatment(Renou, 2008; Chian&Dewalle, 1976).BOD/COD ratio decreases as the landfill ages increase and more degradation products are leached from deposited residues (Copa et al., 1995; Reinhart and Grosh, 1998). Many investigations have been carried out to prove the biological treatment suitability for young landfill leachates (Baig et al.,1996).

Due to previous results and comparing studies, Al-Menya leachate can classified as young leachate related to COD which is more than 2000ppm, BOD/COD>0.3 (Renou, 2008; Chian and Dewalle, 1976).

3.2 Leachate Treatment Using Physical and Biological Methods

This section illustrated the treatment process used. At first, physical treatment as primary stage before the effluent transferred to biological treatment using SBR process, then the effluent from this stage were transferred to physical treatment which represented by using UF and the effluent of UF injected to RO system.

3.2.1 Biological Treatment

The leachate samples were treated using physical, biological and physical processes. The leachate in primary stage was treated using physical process ,the leachate was transferred to separated tank (settling tank) to remove settelable solids before secondary stage as biological treatment process. The biological treatment process consist of activated sludge process using SBR type before transfer to advanced treatment stage included ultra-filtration and reverse osmosis.

The effluent of primary stage passed to SBR reactor for biological treatment. The optimization condition for SBR operation were adjusted according to previous parameters, filling time, reaction time, aeration time, settling time, decant time and idle time, Samples from the influent and effluent of SBR system were taken during the cycles to controlling the biological efficiency, The first stage of SBR operation was adaptation of the system using activated sludge from Jericho WWTP in addition to using dilution samples from Al-Menya leachate samples with different ration (1:10, 1:5, 1:2 and1:1) during three months.

3.2.2 Optimization and Calculations of SBR Model Design

The optimization and calculation of SBR system was requested before starting the biological treatment. Primary calculation of SBR parameters was calculated to have an efficient treatment method. The calculation results were compare with ideal operation conditions of SBR. Tables 9 and 10 summarizes the optimized condition of SBR and Al- Manya leachate calculation.

3.2.2.1 Optimization Parameters

The food/microorganism (F/M) ratio is the digester loading divided by the concentration of volatile suspended solid (biomass) in the digester. For any given loading, efficiency can be improved by lowering the F/M ratio, decreasing the loading, increasing the concentration of biomass in the digester. The F/M can be calculated as follows (Latif., 2011).

F/M= Organic loading rate (OLR)/ volatile solids(VS) (1)

Where,

Organic loading rate = COD of the influent stream (kg-COD/L.day)
Volatile solid = Volatile suspended solid concentration in the reactor (kg-VSS/L)
F/M = kg-COD/kg-VSS.day.

The Hydraulic Retention Time (HRT) isthe calculation of hydraulic retention time before proceeding experiments is also an important process as a control parameter, as in equation (2) it show the total time required by the liquid to degrade. The HRT plays an important role while anaerobic digestion of which the liquid has to stay within the digester until degradation (Latif, 2011).

$$HRT = COD_{in} / OLR \qquad (2)$$

The Flow Rate wascalculated according to equation (3).The HRT and flow rate, measure the exact influent stream from feed inlet to outlet. Normally, flow rate is controlled by means of a dose pump. The flow rate is designed according to the working volume (V_w) of the reactor (Latif, 2011) .

$$Q = V_w / HRT \qquad (3)$$

Table 9. The Conditions parameters of SBR process

Condition	Aerobic
Fill	3 L of raw leachate were pump and mixes with activated sludge in the reactor for 1 hr.
React	Mixing occur by using electrical driving speed. Air supply was provided during the aerobic phase of react period. Biological reactions occur until the desired degree of treatment has been achieved, for 3hrs.
Settle	Aeration is stopped. The activated sludge solids settle down to form a blanket on the base of the reactor beaker, leaving an over-layer of treated effluent, for 2hrs.
Decant	The liquid surface which is effluent (supernatant) is removed from tank, for 1hr.
Idle	Period between Decant and Fill.

From this table, as illustrated there is five phases in the SBR, each phase was optimized with a certain hours; each phase is very important except the final one.

Table 10. A comparison between the typical operation condition for SBR and the operation conditions of our SBR system.

Conditions	Typical	Lab SBR
HRT (day)	0.44 – 12	1. 5
F/M	0.25 - 0. 50	0.477
Q(MG)	**	0.317X 10^{-4}
MLSS (ppm)	500 – 24650	20108.4
MLVSS (Ib)	**	0.2215
Total cycle (hr)	6 – 8	7
SVI (ml/g)	15 -150	24.119
Aeration (l/min)	0.2 - 11.9	3
React time (hr)	3 - 22. 5	3
Settle time (hr)	0.17 - 2.84	2
Decant time (hr)	0.08 – 1	1
Fill time (hr)	0.02 – 3	1

**: not fount

As illustrated in table 10, there were some important conditions for success biological treatment. Some of them illustrated in equations (1 – 3), and some illustrated in table 9. Sludge Volume Index (SVI), used to describe the settling characteristics of sludge in the aeration tank in activated sludge process, it is defined as the volume (in ml) occupied by 1 gram of activated sludge after settling the aerated liquor for 30 minutes. Hydraulic Retention Time (HRT), is the average residence time of wastewater in the aeration tank. Food to Microorganism (F/M), is the amount of BOD to which a unit mass of biosolids is exposed on a daily basis (loading based on microorganisms). Wastewater flow (Q), it measured in million gallons per day (m^3/day). All the parameters were calculated and compared with the typical rates through the optimization stage of the SBR system to make sure the sludge used was effective for biological treatment.

3.3 Stages within SBR Treatment

Biological systems was applied using SBR as type of activated sludge treatment process. The pretreatment stage of biological treatment is the primary stage using settling by gravity. The optimized operation settling time was adjusted according to variable time using different experimental cycles, many experiment were investigated for primary treatment before adaptation the final cycles as a biological treatment results which then transferred for physical treatment. These are as the following:

3.3.1 Experiment of Sludge Efficiency

The primary treatment help to decrease the settelable solids in leachate samples, this will decrease the biodegradable compound in leachate samples. The primary treatment was implemented by settling the leachate samples in separaated tank under variation condition to assess the efficient settling time before secondary treatment. At this stage, before begins in biological treatment, we make justification to the AS, table 11 illustrated the physical parameters of leachate treated using primary treatment process under variation time (2, 4, and 6 hours).

Table 11.Physical characteristics of Al-Menya leachate after primary treatment process at different settling time.

Time (hrs)	PH	EC (Ms/cm)	TDS (mg/l)	Turbidity (NTU)	TSS (mg/l)
After 2:00	8.2 ± 0.5	1060 ± 4.0	530 ± 5.0	2518 ± 2.0	251± 2.0
After 4:00	8.2 ± 0.5	1110 ± 3.0	520 ± 6.0	2423 ± 3.0	220 ± 2.0
After 6:00	8.2 ± 0.6	960 ± 1.0	500 ± 6.0	2361 ± 6.0	265 ± 0.7

From this table, AS is efficient due to the decreasing occur in EC, TDS, Turbidity, and TSS among time. TSS concentrations was increased, this was due to bulky sludge formation.

According to our results the optimum settling time is two hours due to approximately same efficiency removal with low operation time compare to other settling time, this will help to save time to accelerated the other treatment process.

3.3.2 Experiment of Settling Time Adjustment Using SBR

The settling stage of SBR is the step which follow the filling and aeration process at which the aeration process was stopped and sedimentation was happened to separated between liquid phase and solid phase as a function of time. Variation of settling time were examined with different leachate dilutions to investigated the efficient settling time. The decrease in organic load represented by COD in mg/l which is the indication of organic removal in effluent. Figures 15-17 summarizes the variation of dilution and concentrated leachate with organic load concentration represented with COD in mg/l for effluent at different settling time. The dilution samples were first added to SBR system without measurement aimed to adaptation of activated sludge with diluted leachate samples.

The importance of settling stage is to minimize large particles from passing to the SBR, to avoid clogging either in the tubes or in the pump. Figure 9, illustrate how organic matter decrease with increase settling time. So, this stage is important for treatment as a primary treatment. This was studied on three samples from the same leachate container that preserved in the refrigerator.

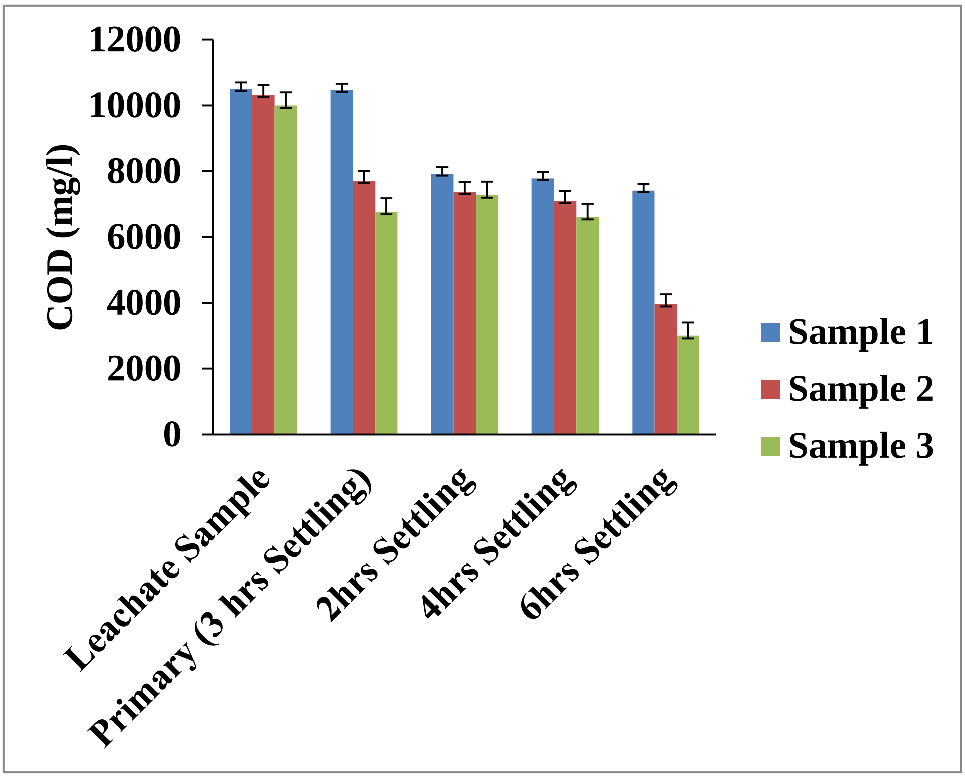

Fig.9: Effect of settling time in SBR process on organic matter.

Figure 10 is for a new experiment for complete SBR cycles extended for 8 hours using diluted (1:4) and concentrated leachate samples. The samples first treated in settling tank as primary treatment and left to settled 2 hours, then samples pumping to SBR reactor for biological treatment. The SBR cycle consist of 1 hour filling, 3 hours aeration, 2 hour settling, 1 hour for decantation and 1 hour for Idle. Samples from raw leachate, after primary treatment and at end of cycles were taken for organic concentration analysis, that represented in figure 10 by tow cycles, each one was 8 hours. The primary results of diluted samples shows higher removal than concentrated samples due to high concentration of organic matter in raw leachate and less adaptation of activated sludge media.

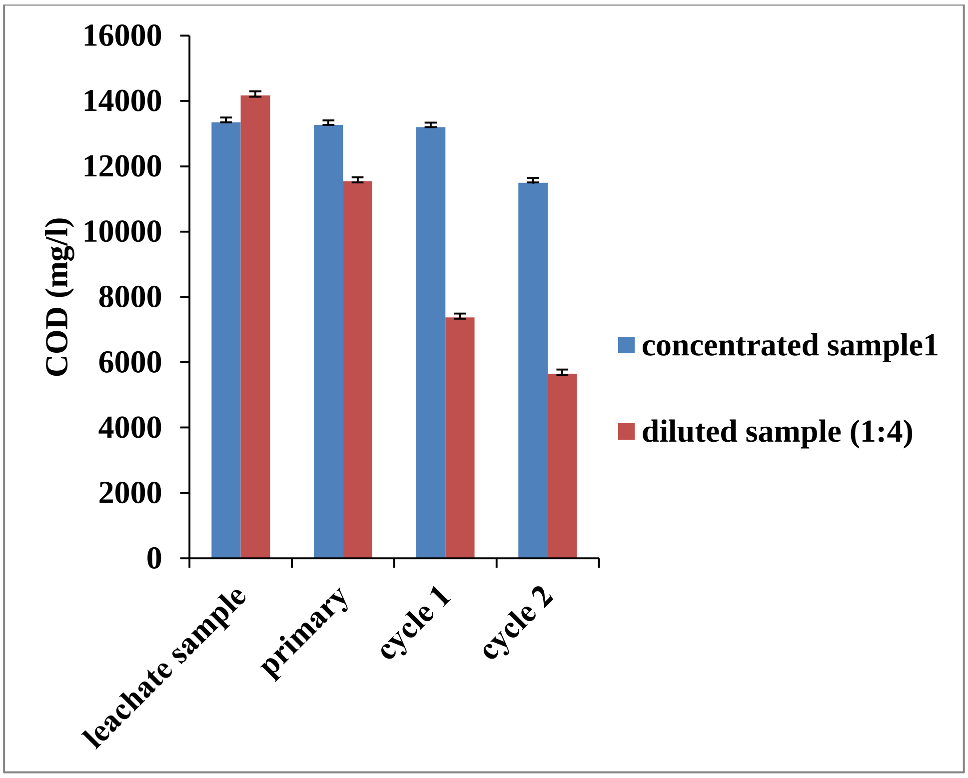

Fig.10: organic matter concentration with cycles for concentrated and diluted samples using SBR.

3.3.2.1 SBR Cycles Characteristics

Many cycles were monitored during adaptation and treatment of diluted and concentrated leachate using SBR. The COD concentration and other leachate quality parameters were measured to assessment the efficiency of SBR treatment.

3.4 Biological Treatment

The leachate samples treated first using primary treatment by settling for 2hrs, then sample was taken to analyze, after that we pump the sample to the SBR. The sample first filling in the reactor within 1 hr, aeration with mixing for 3 hrs, settling for 2 hrs, decantation and finally IDEL, samples were taken from primary and at the end of cycles after 8 hrs.

Table (12) summarizes the average physical and chemical characteristics of leachate after completed SBR treatment. Currently, the quality of landfill leachate effluents has to be comply with discharge standards.

Table 12. The average physical and chemical characteristics of influent and effluent leachate samples after completed biological treatment using SBR cycle. The total time (8 hrs) , filling time: 1hr , reaction time: 3hrs, settling time: 2hrs, decantation time: 1hr, and idle time: 1hr. Under HRT: 1.5 day and temperature: 25°C.

Characteristics	Influent	Effluent	Removal %
COD (mg/l)	11000 ± 400.0	1330 ± 75.0	(88%)
TSS (mg/l)	2500 ±5.3	124 ± 6.0	(95%)
Ammonia-Nitrogen (mg/l): NH_3^+-N/NH_4^+/NH_3	0.48 /0.62 /0.58 ± 0.1	0.0 ± 0.0	(100%)
Nitrate: (mg/l) NO_3—N/NO_3^-	19.57 / 4.4 ± 0.2	13.00/3.0 ± 0.3	(34% /32%)
Phosphate (mg/l)	8.00 ± 0.5	0.289 ± 0.1	(96%)
Na (mg/l)	5700 ± 34.0	730 ± 23.0	(87%)
K (mg/l)	1000 ± 25.0	659 ± 38.0	(34%)

The samples were taken from raw leachate and at the end of SBR cycle. Tow samples were analyzed each time, one after primary (before starting SBR and after settling), and another one after 8 hours from SBR. The results show that COD decreased from 11000 mg/l to 1330mg/l with percentage removal 88%, TSS decreased from 2500 mg/l to 124 mg/l with removal percentage 95% for TSS. Complete removal in Ammonia-Nitrogen from the effluent. But nitrate scored a little reduction ((34 -32) %, from 19.57 mg/l as NO_3—N to 13 mg/l, and from 4.4 mg/l as NO_3^- to 3 mg/l) if compared with the other parameters. Phosphate decreased from 8 mg/l to 0.3 mg/l as 96% percentage removal. Also, the percentage removal of Na was 87%, it decreased from 5700 mg/l to 730 mg/l. K decreased by 34%, from 1000 mg/l to 659 mg/l. The results indicated that SBR was efficient in decreasing the organic load of raw leachate samples.

A. Comparing Percentage Removal with Previous Studies

The COD concentration of Leachate influent was ranging between (11000 and 11500 mg/l) during all experiments, the effluent reduced in biological treatment to 1330 mg/l with 88% removal. This percentage removal if we compared it with a study for (Aziz et al., 2011) a reduction in COD by (75 – 83)% was achieved. Another study showed that the removal efficiency that has been achieved by this process was 94.9% for COD (Mahvi et al., 2005). So, SBR enhanced the COD reduction. On the other hand the TSS removal is 95%. In a study related to (USEPA, 1992), a reduction in TSS recorded (85-97%). But there is a little removal than what we achieved, a removal percentage by 44% (Butkovskyi, 2009). PO_4 - P reduced by 96%. A study by (EPA, 1992) recorded a removal percentage was within the range (57-69%). Another study showed that the removal efficiency that has been achieved by this process was (55.9%) for PO_4 - P (Mahvi et al., 2005).

B. Comparing percentage removal with Palestinian Standards for Treated Wastewater (Ministry of Environmental Affairs, 2000; Zimmo et al., 2005).

By comparing these results with (PSTW), the concentration of ammonia, nitrate, and phosphate, within the range, can dispose as far as 500m to sea water, irrigate (dry feeds, green feeds, parks, beans, citrus trees, olive trees, and almond trees).

The removal of total organic carbon (TOC), COD, BOD, and Ammonium from leachate is prerequisite before discharging leachates into natural waters.

C. Comparing percentage removal with Australian treated wastewater discharge standards (EPA, 2005)

Related to Australian treated wastewater discharge standards, and maximum overseas treated leachate discharge limits, all analysis has confirmed the potential adverse effects of landfill leachate and there is a necessary to treat it to meet these standards, except phosphate which it is acceptable.

3.5 Physical Treatment

As mentioned before the effluents from biological treatment used as influent for physical treatment. First the sample passes through UF then through RO membranes.

3.5.1 Ultrafiltration Treatment

Table 13 summarizes the physical and chemical of leachate samples after treatment using biological stage and UF unit compare to raw leachate influent. As further and enhancement treatment stage in addition to biological treatment, this process prevent and reduce any clogging may occur before leachate reaches the RO. The treatment of SBR effluent using UF unit shows highly efficient of UF unit for TSS, Nitrate, and phosphate, Al, Zn, removal with (100%),(98 %),(95%), (100%), (82%), respectively. The ultrafiltration porosity prevent the suspended and large dissolved solid from passing through the membrane.

Table 13. Physical and chemical characteristics of leachate effluent after treatment using biological stage and UF unit compare to raw leachate influent.

Characteristic	Influent	Effluent (UF)	Removal %
COD (mg/l)	11000 ± 400	975 ± 20.0	(91%)
BOD (mg/l)	4000 ± 250	280 ± 3.0	(93%)
TSS (mg/l)	2500 ± 5.3	0.0 ± 0.0	(100%)
TDS (mg/l)	2000 ± 0.0	350 ± 0.0	(83%)
EC (mS/cm)	5.96 ± 0.1	0.7 ± 0.0	(88%)
Turbidity (NTU)	3000 ± 5.8	0.0 ± 0.0	(100%)
Ammonia-Nitrogen (mg/l): NH_3^+-N/NH_4^+/NH_3	0.48 /0.62 /0.58 ± 0.1	0.0 ± 0.0	(100%)
Nitrate: (mg/l) NO_3¯N/NO_3^-	19.57 / 4.4 ± 0.0	0.3 / 0.1 ± 0.1	(98 % / 98%)
Phosphate (mg/l)	8.00 ± 0.0	0.422 ± 0.0	(95%)
Na (mg/l)	5700 ± 0.1	338.68 ± 0.0	(94%)
K (mg/l)	1000 ± 0.0	377 ±	(62%)
Al (mg/l)	3.86 ± 0.0	0.531 ± 0.0	(100%)
Cd (mg/l)	3.66 ± 0.0	3.64 ± 0.0	(0.55%)
Zn (mg/l)	3.37 ± 3.1	0.622 ± 0.3	(82%)
Ag (mg/l)	***±0.00	***	***
Cr (mg/l)	5.22±0.00	5.07 ± 0.0	3%
Cu (mg/l)	0.643±0.00	0.393 ± 0.0	39%
Ni (mg/l)	5.15±3.38	5.23 ± 3.5	
Pb (mg/l)	***±0.186	*** ± 0.08	***

***: below limit.

3.5.2 Reverse Osmosis Treatment

The effluent of UF then passed through RO membrane under high pressure. Table summarizes the variation between the raw leachate (influent) and RO effluent. It shows the Physical, biological and chemical of leachate effluent after treatment using biological stage and UF unit compare to raw leachate influent.

Table 14. Physical and chemical of leachate effluent after treatment using RO unit compare to raw leachate influent.

Characteristic	Influent	Effluent (RO)	Removal %
COD (mg/l)	11000 ± 400.0	345 ± 24.0	(97%)
BOD (mg/l)	4000.0 ± 250	117 ± 2.0	(97%)
TSS (mg/l)	2500 ± 5.3	0.0 ± 0.0	(100%)
TDS (mg/l)	2000 ± 0.0	40 ± 0.0	(98%)
EC (mS/cm)	5.96 ± 0.1	0.09 ± 0.0	(98%)
Turbidity (NTU)	3000 ± 5.8	0.0	(100%)
Ammonia-Nitrogen (mg/l): NH_3^+-N/NH_4^+/NH_3	0.48 /0.62 /0.58 ± 0.1	0.0 ± 0.0	(100%)
Nitrate: (mg/l) NO_3^-‾N/NO_3^-	19.57 / 4.4 ± 0.0	5 / 1.1 ± 0.0	(74 %) /(75%)
Phosphate (mg/l)	8.00 ± 0.0	0.400 ± 0.0	(95%)
Sodium (mg/l)	5700 ± 0.1	136 ± 0.0	(98%)
K (mg/l)	1000 ± 0.0	9.47 ± 0.0	(99%)
Al (mg/l)	3.86 ± 0.0	0.00 ± 0.0	(100%)
Cd (mg/l)	3.66 ± 0.0	3.63 ± 0.0	(0.82%)
Zn (mg/l)	3.37 ± 3.1	1.09 ± 0.2	(68%)
Ag (mg/l)	***±0.00	***	***
Al (mg/l)	3.86 ±0.00	***	***
Cr (mg/l)	5.22±0.00	4.88 ± 0.0	(7%)

Cu (mg/l)	0.643±0.00	0.669 ± 0.0	
Ni (mg/l)	5.15±3.38	4.93 ± 3.46	(4%)
Pb (mg/l)	***±0.186	1.09 ± 0.2	

***: below limit.

A. Comparing percentage removal with previous studies

The COD concentration of leachate influent was 11000 mg/l during all experiments, the effluent reduced in UF to 975 mg/l with 91% removal. The elimination of COD reached values within the range between 10 and 75% (Bohdziewicz et al., 2001), so related to this study a clear reduction in COD we achieved. On the other hand the effluent using RO lead to more reduction in COD to 345 mg/l with 97% removal Related to experimental studies of (Krug &McDongall, 1989; Kinman&Nutini, 1991; Bilstad&Madland, 1992) showed that RO technology elimination of COD reached 99%. The removal efficiency of some organic and inorganic pollutants exceeded 98% (Liu et al., 2008).

B. FAO guidelines in irrigation water (FAO, 1985)

TDS effluent from UF was 350 mg/l, and from RO was 40 mg/l. The restriction degree of TDS of water quality for irrigation below 450 mg/l, so there is no any restriction for this parameter on use for irrigation.

NO_3- N was 0.3 mg/l by UF, and this value was below the standard limit which it <5 mg/l, and 5.0 mg/l by RO, and this value was within the standard range 5 – 30 mg/l. So, UF effluent considered to be without restricted on use this treated wastewater effluent for irrigation, but there is a slight to moderate restriction on using RO effluent for irrigation.

Na concentration effluent by UF was 338 mg/l, and 136 mg/l by RO. The restriction degree of Na of water quality for irrigation related to these concentrations was >69 mg/l, so the restriction for this parameter on use for irrigation was slight to moderate.

Heavy metalsconcentration in mg/l in the UF effluent are as the following Al, Cd, Zn, Cr, Cu, and Ni, 0.531, 3.64, 0.622, 5.07, 0.393, and 5.23 respectively, and the RO effluent for the same heavy metals with the same order as in UF were 0.00, 3.63, 1.09, 4.88, 0.669, and 4.93 respectively. Related to FAO standards, these heavy metals concentrations as the following 5.00, 0.10, 2.00, 0.10, 0.20, 0.20 mg/l. This treated water either UF or RO effluents were inefficient as irrigated water, because these heavy metals in the leachate sample were exceeded the FAO standards.

C. WHO Guidelines for Interpretations of Water Quality for Irrigation (adapted from University of California Committee of Consultants 1974)

BOD_5effluent from UF was 280 mg/l, and from RO was 116 mg/l. The permitted limit by WHO related to these values were within the range ≤ 240 mg/l, this range permitted irrigation of ornamental fruit trees and fodder crops.

TSS effluent from UF was 0.0 mg/l, and from RO was 0.0 mg/l. The permitted limit by WHO related to these values were within the range ≤ 140 mg/l, this range permitted irrigation of ornamental fruit trees and fodder crops, irrigation of vegetables likely to be eaten uncooked, and for toilet flushing.

D. Comparing percentage removal with Palestinian Standards for Treated Wastewater (Ministry of Environmental Affairs, 2000; Zimmo et al., 2005).

By comparing these results with (PSTW), the concentration of Nitrate - N concentration in UF and RO effluents recorded 0.3 mg/l and 1.1mg/l, respectively. These concentrations are below the range (25 – 50) mg/l according to Palestinian standards. So, related to this parameter we can discharge leachate within all application of Palestinian standards except feeding aquifer by filtration. TSSin the tow effluents (RO, and UF) had a complete removal. So, we can discharge leachate for any application of Palestinian standards acceptable either for (discharge it to sea water along 500m, feeding the aquifer by filtration, irrigate dry and green feed, irrigate garden courts, irrigate grains, irrigate forest trees, irrigate citrus fruits, irrigate olive trees, and irrigate almond trees). COD concentration effluents in UF and RO are 975 mg/l and 345 mg/l, respectively. But it should decrease to the range 150 – 200 mg/l to discharge it as Palestinian standards apply. So we need further treatment to reduce organic matter more.

BOD concentration of Al-Menya leachate by UF is 280 mg/l and 117 mg/l using RO. Palestinian standard for BOD is within the range 40 – 60 mg/l. So we need more treatment to reduce organic matter.

PO_4 – P concentrationis 0.422 mg/l in UF effluent and 0.400 mg/l in RO effluent and these concentrations are below the Palestinian standards (5 – 30) mg/l. Also, Naconcentration in UF effluent is 339 mg/l and it is 136 mg/l in RO effluent. This concentration is more a little than Palestinian standards (200 – 230) mg/l. So, related to these tow parameters (PO_4 – P and Na) we can discharge leachate within all application of Palestinian standards.

Heavy metalsconcentration in mg/l in the UF effluent are as the following Al, Cd, Zn, Cr, Cu, and Ni, 0.531, 3.64, 0.622, 5.07, 0.393, and 5.23 respectively, and the RO effluent for the same heavy metals with the same order as in UF are 0.00, 3.63, 1.09, 4.88, 0.669, and 4.93 respectively. Palestinian standards for these metals are (1 – 5), 0.01, (2 – 5), (0.05 – 0.1), 0.2, and 0.2 mg/l respectively. Further treatment needed for Cd, Cr, Cu, and Ni.

E. Comparing percentage removal with Australian treated wastewater discharge standards (EPA, 2005)

Related to Australian treated wastewater discharge standards BOD in UF and RO need more treatment to be reduced from 280 mg/l and 117 mg/l respectively to reach Australian standards 10 mg/l. PO_4 – P concentration is 0.422 mg/l in UF and 0.4 mg/l in RO, these need a little treatment to reach the standard 0.1 mg/l.

Heavy metalsconcentration in mg/l in UF effluentas the following Cd, Zn, Cr, Cu, and Ni, 3.64, 0.622, 5.07, 0.393, and 5.23 respectively, and the RO effluent for the same heavy metals with the same order as in UF are 3.63, 1.09, 4.88, 0.669, and 4.93 respectively. Palestinian standards for these metals are 0.002, 0.05, 0.001, 0.01, and 0.15 mg/l respectively. All heavy metals mentioned have confirmed the potential adverse effects of UF and RO effluents and there is a necessary to treat these heavy metals to meet these standards.

In general, Australian discharge standards are not compatible with the treated leachate of Al – Menya landfill, either by UF or RO.

Chapter Four: CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. More SBR cycles with considering the activity of the sludge may give more decrease in organic matter, to attain a successful usage for this type of treated water.
2. We observed that there were an obvious decrease in organic matter as indicated by COD and BOD either biologically or physically.
3. Relating to Palestinian Standards for Treated Wastewater, most parameters were within the range , and we need further treatment for the following COD, BOD, Cd, Cr, and Ni, these should decrease by 40%, 50%, 70%, and 96% respectively, to reach the standards that let the treated leachate acceptable either for discharge it to sea water along 500m, feeding the aquifer by filtration, irrigate dry and green feed, irrigate garden courts, irrigate grains, irrigate forest trees, irrigate citrus fruits, irrigate olive trees, and irrigate almond trees.

4.2 Recommendation

The researcher recommended for future researches:

- Physical treatment after biological treatment using different adsorbents will enhance the biological treatment.

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Appendices

Appendix A. ICP RESULTS

Date : 14/10/2015 13:37 Page: 1

ACTIVA Analytical Method

Analytical method:	Sludge Project
Matrix:	
Source type:	ICP
Author:	Administrator
Creation:	13/10/2015 11:36
Last modification:	13/10/2015 12:43

Line: **Ag, 338.289 nm**

Calibr. curve: I = 70920 + 188441 * C

Parameters of curve

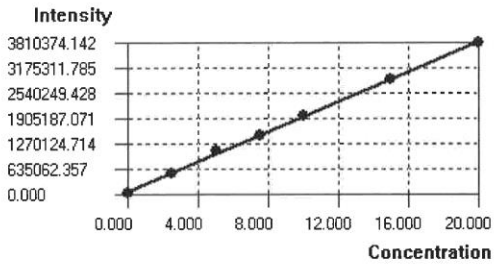
Sigma : 0.226716

BEC : 376 µg/l

LOD : ***

Correl. : 0.999569

Weight: not used



#	Sample Name	Intensity	Chem. Conc.	Calc. Conc.		Rel. dev(%)	Valid
1.	10.0 PPM	1970535.2	10.00	10.08	mg/l	0.81	Yes
2.	15.0 PPM	2908221.7	15.00	15.06	mg/l	0.38	Yes
3.	2.5 PPM	527138.81	2.50	2.42	mg/l	3.16	Yes
4.	20.0 PPM	3810374.1	20.00	19.84	mg/l	0.78	Yes
5.	5.0 PPM	1086406.7	5.00	5.39	mg/l	7.78	Yes
6.	7.5 PPM	1476986.5	7.50	7.46	mg/l	0.51	Yes
7.	Blank	23231.44	0	0	mg/l		Yes

Line: **Al, 237.312 nm**

Calibr. curve: I = 14198 + 18830 * C

Parameters of curve

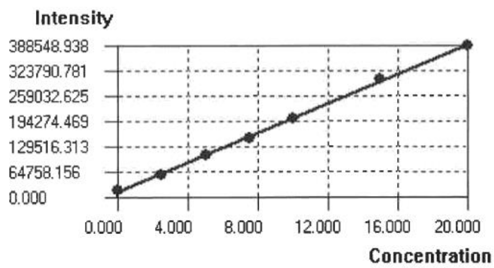
Sigma : 0.183263

BEC : 754 µg/l

LOD : ***

Correl. : 0.999719

Weight: not used



Date: 14/10/2015 13:26 **Analysis** Page 1

ACTIVA : 0.0.0.0.0

Sequence :	Sludge Project Sampl	Sample :	L1
Date :	14/10/2015 12:42	Method :	Sludge Project

Weight : 1.000 Volume: 1.000 Dilution: 1.000

Concentrations

Elements Lines	Conc.	SD		RSD (%)	Low Limit	High Limit
Ag	***	0.000945	mg/l	0.35		
Al	0.386	0	mg/l	0		
Cd	0.366	0	mg/l	0		
Cr	0.522	0	mg/l	0		
Cu	0.0643	0	mg/l	0		
Ni	0.515	3.38	mg/l	657.0		
Pb	***	0.186	mg/l	44.14		
Zn	0.337	3.07	mg/l	912.1		

Date: 14/10/2015 13:26 **Analysis** Page 1

ACTIVA : 0.0.0.0.0

Sequence :	Sludge Project Sampl	Sample :	L2
Date :	14/10/2015 12:48	Method :	Sludge Project

Weight : 1.000 Volume: 1.000 Dilution: 1.000

Concentrations

Elements Lines	Conc.	SD		RSD (%)	Low Limit	High Limit
Ag	***	0.00014	mg/l	0.053		
Al	***	0.00301	mg/l	2.23		
Cd	0.363	0	mg/l	0		
Cr	0.488	0	mg/l	0		
Cu	0.0669	0	mg/l	0		
Ni	0.493	3.46	mg/l	701.3		
Pb	***	0.119	mg/l	19.45		
Zn	0.109	0.162	mg/l	148.4		

Date: 14/10/2015 13:27 **Analysis** Page 1

ACTIVA : 0.0.0.0.0

Sequence :	Sludge Project Sampl	Sample :	L3
Date :	14/10/2015 13:10	Method :	Sludge Project

Weight : 1.000 Volume: 1.000 Dilution: 1.000

Concentrations

Elements Lines	Conc.	SD		RSD (%)	Low Limit	High Limit
Ag	***	0.000697	mg/l	0.27		
Al	0.0531	0	mg/l	0		
Cd	0.364	0	mg/l	0		
Cr	0.507	0	mg/l	0		
Cu	0.0393		mg/l			
Ni	0.523	3.54	mg/l	677.5		
Pb	***	0.0756	mg/l	34.83		
Zn	0.0622	0.305	mg/l	491.0		

Appendix B. Calibration Curves for different water quality analysis:

Figures 1-7 illustrated the calibration curves of variation tests, The tests included COD, Na^+, K^+, Mg^{2+}, Ca^{+2}, PO^{-3}_4 and NH^+_4.

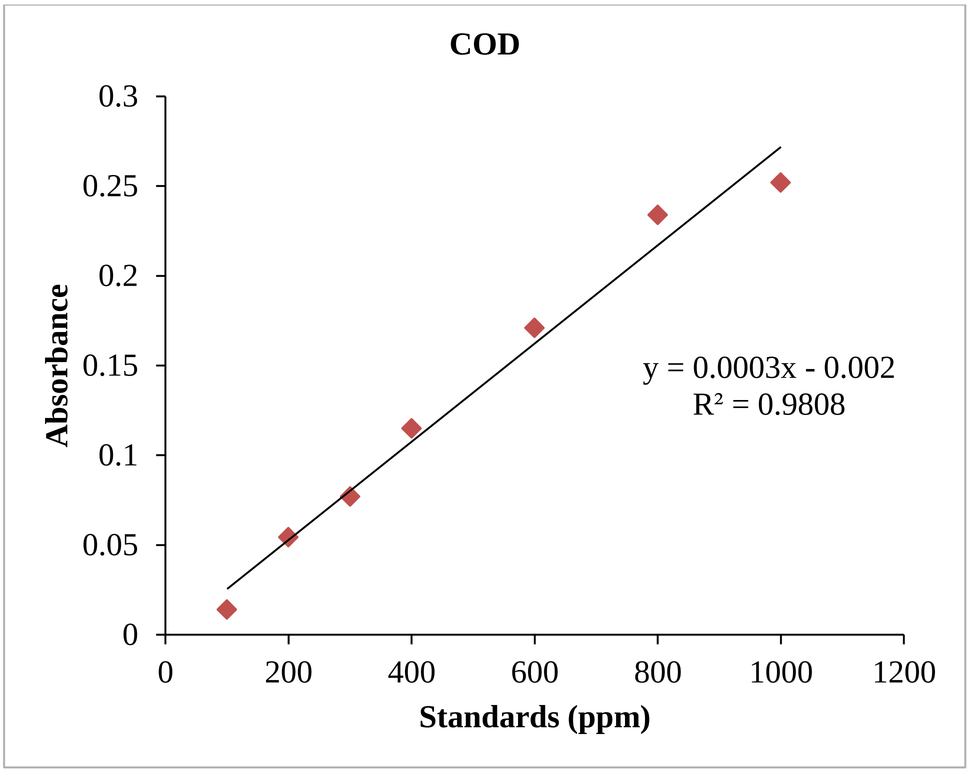


Fig.1: Calibration curve for COD (ppm) measurements.

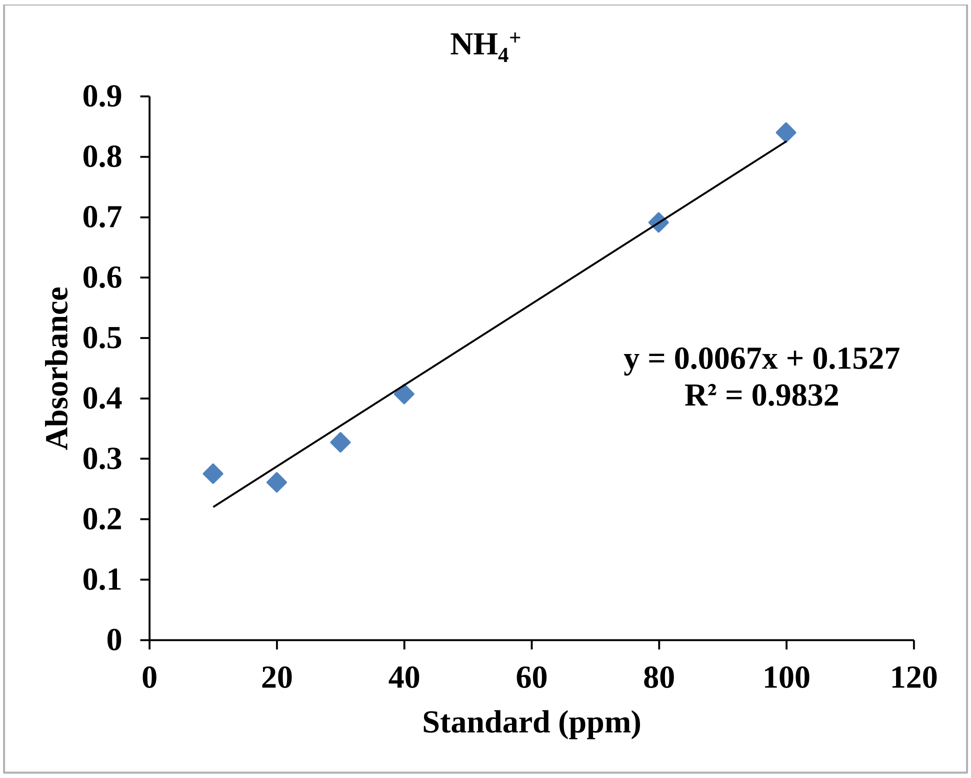


Fig.2: Calibration curve for NH_4^+ in ppm.

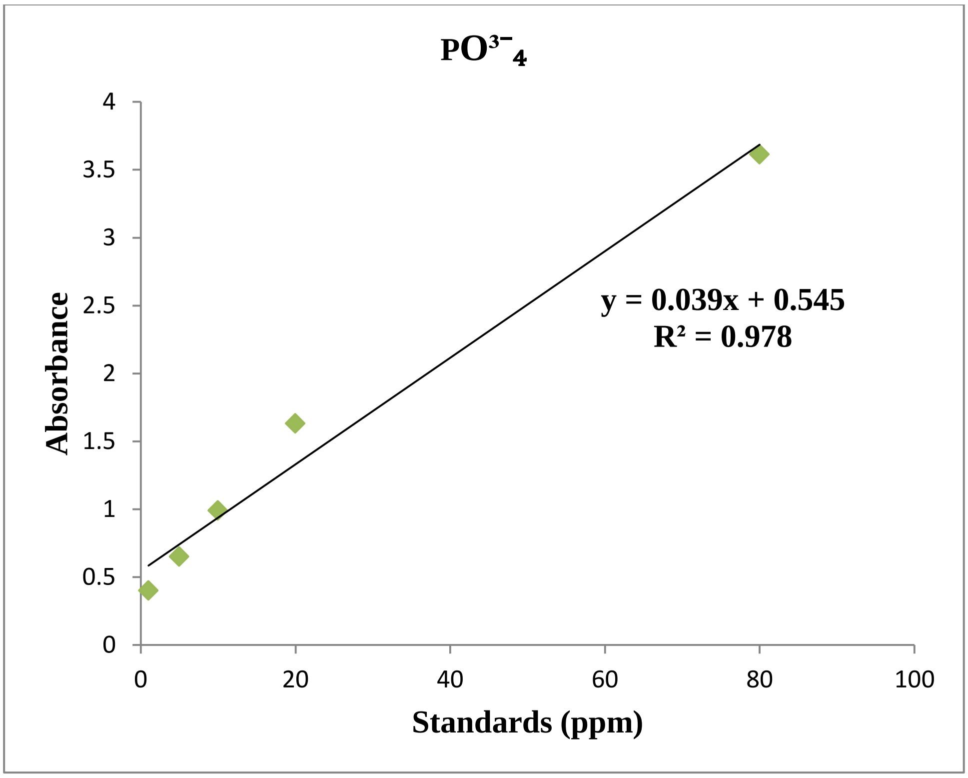


Fig.3: Calibration curve for PO_4^{-3} in ppm.

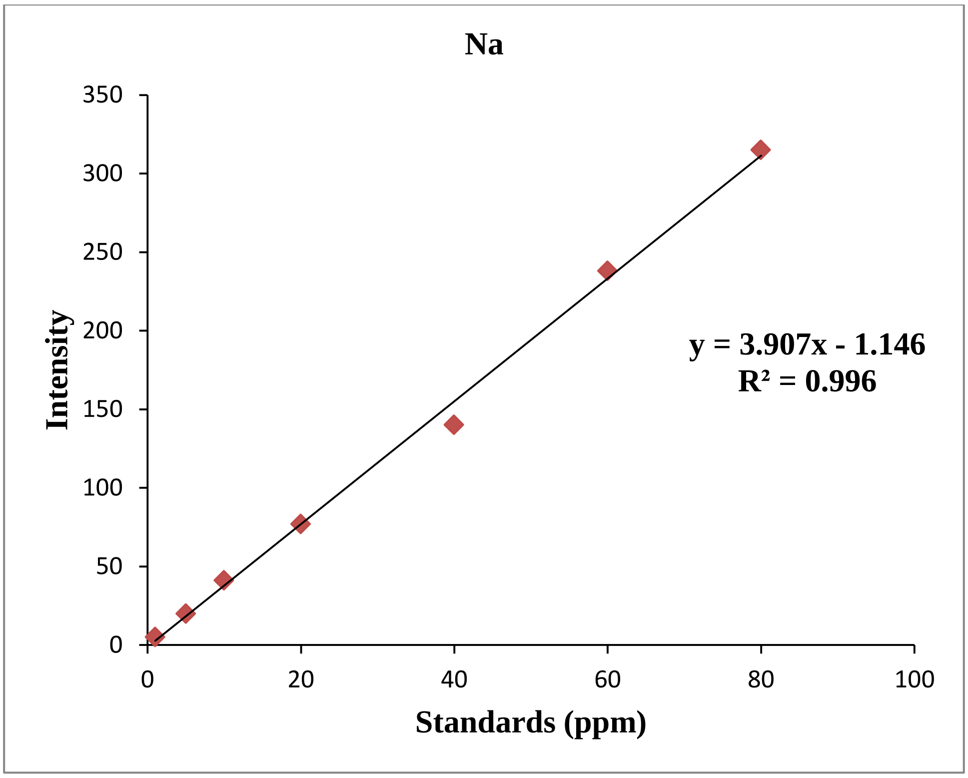


Fig.4: Calibration curve for Na^+ in ppm.

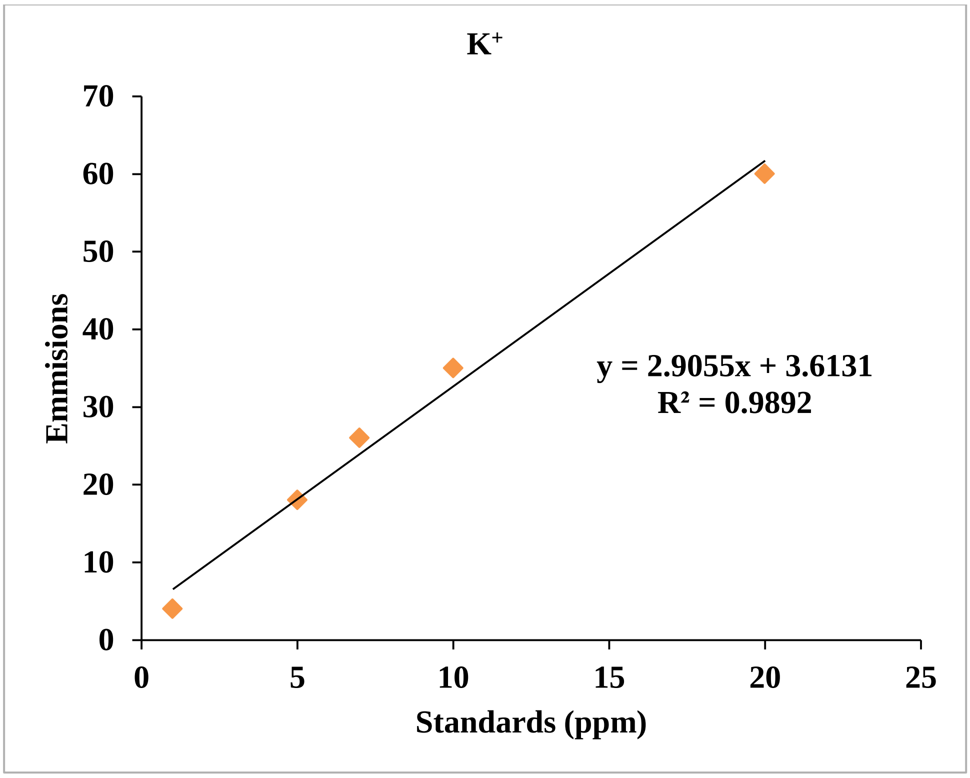


Fig.5: Calibration curve for K^{+} in ppm.

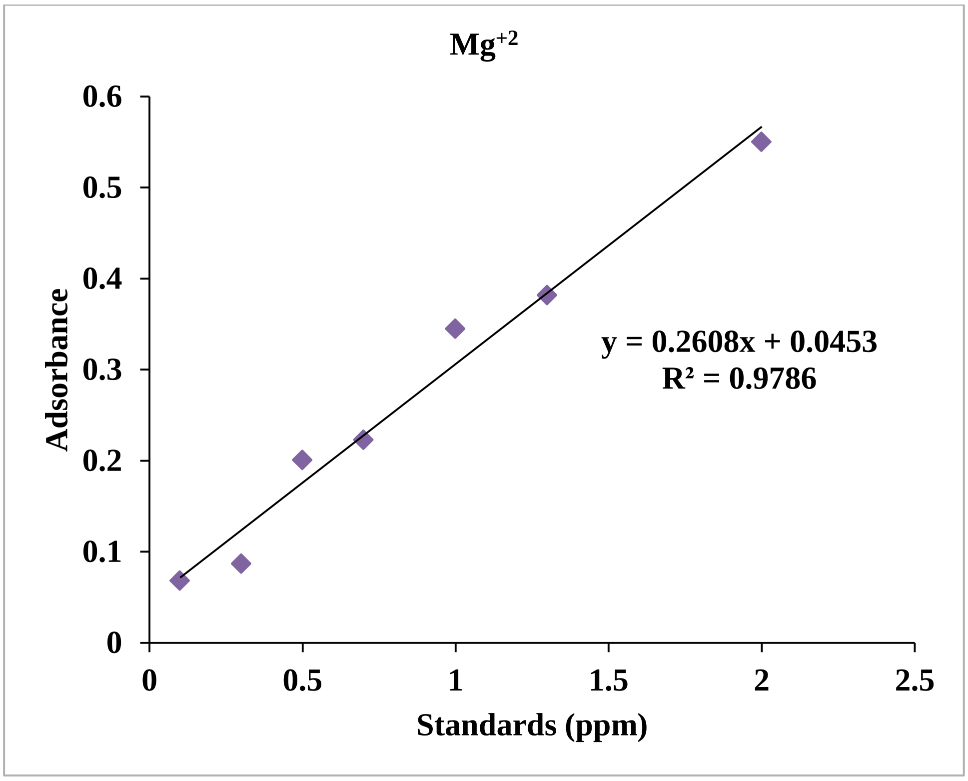


Fig.6: Calibration curve for Mg^{+2} in ppm.

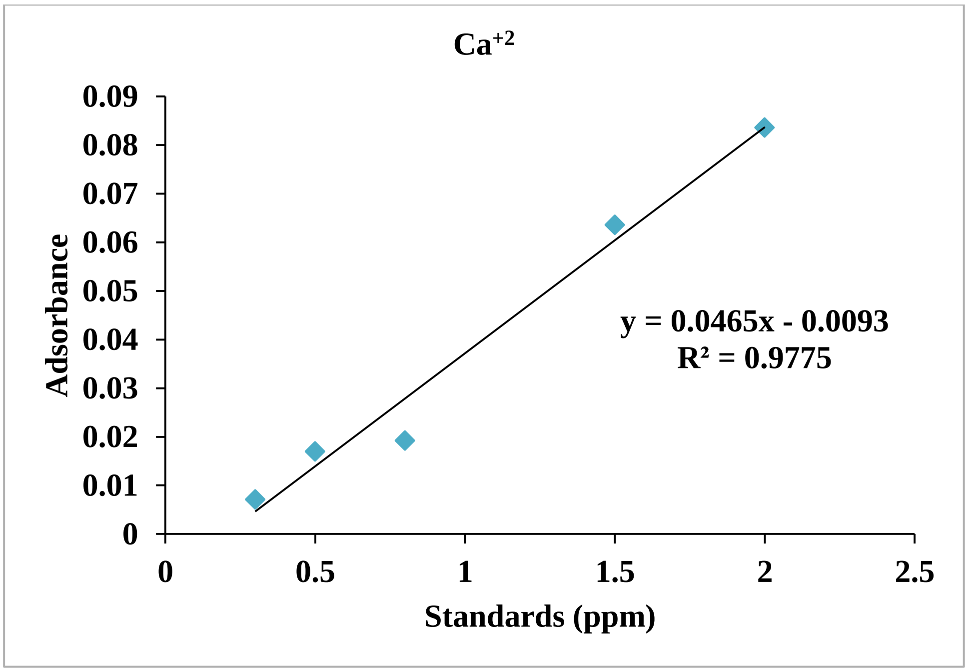


Fig.7: Calibration curve for Ca^{+2} in ppm.

Appendix C. Recommended Guidelines by the Palestinian Standards Institute for Treated Wastewater Characteristics according to different applications (Zimmo et al., 2005).

Quality Parameter Fodder Irrigation	Fodder irrigation		Gardens, Playgrounds,	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	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
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
Phenol	0.002	0.002	0.002	0.002	0.002	1	0.002	0.002	0.002
NO_3-N	50	50	50	50	15	25	50	50	50
NH_4-N	-	-	50	-	10	5	-	-	-
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
Al	5	5	5	5	1	5	5	5	5
Cu	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
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
Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Appendix D. Palestinian Standards for Treated Wastewater (Ministry of Environmental Affairs, 2000).

Parameter (mg/l)	Irrigate almond trees	Irrigate olive trees	Irrigate citrus fruits	irrigate forest trees	Irrigate Grains	Irrigate Parks	Irrigate Garden Courts	Irrigate Dry/ Green Feed	Feeding the aquifer by filtration	Discharge it to sea water along 500m
BOD5	45	45	45	60	60	40	45	60	40	60
COD	150	150	150	200	200	150	150	200	150	200
DO	>0.5	>0.5	> 0.5	> 0.5	>0.5	> 0.5	>0.5	>0.5	>1	>1
TDS	1500	1500	1500	1500	1500	1200	1500	1500	1500	-
TSS	40	40	40	50	50	30	40	50	50	60
pH	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9
Color (PCU)	***	***	***	***	***	***	***	***	***	***
Phenol	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	1
NO_3 (N)	50	50	50	50	50	50	50	50	15	25
NH_4 (N)	-	-	-	-	-	50	-	-	10	5
PO_4 (P)	30	30	30	30	30	30	30	30	15	5
Cl	400	600	400	500	500	350	500	500	600	-
SO_4	500	500	500	500	500	500	500	500	1000	1000
Na	200	200	200	200	200	200	200	200	230	-
Mg	60	60	60	60	60	60	60	60	150	-
Ca	400	400	400	400	400	400	400	400	400	-
SAR	9	9	9		9	10	9	9	9	-
Al	5	5	5	5	5	5	5	5	1	5
Ar	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.05

Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fe	5	5	5	5	5	5	5	5	2	2
Mn	0.2	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	0.2
Pb	1	1	1	1	1	0.1	1	1	0.1	0.1
Se	0.02	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	0.01
Zn	2	2	2	2	2	2	2	2	5	5
Cn	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.1
Cr	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.5
Hg	0.001	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	0.05	0.05	0.05	0.05	1
B	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1	2
Faecal Coliform (CFU/100 ml)	1000	1000	1000	1000	1000	200	1000	1000	1000	50000

***: Empty

Appendix E. Australian treated wastewater discharge standards (EPA, 2005)

Pollutants (mg/l)	Discharge limits	
	Aquatic Ecosystem	
	Fresh water	Marine
PH	6.5-9	-
TOC	15	10
BOD_5	10	10
DO	>6	>6
Turbidity	20	10
SS	20	10
TN	5	5
NH_4-N	0.5	0.2
PO_4-P	0.1	0.1
TP	0.5	0.5
As	0.05	0.05
Cu	0.01	0.01
Cd	0.002	0.002
Cr^{+5}	0.001	0.0044
Fe	1	-
Pb	0.005	0.005
Hg	0.0001	0.0001
Ni	0.15	0.015
Se	0.005	0.07
Ag	0.0001	0.01
Zn	0.05	0.05
Phenol (total)	0.05	0.05

Appendix F. FAO guidelines for interpretation of water quality for irrigation

Potential Irrigation Problem	Degree of Restriction on Use		
	None	Slight to Moderate	Severe
EC (dS/m)	< 0.7	0.7 – 3.0	> 3.0
TDS (mg/l)	< 450.0	450.0 – 2000.0	> 2000.0
Na (mEq/l) (for sprinkler irrigation)	< 3.0	> 3.0	
NO_3 – N (mg/l)	< 5.0	5.0 – 30.0	> 30.0

Appendix G. The permitted limit for greywater reuse according to the use type, WHO/AFESD report.

Test	Permitted Limit		
	Irrigation of ornamental fruit trees and fodder crops	Irrigation of vegetables likely to be eaten uncooked	Toilet flushing
BOD_5 (mg/l)	≤ 240	≤ 20	≤ 10
TSS (mg/l)	≤ 140	≤ 20	≤ 10
Thermotolerant coliforms (cfu/100 mL)	≤ 1000	≤ 200	≤ 10