# TREATMENT OF LANDFILL LEACHATE USING MODIFIED ANAEROBIC BAFFLED REACTOR

IMRAN AHMAD

UNIVERSITI TEKNOLOGI MALAYSIA

# TREATMENT OF LANDFILL LEACHATE USING MODIFIED ANAEROBIC BAFFLED REACTOR

IMRAN AHMAD

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Razak Faculty of Technology and Informatics
Universiti Teknologi Malaysia

JANUARY 2019

# DEDICATION

Dedicated to my respected and honorable father (late) Prof. Dr Qamar-e-Hasan and my beloved mother whose blessings helped me at every step.

**ACKNOWLEGEMENT**

First and foremost, I would thank and glorify Allah Subhanahu Ta'ala for the inestimable blessings and bounties bestowed by Him, nothing can be accomplished without His help and favour. After that, I would like to express my sincere gratitude to my supervisor, Professor Dr. C. Shreeshivadasan for the continuous support of my MPhil study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in both experimental and writing phases of research. I could not have imagined having a better advisor and mentor for my MPhil study. I have been extremely lucky to have a supervisor who cared so much about my work, and who responded to my questions and queries so promptly whenever required. Also, not to forget the contribution of my co-supervisor Dr. Norazli binti Othman for being the extra support towards the completion of my thesis.The source of inspiration for me is my ideal and and role model, a legend who is a versatile man of character and qualities, an exemplary and unique identity Dr. Sanaullah Khan(d.b).

Nobody has been more important to me in the pursuit of this project than the members of my family, my wife who stimulated the work as a catalyst and consoled me at the moment of distress not to forget my little children who were just like luminous stars who soothed my heart at time of crux. I would like to thank my parents, whose love and guidance are with me in whatever I pursue, especially my elder brother Dr. Rizwan Ahmad, who stood as custodian for me after the demise of my father, his affection, caring and beneficence can't be described in words. My elder sister whose solicitude and magnanimity worked as propellent. Special thanks to all my colleagues and lab mates in the environmental laboratories, Razak Faculty of Technology and Informatics, UTM. Also, special notes of appreciation to the help of Mr. Azmi Abu Bakar for helping during the experimental stage. Finally, I would like to thank Mr. Danish Ahmad, whose talent, skills and sincere efforts were worth appreciation and an asset in the preparation of the thesis. Finally, I also would like to extend my gratitude to UTM for funding this research.

# ABSTRACT

Landfill leachate is highly concentrated organic wastewater with complex composition. It is a major source of pollution potentially threatening the quality of groundwater, surface water and life forms. Leachate needs to undergo a series of treatment prior to discharge into soil, ground water and surface water bodies. Current biological treatment of landfill leachate using aerobic ponds has some drawbacks such as low removal of organic matter and heavy metals. As a result, further treatment of the effluent from the aerobic ponds is required. Hence, chemical and physical treatments are provided which in turn increase the cost of treatment. In this study, raw leachate was subjected to an anaerobic treatment using a modified anaerobic baffled reactor (MABR). In phase I of the study, the design, development and start-up of the MABR system were accomplished. The synthetic feed which was used in the start-up of the reactor was meat extract. When the chemical oxygen demand (COD) removal efficiency reached up to 99%, leachate was gradually introduced until 100% COD. In phase II of the study, a full treatment of the landfill leachate was carried out by maintaining the hydraulic retention time (HRT) and gradually increasing the organic loading rate (OLR). In phase III of the study, the effect of variation of OLR on the treatment performance of the MABR was investigated by reducing the HRT. Results showed that the COD, As, Cr, Fe and color removal values during the treatment of landfill leachate at an OLR of 1.4 kgCOD/$m^3$/d were 79.3%, 87.5%, 88.8%, 87.8% and 78.2%, respectively. In decreasing the HRT (4, 3, 2 and 1 days) and subsequently increasing the OLR (1.4, 1.86, 2.8 and 5.6 kgCOD/$m^3$/d), the efficiency of the MABR showed reduction in the treatment performance. At an OLR of 5.6 kgCOD/$m^3$/d and HRT of 1 day, the COD, As, Cr, Fe and color removal values were found to be 71%, 8.3%, 59.3%, 63.5% and 37.1%, respectively. In addition, the stable population of bacteria has tolerated the heavy metals when the OLR was gradually increased from 1.4 - 5.6 kgCOD/$m^3$/d. The efficient removal of the heavy metals provides evidence that heavy metals can be degraded in anaerobic environments using the MABR. In sum, the MABR may be an efficient solution for the treatment of leachate at the site of a sanitary landfill.

# ABSTRAK

Larut lesapan di tapak pelupusan merupakan air kumbahan organik yang sangat tertumpu dengan komposisi kompleks. Ia merupakan sumber utama pencemaran yang berpotensi mengancam kualiti air bawah tanah, air permukaan dan bentuk kehidupan. Larut lesapan perlu menjalani rawatan yang rapi sebelum ianya dibuang ke alam sekitar, air bawah tanah dan permukaan air. Rawatan biologi semasa pelupusan menggunakan kolam aerobik mempunyai beberapa kelemahan seperti penyingkiran bahan organik dan logam berat yang rendah. Oleh yang demikian, rawatan lanjut mengenai efluen dari kolam aerobik diperlukan. Oleh itu, rawatan kimia dan fizikal disediakan yang seterusnya meningkatkan kos rawatan. Dalam kajian ini, larut resapan telah dirawat secara anaerobik menggunakan reaktor anaerobik yang diubah suai (MABR). Dalam Fasa I kajian ini, reka bentuk, pembangunan dan permulaan sistem MABR telah dicapai. Air sisa sintetik yang digunakan dalam permulaan reaktor adalah ekstrak daging. Apabila kecekapan penyingkiran COD mencapai 98%, larut lesapan secara beransur-ansur diperkenalkan sehingga 100% COD. Dalam Fasa II kajian ini, rawatan penuh larut lesapan telah dijalankan dengan mengekalkan masa pengekalan hidrolik (HRT) dan secara berperingkat meningkatkan kadar pemuatan organik (OLR). Dalam Fasa III pula, kesan OLR terhadap prestasi rawatan MABR dikaji dengan mengurangkan HRT. Keputusan menunjukkan bahawa COD, As, Cr, Fe dan nilai penyingkiran warna semasa rawatan larut lesapan pada OLR sebanyak 1.4 kgCOD/m$^3$/d adalah 79.3%, 87.5%, 88.8%, 87.8% dan 78.2%. Dalam mengurangkan HRT (4, 3, 2 dan l hari) dan seterusnya meningkatkan OLR (1.4, 1.86, 2.8 dan 5.6 kgCOD/m$^3$/d), kecekapan MABR menunjukkan pengurangan prestasi rawatan. Pada OLR 5.6 kgCOD/m$^3$/d dan HRT 1 hari, COD, As, Cr, Fe dan nilai penyingkiran warna didapati 71%, 8.3%, 59.3%, 63.5% dan 37.1%. Pada OLR 5.6 kgCOD/m$^3$/d dan HRT 1 hari, COD, As, Cr, Fe dan nilai penyingkiran warna didapati 71%, 8.3%, 59.3%, 63.5% dan 37.1%. Di samping itu, populasi bakteria yang stabil telah menerima toleransi logam berat apabila OLR secara beransur-ansur meningkat dari 1.4 - 5.6 kgCOD/m$^3$/d. Penyingkiran logam berat membuktikan bahawa logam berat boleh diurai dalam persekitaran anaerobik menggunakan MABR. Dalam jumlah itu, MABR boleh menjadi penyelesaian yang efektif untuk rawatan larut resapan di tapak tapak pelupusan sanita.

**TABLE OF CONTENTS**

| | TITLE | PAGE |
|---|---|---|

## LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ADMI | - | American Dye Manufacturers Institute |
| AOP | - | Advanced Oxidation Processes |
| APHA | - | American Public Health Association |
| atm | - | Atmospheric Pressure |
| Ba | - | Barium |
| BOD | - | Biochemical Oxygen Demand |
| FA | - | Formaldehyde |
| FAO | - | Food and Agriculture Organization of the United Nations |
| FTIR | - | Fourier Transform Infrared Spectrometer |
| GAC | - | Granular Activated Carbon |
| GHG | - | Green House Gases |
| HPLC | - | High Performance Liquid Chromatography |
| HRT | - | Hydraulic Retention Time |
| MBBR | - | Moving Bed Bioreactor |
| MABR | - | Modified Anaerobic Baffled Reactor |
| MF | - | Microfiltration |
| MLSS | - | Mixed Liquor Suspended Solids |
| MLVSS | - | Mixed Liquor Volatile Suspended Solids |
| MSW | - | Municipal Solid Waste |
| NF | - | Nanofiltration |
| OC | - | Organic Carbon |
| OLR | - | Organic Loading Rate |
| PAC | - | Powdered Activated Carbon |
| RF | - | Response Factor |
| RO | - | Reverse Osmosis |
| SBR | - | Sequencing Batch Reactor |
| SS | - | Suspended Solids |

| | | |
|---|---|---|
| SWCORP | - | Solid Waste and Public Cleansing Management Corporation |
| T-N | - | Total Nitrogen |
| TOC | - | Total Organic Carbon |
| TSS | - | Total Suspended Solids |
| TVA | - | Total Volatile Acid |
| UASB | - | Up-flow Anaerobic Sludge Blanket |
| UF | - | Ultrafiltration |
| UTM | - | Universiti Teknologi Malaysia |
| VFA | - | Volatile Fatty Acid |
| VA | - | Volatile Acid |
| VSS | - | Volatile Suspended Solids |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Various driving factors influence the waste management system in a country. It is vital to identify the related obstacles to achieve sustainable practice. Waste management has become an issue in developing countries, particularly in the Asian region. The increase in population has resulted in a huge amount of waste being generated and the greater the population density the more important is the waste management system (Botetzagias *et al.,* 2015). Initially, waste management systems were implemented solely to remove food and breeding media for flies and rats. However, with the development of modern civilization, simply removing waste became an insufficient solution. Therefore, various strategies have been introduced to improve the concepts of waste management (Agamuthu *et al.,* 2009a). Waste reduction, reutilization and recycling are widely practised to achieve sustainable waste management (Agamuthu *et al.,* 2008; Agamuthu *et al.,* 2009a; Damgaard, 2009). Sustainable landfilling is a necessary part of an efficient integrated waste management system. Sanitary landfilling is one of the most common methods for disposing of Municipal Solid Waste (MSW) (Nghiem *et al*., 2016). Modern sanitary landfills are designed, constructed, and maintained to minimize the adverse environmental impacts from the waste disposal over both the short and long terms. After landfilling, solid waste undergoes physico-chemical and biological changes. Consequently, the degradation of the organic fraction of the wastes in combination with percolating rainwater leads to the production of "leachate". Leachates may contain enormous quantities of organic contaminants, ammonia, suspended solids, heavy metals, and inorganic salts, phenols and phosphorus (Rahim *et al.,* 2010; Yoshida *et al.,* 2002).

The complexity of these characteristics makes the leachate more difficult to manage (Zainol *et al.,* 2012; Renou *et al.,* 2008). If not treated and carefully disposed of, leachate may enter the surrounding soil, groundwater, or surface water (Razarinah *et al.,* 2015; Kumari *et al.,* 2016). Regulations concerning leachate discharge into receiving waters are becoming more and more stringent (Renou *et al.,* 2008; Peyravi *et al.,* 2016), therefore, landfill leachate must be collected and treated.

In Malaysia, the population has increased at a rate of about 2.4% per annum since 1994 (Aja and Al-Kayiem, 2014). This has resulted in a tremendous amount of solid wastes being generated. The daily generation of waste in Peninsular Malaysia has escalated from 13,000 tonnes in 1996 to 19,100 tonnes in 2006 and it is expected to increase approximately 1,000 tons per year (Tiew *et al*., 2015; Agamuthu *et al*., 2009a). The urban population in Malaysia increased from 8.1 million in 1960 to more than 32 million in 2017 (Department of Statistics, Malaysia, 2017). This phenomenon has resulted in an increase in waste generation in urban areas. It was estimated that the total MSW generated in 2016 was 38,200 tons per day, 82.5% of which is disposed of in landfills (Agamuthu and Fauziah, 2010). The per capita solid waste generation is estimated to be about 1.12/cap/day (Solid Waste Corporation, 2016). Non-operating landfill sites are 130, operating non-sanitary landfill sites are 157 with operating sanitary landfill sites of 13 (JPSPN, 2015a).

Rain is the major environmental agent that contributes to the generation of landfill leachate (Agamuthu and Fauziah, 2010). Malaysia annually receives 990 billion $m^3$ of rainwater (Malaysian Meteorological Department, 2015). Of this staggering amount, more than 35,490 $m^3$ could possibly turn into leachate annually (Salleh and Hamid, 2013). According to Agamuthu *et al.* (2010), Malaysian MSW landfill produced 150-200 L/tonne of leachate or approximately $2.1 \times 10^7$ L/day. The treatment of leachate prior to discharge is a legal requirement to avoid contamination of water resources to prevent both acute and chronic toxicity (Aziz *et al*., 2011; Ngo *et al*., 2008). To reduce the negative impact of discharged leachate on the environment, several techniques of treatment have been used.

The technologies which were developed for the treatment of landfill leachate could be classified as physical, chemical, and biological (Mojiri *et al.*, 2014; Bashir *et al.*, 2013; Renou *et al.*, 2008). In general, biological treatment processes are effective for young (<5 years) produced leachate. However, it is ineffective for leachate from older landfills (>10 years old).

Physical–chemical methods which are not favoured for young leachate treatment are advised for older leachate treatment (Mojiri *et al.*, 2014; Bashir *et al.*, 2013). Normally, the techniques are applied as an integrated system because it is not easy to achieve the satisfying treatment efficiency by using only one technology. To set up an acceptable treatment process for removal of contaminants from leachates, various physico-chemical and biological techniques combinations could be applied. The implementation of the most suitable technique for the treatment of leachate is directly governed by the characteristics of the leachate. Leachates from different landfills vary considerably in their chemical compositions (Bashir *et al.,* 2015; Renou *et al.*, 2008). The current major leachate treatment method in Malaysia is by aerobic treatment combined with chemical and physical treatment. The aerobic treatment mechanism mainly consists of microorganisms degrading the pollutants in the leachate using aeration. However, this method is still insufficient to remove some toxic pollutants in the leachate. Accordingly, chemical and physical treatments such as coagulation and activated carbon, sand filter and membrane filters are used for complete removal of pollutants.

The anaerobic treatment is a biological process of decomposition of organic matter which does not only remove most pollutants, but also generates valuable by-product, namely biogas, in the form of methane (Lim and Kim, 2014). Anaerobic treatment of wastewater gained wide attention among researches and sanitary engineers, mainly due to its economical merits over the conventional aerobic methods. The major advantages of anaerobic treatment are: (1) no aeration required, (2) very low excess sludge production, (3) biogas production with high energy content, (4) low nutrients requirement, and (5) application of high organic loading (Aqaneghad *et al.*, 2017).

The technological challenge to improve the anaerobic reactors lies in providing the best growing environment for acidogenic bacteria and methanogens and enhancing the bacterial activity taking place. In addition, the contact between the microorganisms and their substrate is critical to efficient anaerobic reactor operation. Among the high rate anaerobic reactors, the anaerobic baffled reactor (ABR) is a promising treatment technology for many wastewaters.

ABR is described as a series of up-flow anaerobic sludge blanket (UASB) reactor in which the wastewater is forced to flow under and over of a series of the vertical baffles as it passes from the inlet to the outlet (Aqaneghad *et al*., 2017). The compartmentalization of the reactor prevents horizontal movement of the biomass and thus a high amount of active biomass retains in each compartment. This feature provides the excellent contact between the contaminants and the microorganisms, longer biomass retention times and better resilience to organic and hydraulic shock loadings (Chelliapan *et al*., 2006). Moreover, it is simple to design, construct and operate (Barber and Stuckey, 1999). Its design ensures contact of biomass with substrates without the need to use any mechanical mixing. This is done by the narrow down-flow and the wide up flow inside each compartment of the ABR. Some of the bacteria also move horizontally down the reactor at a relatively slow rate, giving rise to cell retention time of 100 days at HRT of 20h (Grobicki and Stuckey, 1991). Therefore, the wastewater can come into intimate contact with a large amount of active biomass as it passes through the ABR with short HRTs (6-20h), while the effluent remains relatively free of biological solids.

## 1.2 Problem Statement

The current system of leachate treatment consists of various unit processes which require larger area, energy and cost. In addition, the current aerobic treatment is not able to treat entirely the pollutants which require further treatment of the leachate (Del Moro *et al*., 2016). There are situations whereby only 50% COD removal was observed in some aerobic treatments of leachate in Malaysia (Worldwide Landfills Sdn Bhd, 2017).

This leads to a larger consumption of chemicals and activated carbon in the treatment system. Though the ABR has several advantages, disadvantages of conventional ABR include the requirement of building a shallow reactor to maintain acceptable liquid and gas up-flow velocities which can lead to bacterial washout and delay the start-up of the reactor (Barber and Stuckey, 1999).

In addition, potential problems can arise during start-up because of plug-flow characteristics, the accumulation of volatile fatty acid (VFA) and low pH, exposing sensitive bacteria in the front compartments to toxic levels of inorganic and organic compounds in the high strength feeding wastewater. To overcome these difficulties, some approaches such as low organic loading rate (OLR), feed dilution, periodic feeding and effluent recycling have been recommended (Barber and Stuckey, 1999; Skiadas and Lyberatos, 1998). However, they may not be the best solution to the prompt start-up of ABR because the compartmentalised structure of ABR brings with another problem such as nutrient limits in the final compartment and elimination of phase separation (Chelliapan *et al*., 2006).Furthermore, it has also some drawbacks such as high quantity of solids washout, inactive and stagnant sludge at the bottom and poor performance for some recalcitrant wastewater. As a result, a novel modified anaerobic baffled reactor (MABR) is proposed in this study. The MABR consists of compartments supported by slanted baffles for better removal efficiency. To date, there is no reported study on the treatment of landfill leachate containing heavy metals using ABR.

There are very limited studies which explored the removal of heavy metals from landfill leachate using anaerobic reactors (Hashemi *et al*., 2016; Duncan *et al*., 2004). Most of the previous studies on the treatment of landfill leachate using anaerobic reactor concentrated on the removal of COD, ammoniacal nitrogen and color, but neglected the heavy metal degradation in the process. To date, there is no reported study on the use of ABR for the treatment of landfill leachate focussing on heavy metals.

## 1.3 Research Questions

Based on the research problem, research questions are summarized, which are as follows:

a) What is the performance of MABR during start-up using meat extract?
b) What is the treatment performance of MABR in treating the landfill leachate containing heavy metals?
c) Does the MABR is to be operated at different OLR and HRT?

## 1.4 Research Objectives

The aim of this research is to treat the landfill leachate by using modified anaerobic baffled reactor (MABR). The specific objectives of this research are:

1. To design, develop and to investigate the start-up of a modified anaerobic baffled reactor (MABR) system using meat extract.
2. To investigate the treatment of landfill leachate containing heavy metals (As, Cr and Fe) using MABR system.
3. To analyze the effect of variation of HRT and OLR in the treatment performance of landfill leachate using MABR system.

## 1.5 Research Scope

Following is the scope of this study:

a) The raw leachate was taken from Jeram Sanitary Landfill, Selangor. The site is operated by Worldwide Landfills Sdn. Bhd. Landfill leachate is of intermediate nature.
b) The MABR is a laboratory scale plexiglass reactor having 28 L capacity containing four uniform compartments (7 L capacities) and each having a slanted baffle (45°), heater and sludge and gas sampling ports.
c) The treatment performance of the MABR was evaluated, based on COD removal, color removal, pH and VA profile, and biogas production.

d) The heavy metals focused in this study were Arsenic, Chromium and Iron due to their high concentration at the landfill site.

## 1.6 Significance of Study

Anaerobic digesters for wastewater treatment are gaining popularity in Malaysia. It has been used in other sectors in Malaysia such as palm oil industries, sewage treatment plants and other industries, except for landfill leachate treatment. Moreover, to date, there is no reported study on the MABR system treating landfill leachate. Hence, the treatment of landfill leachate using MABR will hopefully lead to the efficient treatment solution of landfill leachate compared to available technologies. Moreover, it will be an accomplishment in the area of anaerobic wastewater technology which will hopefully improvise the limitations of conventional ABR.

# REFERENCES


Abbas, A.A., Jingsong, G., Ping, L.Z., Ya, P.Y. and Al-Rekabi, W.S. (2009). Review on landfill leachate treatments. *Journal of Applied Sciences Research*, 5(5), 534-545.

Abbasi, T. and Abbasi, S.A. (2012). Formation and impact of granules in fostering clean energy production and wastewater treatment in upflow anaerobic sludge blanket (UASB) reactors. *Renewable and Sustainable Energy Reviews,* 16(3), 1696-1708.

Abbasi, T., Tauseef, S. M. and Abbasi, S. A. (2012). Anaerobic digestion for global warming control and energy generation - An overview. *Renewable And Sustainable Energy Reviews,* 16, 3228-3242.

Abdallah, R., Djelal, H., Amrane, A., Sayed, W., Fourcade, F., Labasque, T., Geneste, F., Taha, S. and Floner, D. (2016). Dark fermentative hydrogen production by anaerobic sludge growing on glucose and ammonium resulting from nitrate electroreduction. *International Journal Of Hydrogen Energy,* 41, 5445-5455.

Abdelgadir, Awad., Chen, Xiaoguang., Liu, Jianshe., Xie, Xuehui., Zhang, Jian., Zhang, Kai., Wang, Heng. and Liu, Na. (2014). Characteristics, Process Parameters, and Inner Components of Anaerobic Bioreactors. *BioMed Research International,* 2014,1-10.

Abood, A. R., Bao, J. and Abudi, Z. N. (2013). Biological nutrient removal by internal circulation upflow sludge blanket reactor after landfill leachate pretreatment. *Journal Of Environmental Sciences,* 25, 2130-2137.

Adeolu, A., Oriaku A.V., Adewumi G.A. and Adebayo, O. (2011). Assessment of groundwater contamination by leachate near a municipal solid waste landfill. *African Journal of Environmental Science and Technology*, 5, 933-940.

Agamuthu, P., Fauziah, S.H. and Khidzir, K.M. (2010). Sustainable 3R Practice in the Asia and Pacific Regions: The Challenges and Issues In: Municipal Solid Waste Management in Asia and the Pacific Islands. (Eds: Agamuthu, P. and Tanaka, M.) Penerbit ITB, Indonesia.

Agamuthu, P. and Fauziah, S.H. (2010). Challenges and issues in moving towards sustainable landfilling in a transitory country-Malaysia. *Waste Management and Research*, 29(1),13-19.

Agamuthu, P., Khidzir, K. and Fauziah, S.H. (2009b). Drivers of sustainable waste management in Asia. *Waste Management and Research,* 27, 625-633.

Aghamohammadi, N., Aziz, H. B. A., Isa, M. H. and Zinatizadeh, A. A. (2007). Powdered activated carbon augmented activated sludge process for treatment of semi-aerobic landfill leachate using response surface methodology. *Bioresource Technology,* 98, 3570-3578.

Aja, O.C. and Al-Kayiem, H.H. (2014). Review of municipal solid waste management options in Malaysia, with an emphasis on sustainable waste-to-energy options. *Journal of material cycles and waste management,*16,693-710.

Akunna, J.C and Clark, M. (2000). Performance of a granular-bed anaerobic baffled reactor (GRABBR) treating whisky distillery wastewater. *Bioresource Technology*, 74, 257-261.

Akuzawa, M., Hori T., Haruta, S., Ueno, Y., Ishii, M. and Igarashi, Y. (2011). Distinctive responses of metabolically active microbiota to acidification in a thermophilic anaerobic digester. *Microbial Ecology*, 61,595–605.

Al-Raisi, S.A.H., Sulaiman, H., Suliman, F.E. and Abdallah, O. (2014). Assessment of heavy metals in leachate of an unlined landfill in the Sultanate of Oman. *International Journal of Environmental Science and Development.* 5(1):60

Alkarimia, R., Mahat, S. B., Yuzir, A., Fadhil, M., and Chelliapan, S. (2011). Performance of an innovative multi stage anaerobic reactor during start-up period. *African Journal of Biotechnology,*10, 11294-11302.

Alvarez, H.V., Jefferson, B., Judd, S.J. (2004). Membrane bioreactorsvs conventional biological treatment of landfill leachate: abrief review. *Journal of Chemical Technology and Biotechnology* ,79, 1043-1049.

Amor, C., Torres-Socías, E. D., Peres, J. A., Maldonado, M. I., Oller, I., Malato, S. and Lucas, M. S. (2015). Mature landfill leachate treatment by coagulation/flocculation combined with fenton and solar photo-fenton processes. *Journal Of Hazardous Materials,* 286, 261-268.

Amirfakhri, J., Vossoughi, M. and Soltanieh, M.(2006). Assessment of desulfurization of natural gas by chemoautotrophic bacteria in an anaerobic baffled reactor (ABR). *Chemical Engineering and Processing: Process Intensification,* 45 (3), 232-237.

APHA (2005) Standard methods for the examination of water and waste water, 21st edn., Washington, D.C:American Public Health Association.

Aqaneghad, M., Moussavi, G. and Ghanbari R. (2017) .Anaerobic Baffled Reactor and Hybrid Anaerobic Baffled Reactor Performances Evaluation in Municipal Wastewater Treatment. *Iranian Journal of Health, Safety and Environment*, 5 (3), 1027-1034.

Asnie, M., Chelliapan,S., Dina, F., Anuara,A., Shahperi,R., Selvam,S.B., Norhayati Abdullahd,N. and Yuzir,A.(2017). Effect of organic loading rate (OLR) on the performance of modified anaerobic baffled reactor (MABR) supported by slanted baffles *Desalination and Water Treatment* ,79,56-63.

Aziz, H.A., Alias, S., Adlan, M. N., Asaari, F. A. H. and Zahari M. S. M. (2007) .Color removal from landfill leachate by coagulation and flocculation process. *Bioresource Technology*, 98, 218-220.

Aziz, S. Q., Ling, T. J., Haque, A. A. M., Umar, M. and Adlan, M. N. (2011a). Leachate Treatment By Swim-Bed Bio Fringe Technology. *Desalination,* 276**,** 278-286.

Aziz, S. Q., Aziz, H. A. and Yusoff, M. S. (2011b). Powdered activated carbon augmented double react-settle sequencing batch reactor process for treatment of landfill leachate. *Desalination,* 277, 313-320.

Aziz, S. Q., Aziz, H. A., Yusoff, M. S. and Bashir, M. J. K. (2011c). Landfill leachate treatment using powdered activated carbon augmented sequencing batch reactor (SBR) process: optimization by response surface methodology. *Journal Of Hazardous Materials,* 189, 404-413.

Aziz, S.Q., Aziz, H.A., Yusoff, M.S., Bashir, M.J.K. and Umar, M. (2010).Leachate characterization in semi-aerobic and anaerobicsanitary landfills: a comparative study. *Journal of Environmental Management*, 91, 2608-2614.

Aziz, S.Q., Aziz, H.A., Yusoff, M.S., Mojiri, A. and Amr, S.S.A. (2012). Adsorption isotherms in landfill leachate treatment usingpowdered activated carbon augmented sequencing batchreactor technique: statistical analysis by response surfacemethodology. *International Journal of Chemical Reactor Engineering*, 10, 1-21.

Aziz, S. Q., Aziz, H. A., Mojiri, A., Bashir, M. J. K., and Amr, S. S. A. (2013). Review Paper Landfill Leachate Treatment Using Sequencing Batch Reactor (SBR) Process: Limitation of Operational Parameters and Performance. *International Journal of Scientific Research in Knowledge (IJSRK)*, 1(3),34-43.

Al-Raisi, S.A.H., Sulaiman, H., Suliman, F.E. and Abdallah, O. (2014). Assessment of heavy metals in leachate of an unlined landfill in the Sultanate of Oman. *International Journal of Environmental Science and Development.* 5(1):60.

Babaee, A., Shayegan J. (2011). Effects of Organic Loading Rates (OLR) on Production of Methane from Anaerobic Digestion of Vegetable Waste; Proceedings of the World *Renewable Energy Congress; Linköping, Sweden*. 8–13 May; pp. 411–417.

Bachmann, A., Beard, V.L., and McCarty, P.L. (1985). Performance characteristics of the anaerobic baffled reactor. *Water Research,* 19, 99-106.

Bagchi, A. (1994). *Design Construction and Monitoring of Landfills*. New York:John Wiley & Sons.

Bakraouy, H., Souabi S., Digua K., Dkhissi O., Sabar, M. and Fadil, M. (2017). Optimization of the treatment of an anaerobic pretreated landfill leachate by a coagulation–flocculation process using experimental design methodology. *Process Safety and Environmental Protection,*109, 621-630.

Barber, W. P. and Stuckey, D. C.(1999). The use of anaerobic baffled reactor (ABR) for the wastewater treatment: *A review. Water Research*,33(7),1559-1578.

Barros, V.G. de, Duda, R.M. and Oliveira, R.A.de. (2016).Biomethane production from vinasse in upflow anaerobic sludge blanket reactors inoculated with granular sludge.*Brazilian Journal of Microbiology*,47(3),628-639.

Bashir, M. J. K., Aziz, H. A., Amr, S. S. A., Sethupathi, S. A. P., Ng, C. A. and Lim, J. W. (2015). The competency of various applied strategies in treating tropical municipal landfill leachate. *Desalination And Water Treatment,* 54, 2382-2395.

Bashir, M. J. K., Aziz, H. A. and Yusoff, M. S. (2011). New sequential treatment for mature landfill leachate by cationic/anionic and anionic/cationic processes: Optimization and comparative study. *Journal Of Hazardous Materials,* 186, 92-102.

Bashir, M.J.K., Aziz, H.A., Yusoff, M.S., Huqe, A.A.M. and Mohajeri, S. (2010). Effects of ion exchange resins in different mobileionforms on semi-aerobic landfill leachate treatment. *Water Science and Technology*, 63, 641-649.

Bashir, M.J.K., Aziz, H.A., Yusoff, M.S. and Aziz, S.Q. (2012). Investigation of color and COD eliminations from maturesemi-aerobic landfill leachate using anion-exchange resin:equilibrium and kinetic study. *Environmental Engineering and Science,* 29, 297-305.

Bashir, M.J.K., Aziz, H.A., Aziz, S.Q., and Abu Amr, S.S. (2013). Anoverview of electro-oxidation processes performance instabilized landfill leachate treatment. *Desalination and Water Treatment*, 51, 2170-2184.

Baun, A., Kløft, L., Bjerg, P.L. and Nyholm, N. (1999). Toxicity testing of organic chemicals in groundwater polluted with landfill leachate. *Environmental Toxicology and Chemistry*,18(9), 2046-2053.

Begum, S., Ahuja, S., Rao, A.G., Kiran, G., Gandu, B., Kuruti, K., Swamy, Y.V., Ahuja, D.K., (2016). Significance of decentralized biomethanation systems in the framework of municipal solid waste treatment in India. *Current Biochemical Engineering.* 3(1).

Bohdziewicz, J. and Kwarciak, A. (2008). The Application of hybrid system uasb reactor-ro in landfill leachate treatment. *Desalination,* 222, 128-134.

Bose-O'reilly, S., Schierl, R., Nowak, D., Siebert, U., William, J. F., Owi, F. T. and Ir, Y. I. (2016). A preliminary study on health effects in villagers exposed to mercury in a small-scale artisanal gold mining area in Indonesia. *Environmental Research,* 149, 274-281.

Botetzagias, I., Dima, A.F. and Malesios, C. (2015). Extending the theory of planned behavior in the context of recycling: The role of moral norms and of demographic predictors. *Resources, Conversation and Recycling*, 95, 58-67.

Boopathy, R., Larsen, V. F., and Senior E. (1988). Performance of Anaerobic Baffled Reactor (ABR) in treating distillery wastewater from a Scotch Whisky factory. *Biomass,*16, 133-143.

Buitrón, G., Melgoza, R.M. and Jiménez, L. (2003). Pharmaceutical wastewater treatment using an anaerobic/aerobic sequencing batch biofilter. *Environmental Science and Health*, Part A: Toxic/Hazardous Substances and Environmental Engineering, 38(10), 2077-2088.

Burbano, -F.O., Jaramillo, M., Moreno, -M. M. and Fernández, -I. P. (2015).Effect of sulfate loading rate and organic loading rate anaerobic baffled reactors used for treatment of sanitary Landfill Leachates. *Brazilian Journal of Chemical Engineering*, 32 (2), 385-395.

Burton, S.Q. and Watson-Craik, I.A. (1998). Ammonia and nitrogen fluxes in landfill sites: applicability to sustainable landfilling. *Waste Management and Research*, 16, 41-53.

Cestonaro do Amaral, A., Kunz, A., Radis Steinmetz, R.L. and Justi, K.C. (2014). Zinc and copper distribution in swine wastewater treated by anaerobic digestion. *Journal of Environmental Management,* 141:132-137.

Cestonaro do Amaral, A., Kunz, A., Radis Steinmetz R.L. and Justi, K.C. (2014). Zinc and copper distribution in swine wastewater treated by anaerobic digestion. *Journal of Environmental Management*, 141,132-137.

Chelliapan, S., Wilby, T., Yuzir, A. and Sallis, P.J., (2006). Performance of an up-flow anaerobic stage reactor (UASR) in the treatment of pharmaceutical wastewater containing macrolide antibiotics. *Water Resources*, 40, 507-516.

Chen, S., Sun, D. and Chung, J.S. (2008). Simultaneous removal of COD and ammonium from landfill leachate using an anaerobic–aerobic moving-bed biofilm reactor system. *Waste Management*, 28, 339-346.

Chen, H., Meng, H., Nie, Z. and Zhang, M. (2013). Polyhydroxyalkanoate production from fermented volatile fatty acids: Effect of pH and feeding regimes. *Bioresource Technology,* 128, 533-538.

Chollom, Martha & Rathilal, Sudesh & Swalaha, Feroz & Bakare, Babatunde & Tetteh, Emmanuel. (2017). Study of the start-up of an upflow laboratory-scale anaerobic sludge blanket for the treatment of slaughterhouse wastewater. WIT *Transactions on Ecology and the Environment*. 216. 123-130. 10.2495/WS170111.

Chu, L. and Wang, J. (2011). Comparison of polyurethane foam and biodegradable polymer as carriers in moving bed biofilm reactor for treating wastewater with a low C/N ratio. *Chemosphere,* 83, 63-68.

Cui, D., Guo Y.Q., Lee H.S., Wu W.M., Liang B., Wang A.J. and Cheng H.Y. (2014). Enhanced decolorization of azo dye in a small pilot-scale anaerobic baffled reactor coupled with biocatalyzed electrolysis system (ABR-BES): A design suitable for scaling-up. *Bioresource Technology*, 163, 254-261.

Damasceno L.H.S., Rodrigues J.A.D., Ratusznei S. M., Zaiat M. and Euge^nio Foresti. (2007). Effects of feeding time and organic loading in an anaerobic sequencing batch biofilm reactor (ASBBR) treating diluted whey. *Journal of Environmental Management*,85,927-935.

Damgaard, C. (2009). On the distribution of plant abundance data. *Ecological Informatics,* 4, 76-82.

Dastyar, W., Amani, T. and Elyasi, S. (2015). Investigation of affecting parameters on treating high-strength compost leachate in a hybrid EGSB and fixed-bed reactor followed by electrocoagulation–flotation process. *Process Safety And Environmental Protection,* 95, 1-11.

Degueurce, A., Tomas, N., Le Roux, S., Martinez, J. and Peu, P. (2016). Biotic and abiotic roles of leachate recirculation in batch mode solid-state anaerobic digestion of cattle manure. *Bioresource Technology,* 200, 388-395.

Del Moro, G., Prieto-Rodríguez, L., De Sanctis, M., Di Iaconi, C., Malato, S. and Mascolo, G. (2016). Landfill leachate treatment: comparison of standalone electrochemical degradation and combined with a novel biofilter. *Chemical Engineering Journal,* 288, 87-98.

Deng, L., Guo, W., Ngo, H. H., Zhang, X., Wang, X. C., Zhang, Q. and Chen, R. (2016). New functional biocarriers for enhancing the performance of a hybrid moving bed biofilm reactor–membrane bioreactor system. *Bioresource Technology,* 208, 87-93.

Dolar, D., Košutić, K. and Strmecky, T. (2016). Hybrid processes for treatment of landfill leachate: Coagulation/Uf/Nf-Ro and adsorption/Uf/Nf-Ro. *Separation And Purification Technology,* 168, 39-46.

Dong, B.; Liu, X.G.; Dai, L.L.; Dai, X.H. (2013). Changes of heavy metal speciation during high-solid anaerobic digestion of sewage sludge. *Bioresource Technol*ogy, 131, 152–158.

Duncan, W.F.A., Mattes, A.G., Gould, W.D. and Goodarzi, F. (2004). Multi-stage biological treatment system for the removal of heavy metal contaminants. *In Waste Processing and Recycling in Mineral and Metallurgical Industries.* Fifth, V., Amaratunga, L.M., Cheng, T.C. and Richards, G.C. (eds.). Hamilton, Ontario, Canada,469-483.

El-Gohary, F. A. and Kamel, G. (2016). Characterization and biological treatment of pre-treated landfill leachate. *Ecological Engineering,* 94, 268-274.

Eldyasti, A., Chowdhury, N., Nakhla, G. and Zhu, J. (2010). Biological nutrient removal from leachate using a pilot liquid–solid circulating fluidized bed bioreactor (LSCFB). *Journal Of Hazardous Materials,* 181, 289-297.

Enright, A. M., McHugh, S., Collins, G. and O'Flaherty V. (2005). Low-temperature anaerobic biological treatment of solvent-containing pharmaceutical wastewater. *Water Research*, 39 (19), 4587-4596.

Ernst, W.R., Hennigar, P., Doe, K., Wade, S. and Julien, G. (1994). Characterization of the chemical constituents and toxicity to aquatic organisms of a municipal landfill leachate. *Water Pollution Research Journal of Canada*, 29, 89–101.

E.U. Tilley, L. Luethi, C. Reymond, P. Zurbruegg, Compendium of sanitation systems and technologies. in: 2nd Revised Edition, *The International Water Association, UK*, (2014).

Faisal, M. and Unno, H. (2001). Kinetic analysis of palm oil mill wastewater treatment by a modified anaerobic baffled reactor. *Journal of Biochemistry Engineering,* 9, 25 -31.

Fauziah, S. H. and Agamuthu, P. (2012). Trends in sustainable landfilling in Malaysia, a developing country. *Waste Management and Research,* 30, 656-63.

Fauziah, S.H., Emenike, C.U. and Agamuthu, P., (2013). Leachate risk and identification of accumulated heavy metals in P. Sutchi. *Waste Management and Research* , 10, 75–80.

Feng, H., Hu, L., Mahmood, Q., Fang, C., Qiu, C. and Shen D. (2009). Effects of temperature and feed strength on a carrier anaerobic baffled reactor treating dilute wastewater. *Desalination*, 239(1), 111-121.

Foo, K. Y., Lee, L. K. and Hameed, B. H. (2013a). Batch adsorption of semi-aerobic landfill leachate by granular activated carbon prepared by microwave heating. *Chemical Engineering Journal,* 222, 259-264.

Foo, K. Y., Lee, L. K. and Hameed, B. H. (2013b). Preparation of activated carbon from sugarcane bagasse by microwave assisted activation for the remediation of semi-aerobic landfill leachate. *Bioresource Technology,* 134, 166-172.

Foo, K. Y., Lee, L. K. and Hameed, B. H. (2013c). Preparation of banana frond activated carbon by microwave induced activation for the removal of boron and total iron from landfill leachate. *Chemical Engineering Journal,* 223, 604-610.

Fox, P., and Venkatasubbiah, V. (1996). Coupled anaerobic-aerobic treatment of high-sulfate wastewater with sulphate reduction and biological sulphide oxidation. *Water Science and Technology*, 34, 359-366.

Food And Agriculture Organization Of The United Nations, (2012). The State Of World Fisheries And Aquaculture-(2012). Viale Delle Terme Di Caracalla00153 Rome, Italy: Fisheries And Aquaculture Department.

Foxon, K.M., Pillay, S., Lalbahadur, T., Rodda, N., Holder, F. and Buckley, C.A. (2007).The anaerobic baffled reactor (ABR): an appropriate technology for on-site sanitation. *Water SA*, 30(5), 44-50.

Fu, F. and Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management,* 92, 407-418.

Grobicki, A. and Stuckey, D.C. (1991). Performance of the anaerobic baffled reactor under steady-state and shock loading conditions. *Biotechnology and. Bioengineering*, 37, 344-355.

Grover, R., Marwaha, S.S. and Kennedy, J.F.(1999). Studies on the use of an Anaerobic baffled reactor for the continuous anaerobic digestion of pulp and paper mill black liquors. *Process Biochemistry,* 34,653-657.

Hamza, R. A., Iorhemen, O. T. and Tay, J. H. (2016). Advances in biological systems for the treatment of high-strength wastewater. *Journal Of Water Process Engineering,* 10, 128-142.

Hashemi, H., Ebrahimi,A., Mokhtari, M., and Jasemizad,T. (2016). Removal of PAHs and heavy metals in composting leachate using the anaerobic migrating blanket reactor (AMBR) process. *Desalination and Water Treatment*, 57 (52), 24960-24969.

Hashisho, J., El-Fadel, M., Al-Hindi, M., Salam, D. and Alameddine, I. (2016). Hollow fiber vs. flat sheet mbr for the treatment of high strength stabilized landfill leachate. *Waste Management,* 55, 249-256.

He, J. and Chen, J. P. (2014). A comprehensive review on biosorption of heavy metals by algal biomass: Materials, performances, chemistry, and modeling simulation tools. *Bioresource Technology,* 160, 67-78.

Hossain, M.K., Hossain, M.L. and Das, S.R. (2014). Impact of Landfill Leachate on Surface and Ground Water Quality. *Journal of Environmental Science and Technology.*;7(6),337–346.

Hua, J., Bai, S.Y., Li, Z.Y. and Zhou, H. C. (2017). Treatment of landfill leachate using an up-flow anaerobic sludge semi-fixed filter. *Proceedings of 3rd International Conference on Water Resource and Environment(WRE 2017)*, 26-29 June,Qingdao,China 82-91.

Huang, Q., Yang, Y., Pang, X. and Wang, Q. (2008). Evolution onqualities of leachate and landfill gas in the semi-aerobiclandfill. *Journal of Environmental Sciences*. 20, 499–504.

Huda, N., Raman, A.A.A., Bello, M.M. and Ramesh, S. (2017). Electrocoagulation treatment of raw landfill leachate using iron-based electrodes: Effects of process parameters and optimization. *Journal of Environmental Management,* 204, 75-81.

Intanoo, P., Chaimongkol, P. and Chavadej, S. (2016). Hydrogen and methane production from cassava wastewater using two-stage upflow anaerobic sludge blanket reactors (UASB) with an emphasis on maximum hydrogen production. *International Journal Of Hydrogen Energy,* 41, 6107-6114.

Iskander, S. M., Brazil, B., Novak, J. T. and He, Z. (2016). Resource recovery from landfill leachate using bioelectrochemical systems: Opportunities, challenges, and perspectives. *Bioresource Technology,* 201, 347-354.

Ismail, S. and Tawfik, A. (2016). Performance of passive aerated immobilized biomass reactor coupled with fenton process for treatment of landfill leachate. *International Biodeterioration and Biodegradation,* 111, 22-30.

Kale, S.S., Kadam, A.K., Kumar, S. and Pawar, N.J. (2009). Evaluating pollution potential of leachate from landfill site, from the Pune metropolitan city and its impact on shallow basaltic aquifers. *Environmental Monitoring and Assessment*,162(1-4),327–346.

Karabelnik, K., Kõiv, M., Kasak, K., Jenssen, P. D. and Mander, Ü. (2012). High-strength greywater treatment in compact hybrid filter systems with alternative substrates. *Ecological Engineering,* 49, 84-92.

Karolina, K.H., Błażej, P. and Anna,S. (2017). Heavy metals – a silent threat to health. *Journal of Education, Health and Sport*, 7(1),121-132.

Kawai, M., Kishi, M., Hamersley, M. R., Nagao, N., Hermana, J. and Toda, T. (2012). Biodegradability and methane productivity during anaerobic co-digestion of refractory leachate. *International Biodeterioration and Biodegradation,* 72, 46-51.

Kim, K.H., Keller, A.A. and Yang, J.K. (2013). Removal of heavy metals from aqueous solution using a novel composite of recycled materials. *Colloids And Surfaces A: Physicochemical and Engineering Aspects,* 425, 6-14.

Kim, S.C. (2016). Application of response surface method as an experimental design to optimize coagulation-flocculation process for pre-treating paper wastewater. *Journal of Industrial and Engineering Chemistry*, 38, 93-102.

Kjeldsen, P., Barlaz, M., Rooker, A., Baun, A., Ledin, A. and Christensen, T., (2002). Present and long-term composition of MSW landfill leachate: A review. *Critical Reviews in Environmental Science and Technology*, 32 (4), 297–336.

Krishna, G.G.V.T., Kumar, P. and Kumar, P. (2007). Complex wastewater treatment using an anaerobic baffled reactor. *Environmental Progress,* 26, 391-398.

Ko, J. H., Yang, F. and Xu, Q. (2016). The impact of compaction and leachate recirculation on waste degradation in simulated landfills. *Bioresource Technology,* 211, 72-79.

Kurniawan, T. A., Lo, W.H. and Chan, G. Y. S. (2006). Physico-chemical treatments for removal of recalcitrant contaminants from landfill leachate. *Journal Of Hazardous Materials,* 129, 80-100.

Kulikowska, D. and Klimiuk, E. (2008). The effect of landfill age onmunicipal leachate composition. *Bioresource Technology*, 99, 5981-5985.

Kumari, M., Ghosh, P. and Thakur, I. (2016). Landfill leachate treatment using bacto-algal co-culture: An integrated approach using chemical analyses and toxicological assessment. *Ecotoxicology and Environmental Safety*, 128. 44-51.

Kuruti, K., Nakkasunchi, S., Begum, S., Juntupally, S., Arelli, V., Anupoju, G.R., (2017). Rapid generation of volatile fatty acids (VFA) through anaerobic acidification of livestock organic waste at low hydraulic residence time (HRT). *Bioresource Technology,* 238, 188–193.

Langenhoff, A.M.A., Intrachandra, N., and Stuckey, D.C. (2000). Treatment of dilute soluble and colloidal wastewater using an anaerobic baffled reactor: influence of hydraulic retention time. *Water Research*, 34, 1307-1317.

Lee, Y.J., Lim, S.-S., Baek, B. J., An, J.M., Nam, H.S., Woo, K.M., Cho, M.K., Kim, S.H. and Lee, S.H. (2016). Nickel(Ii)-induced nasal epithelial toxicity and oxidative mitochondrial damage. *Environmental Toxicology and Pharmacology,* 42, 76-84.

Lesmana, S. O., Febriana, N., Soetaredjo, F. E., Sunarso, J. and Ismadji, S. (2009). Studies on potential applications of biomass for the separation of heavy metals from water and wastewater. *Biochemical Engineering Journal,* 44, 19-41.

Lema, J.M., R. Mendez and R. Blazquez, (1988). Characteristics of landfill leachates and alternatives for their treatment: A review. *Water,air and soil pollution*, 40, 223-250.

Lim,C.K., Seow,T.W., Neoh,C.H., Nor,M.H.M., Ibrahim,Z., Ware,I. and Sarip,S.H.M. (2016). Treatment of landfill leachate using ASBR combined with zeolite adsorption technology. *3 Biotech* ,195,6.

Li, H., Han, H., Du, M. and Wang, W. (2011). Inhibition and recovery of nitrification in treating real coal gasification wastewater with moving bed biofilm reactor. *Journal Of Environmental Sciences,* 23, 568-574.

Li, H., Tan, F., Ke, L., Xia, D., Wang, Y., He, N., (2016). Mass balances and distributions of c, n, and p in the anaerobic digestion of different substrates and relationships between products and substrates. *Chemical Engineering Journal 287,* 329–336.

Li, H.S., Zhou, S.Q., Sun, Y.B., Feng, P. and Li, J.D. (2009). Advanced treatment of landfill leachate by a new combination processin a full-scale plant. *Journal of Hazardous Materials*, 172, 408-415.

Li, W., Hua, T., Zhou, Q., Zhang, S. and Li, F. (2010). Treatment of stabilized landfill leachate by the combined process of coagulation/flocculation and powder activated carbon adsorption. *Desalination,* 264,56–62.

Liang, Y.J., Chai, L.Y., Min, X.B., Tang, C.J., Zhang, H.J., Ke, Y. and Xie, X.D. (2012). Hydrothermal sulfidation and floatation treatment of heavy-metal-containing sludge for recovery and stabilization. *Journal Of Hazardous Materials,* 217-218, 307-314.

Lim, S.J. and Kim, T.H. (2014). Applicability and trends of anaerobic granular sludge treatment processes. *Biomass and Bioenergy*, 60, 189-202.

Lim, P.E., Lim, S.P., Seng, C.E. and Noor, A. M. (2010). Treatment of landfill leachate in sequencing batch reactor supplemented with activated rice husk as adsorbent. *Chemical Engineering Journal,* 159, 123-128.

Lin, Q., He, G., Rui, J., Fang,X., Tao, Y., Li, J. and Li, X. (2016). Microorganism-regulated mechanisms of temperature effects on the performance of anaerobic digestion. *Microbial Cell Factories,*15,96-113.

Liu, H., Wang, J., Liu, X., Fu, B., Chen, J., Yu, H.Q., (2012). Acidogenic fermentation of proteinaceous sewage sludge: effect of pH. *Water Resources,* 46, 799–807.

Liu, J., Zhang, H., Zhang P., Yan Wu, Gou, X., Song, Y., Tian, Z. and Zeng, G. (2017). Two-stage anoxic/oxic combined membrane bioreactor system for landfill leachate treatment: Pollutant removal performances and microbial community. *Bioresource Technology,* 243, 738–746.

Liu, Y. Q., Peng, Y., Liu, T., Xiao, H. and Wang, S. (2015). Treatment performance and $N_2O$ emission in the UASB-A/O shortcut biological nitrogen removal system for landfill leachate at different salinity. *Journal Of Industrial And Engineering Chemistry,* 32, 63-71.

Lu, T., George, B., Zhao, H. and Liu, W. (2016a). A case study of coupling upflow anaerobic sludge blanket (UASB) and anita mox process to treat high-strength landfill leachate. *Water Science and Technology,* 73, 662-668.

Lu, T., Xiang, T., Huang, X.L., Li, C., Zhao, W.F., Zhang, Q. and Zhao, C.S. (2015). Post-crosslinking towards stimuli-responsive sodium alginate beads for the removal of dye and heavy metals. *Carbohydrate Polymers,* 133, 587-595.

Lu, T., Zhen, G., Ni, J., Hojo, T., Kubota, K. and Li, Y.Y. (2016b). Effect of influent COD/$SO_4^{2-}$ ratios on biodegradation behaviors of starch wastewater in an upflow anaerobic sludge blanket (UASB) reactor. *Bioresource Technology,* 214, 175-183.

Lu, X., Guangyin, Z., Adriana Ledezma Estrada , Mo Chen , Jialing Ni , Toshimasa Hojo , Kengo Kubota , Yu-You Li. (2015). Operation performance and granule characterization of upflow anaerobic sludge blanket (UASB) reactor treating wastewater with starch as the sole carbon source. *Bioresource Technology,* 180, 264–273.

Luo, J., Qian, G., Liu, J. and Xu, Z. P. (2015). Anaerobic methanogenesis of fresh leachate from municipal solid waste: A brief review on current progress. *Renewable and Sustainable Energy Reviews,* 49, 21-28.

Mahmoudkhani R., Hassani A. H., Torabian A., Borghei S. M. and Borghei S. M. (2011). Study on high-strength anaerobic landfill leachate treatability by membrane bioreactor coupled with reverse osmosis. *International Journal of Environmental Research*, 6(1), 129-138.

Mai, L., Van Den Akker, B., Du, J., Kookana, R. S. and Fallowfield, H. (2016). Impact of exogenous organic carbon on the removal of chemicals of concern in the high rate nitrifying trickling filters. *Journal of Environmental Management,* 174, 7-13.

Maiti, S.K., De, S., Hazra, T., Debsarkar, A. and Dutta A. (2016). Characterization of Leachate and Its Impact on Surface and Groundwater Quality of a Closed Dumpsite – A Case Study at Dhapa, Kolkata, India. *Environmental Science: Processes and Impacts,* 35, 391–399.

Makisha Nikolay and Semenova Daria (2018). Production of biogas at wastewater treatment plants and its further application MATEC Web of Conferences 144, 04016 ,1-7.*International Conference on Research in Mechanical Engineering Sciences.*

Malaysia. (2016). *Solid Waste And Public Cleansing Management Corporation (SWCorp)*, Solid Waste and Public Cleansing Management Act 2007 (Act 673).

Malaysia. (2009). Environmental Quality (*Control of Pollution From Solid Waste Transfer Station And Landfill*) Regulations. P.U.(A) 433/2009.

Masirin, M.I.M., Ridzuan, M.B., Mustapha, S. and Adon, R. (2008). An overview of landfill management and technologies : a malaysian case study at Ampar tenang.*Proceedings of PSIS Enviro,Ist seminar on Environment, development and sustainability*,157-165.

McCarty, P.L., (1981). One Hundred Years of Anaerobic Treatment. In: Anaerobic Digestion, Hughes, D.E. (Ed.). New York: Elsevier Biomedical Press, 4,30-41.

McHugh Sharon, Caroline O'Reilly , The´re`se Mahony , Emer Colleran & Vincent O'Flaherty. (2003). Anaerobic granular sludge bioreactor technology Reviews in *Environmental Science and Bio Technology* 2: 225–245.

Metcalf and Eddy. (2014). *Wastewater Engineering: Treatment and Resource Recovery.* 5th Edition, McGraw-Hill, New York.

Moharram, M. A., Abdelhalim, H.S. and Rozaik, E.H. (2015). Performance appraisal of the A2/O process in domestic wastewater treatment replacing the anaerobic unit with UASB. *HBRC Journal*, 13(1), 98-105.

Mohd Dinie and Mashitah, M.D. (2013). Municipal solid waste management in malaysia: current practices, challenges and prospect. *Jurnal Teknologi (Sciences and Engineering),* 62(1), 95-101.

Mohtashami, S. R., Jashnie, A.K. and Bidokhti, N.T. (2008). Performance of Anaerobic Baffled Reactor (ABR) in Landfill Leachate Treatment.*Journal of water and wastewater*, 19(2),10-18.

Mojiri, A., Aziz, H. A., Zaman, N. Q., Aziz, S. Q. and Zahed, M. A. (2014). Powdered zeliac augmented sequencing batch reactors (SBR) process for co-treatment of landfill leachate and domestic wastewater. *Journal of Environmental Management,* 139, 1-14.

Mojiri, A., Ziyang, L., Hui, W., Ahmad, Z., Tajuddin, R.M., , Amr, S.S.A., Kindaichi, T., Aziz, H.A. and Farraji, H. (2017) . Concentrated landfill leachate treatment with a combined system including electro-ozonation and composite adsorbent augmented sequencing batch reactor process. *Process Safety and Environmental Protection,* 111, 253-262.

Mojiri, A., Ziyang, L., Tajuddin, R. M., Farraji, H. and Alifar, N. (2016). Co-treatment of landfill leachate and municipal wastewater using the zeliac/zeolite constructed wetland system. *Journal of Environmental Management,* 166, 124-130.

Montalvo, S., Guerrero, L., Robles, M., Mery, C., Huiliñir, C. and Borja, R. (2014a). Start-up and performance of uasb reactors using zeolite for improvement of nitrate removal process. *Ecological Engineering,* 70, 437-445.

Montalvo, S., Martin, J. S., Huiliñir, C., Guerrero, L. and Borja, R. (2014b). Assessment of a UASB reactor with high ammonia concentrations: effect of zeolite addition on process performance. *Process Biochemistry,* 49, 2220-2227.

Mor, S., Ravindra, K., Dahiya, R.P. and Chandra, A. (2006). Leachate Characterization and Assessment of Groundwater Pollution Near Municipal Solid Waste Landfill Site. *Environmental Monitoring and Assessment.*118(1-3):435–456.

Muhamad, M. H., Sheikh Abdullah, S. R., Abu Hasan, H. and Abd. Rahim, R. A. (2015). Comparison of the efficiencies of attached- versus suspended-growth SBR systems in the treatment of recycled paper mill wastewater. *Journal Of Environmental Management,* 163, 115-124.

Murto, M., Bjo¨ rnsson, L. and Mattiasson, B. (2004). Impact of food industrial waste on anaerobic codigestion of sewage sludge and pig manure. *Journal Of Environmental Management,* 70,101-107.

Nascimento, S., Baierle, M., Göethel, G., Barth, A., Brucker, N., Charão, M., Sauer, E., Gauer, B., Arbo, M. D., Altknecht, L., Jager, M., Dias, A. C. G., De Salles, J. F., Pierre, T. S., Gioda, A., Moresco, R. and Garcia, S. C. (2016). Associations among environmental exposure to manganese, neuropsychological performance, oxidative damage and kidney biomarkers in children. *Environmental Research,* 147, 32-43.

Nasr, F.A., Doma, H.S. and Nassar, H.F. (2009). Treatment of domestic wastewater using an anaerobic baffled reactor followed by a duckweed pond for agricultural purposes. *The Environmentalist*, 29(3),270-279.

Naveen, B.P., Sivapullaiah, P.V. and Sitharam, T.G. (2014). Compressibility and Shear Strength of Dumped Municipal Solid Waste. *Journal of Solid Waste Technol*ogy and *Management*. 40(4),327–334.

Nghiem, L. D., Hai, F. I. and Listowski, A. (2016). Water reclamation and nitrogen extraction from municipal solid waste landfill leachate. *Desalination and Water Treatment*, 57 (60), 29220-29227.

Ngo, H.H., Guo, W. and Xing, W. (2008) Applied technologies in municipal solid waste landfill leachate treatment. In: Vigneshwaran S (ed) Water and wastewater treatment technologies, vol. 2. Eolss Publishers Co Ltd., Oxford, 17.

Nuansawan, N., Boonnorat, J., Chiemchaisri, W. and Chiemchaisri, C. (2016). Effect of hydraulic retention time and sludge recirculation on greenhouse gas emission and related microbial communities in two-stage membrane bioreactor treating solid waste leachate. *Bioresource Technology,* 210, 35-42.

Palaniandy, P., Adlan, M. N., Aziz, H. A. and Murshed, M. F. (2010). Application of dissolved air flotation (DAF) in semi-aerobic leachate treatment. *Chemical Engineering Journal,* 157, 316-322.

Peyravi, M., Jahanshahi, M., Alimoradi, M. and Ganjian, E. (2016). Old landfill leachate treatment through multistage process: Membrane adsorption bioreactor and nanofitration. *Bioprocess and Biosystems Engineering*, 39, 1803-1816.

Plazinski, W. (2013). Binding of heavy metals by algal biosorbents: Theoretical models of kinetics, equilibria and thermodynamics. *Advances In Colloid And Interface Science,* 197-198, 58-67.

Polprasert, C., Kemmadamrong, P. and Tran, F. (1992). Anaerobic baffle reactor (ABR) process for treating a slaughterhouse wastewater. *Environmental Technology*, 13(9), 857-865.

Prakash N.B., Vimala,S. and Jayakaran, P. (2015). Mathematical model development for bod removal efficiency in tannery waste treatment. *British Journal of Environmental Sciences,* 3, 1-12.

Rafizul, I. M. and Alamgir, M. (2012). Characterization and tropical seasonal variation of leachate: results from landfill lysimeter studied. *Waste Management,* 32, 2080-2095.

Raghab, S. M., Abd El Meguid, A. M. and Hegazi, H. A. (2013). Treatment of leachate from municipal solid waste landfill. *HBRC Journal,* 9, 187-192.

Rahim, E.A.-B, Yusoff, I., Samsudin A.R., Yaacob, W.Z.W. and Rafek, A.G.M. (2010). Deterioration of groundwater quality in the vicinity of an active open-tipping site in West Malaysia. *Hydrogeology Journal*, 18, 997-1006.

Rahmaninezhad, S. A., Fathi, H., Pendashteh, A. R., Chaibakhsh, N. and Tavakoli, B. (2016). Investigation of the impact of immobilized cells and the nitrification process using a coupled moving bed biofilm reactor and activated sludge bioreactor for biodegradation of high concentrations of dimethyl formamide. *Process Safety And Environmental Protection*, 102,523-533.

Raposo, F., De la Rubia, M.A., Borja, F.C.R., (2012). Anaerobic digestion of solid organic substrates in batch mode: An overview relating to methane yields and experimental procedures. *Renewable and Sustainable Energy Reviews,* 16 (3), 861–877.

Raposo, F., De la Rubia M.A., Fernández-Cegrí, V. and Borja, R. (2012). Anaerobic digestion of solid organic substrates in batch mode: An overview relating to methane yields and experimental procedures. *Renewable and Sustainable Energy*, 16(1), 861-877.

Rasool, M. A., Tavakoli, B., Chaibakhsh, N., Pendashteh, A. R. and Mirroshandel, A. S. (2016). Use of a plant-based coagulant in coagulation–ozonation combined treatment of leachate from a waste dumping site. *Ecological Engineering,* 90, 431-437.

Ray, N. H. S., Mohanty, M. K., & Mohanty, R. C. (2013). Anaerobic digestion of kitchen waste: Biogas production and pre-treatment waste, a review. *International Journal of Scientific and Research Publication,* 3 (11),1-6.

Razarinah, W., Mahmood, N. and Abdullah, N. (2014). Treatment of landfill leachate by immobilized Ganoderma australe and crude enzyme. *Science Asia*, 40, 335-339.

Renou, S., Givaudan, J. G., Poulain, S., Dirassouyan, F. and Moulin, P. (2008). Landfill leachate treatment: Review and opportunity. *Journal Of Hazardous Materials,* 150, 468-493.

Rizvi, H., Ahmad, N., Abbas, F., Bukhari, I.H., Yasar, A., Ali, S., Yasmeen, T. and Riaz, M. (2015). Start-up of UASB reactors treating municipal wastewater and effect of temperature/sludge age and hydraulic retention time (HRT) on its performance. *Arabian Journal of Chemistry*, 8(6), 780-786.

Rongrong, L., Xujie, L., Qing, T., Bo, Y. and Jihua, C. (2011). The performance evaluation of hybrid anaerobic baffled reactor for treatment of pva-containing desizing wastewater. *Desalination,* 271, 287-294.

Salleh, N. F. D. M., and Hamid, K. H. K. (2013). Pencirian air larut resap dari tapak pelupusan ditutup Air Hitam, Puchong, Malaysia. *Malaysian Journal of Analytical Sciences*, 17(1), 24-29.

Sahinkaya, E., Dursun, N., Ozkaya, B. and Kaksonen, A. H. (2013). Use of landfill leachate as a carbon source in a sulfidogenic fluidized-bed reactor for the treatment of synthetic acid mine drainage. *Minerals Engineering,* 48, 56-60.

Samsudina, D. (2013). Municipal solid waste management in malaysia: Current practices,challenges and prospect. *Jurnal Teknologi,* 62, 95-101.

Şentürk, E., İnce, M. and Engin, G. O. (2013). The effect of transient loading on the performance of a mesophilic anaerobic contact reactor at constant feed strength. *Journal Of Biotechnology,* 164, 232-237.

Şentürk, E., İnce, M. and Onkal Engin, G. (2010). Kinetic evaluation and performance of a mesophilic anaerobic contact reactor treating medium-strength food-processing wastewater. *Bioresource Technology,* 101, 3970-3977.

Silva, A.C., Dezotti, M., and Sant'Anna, J.G.L. (2004). Treatment and detoxification of a sanitary landfill leachate. *Chemosphere*, 55, 207-214.

Singh, V. and Mittal, A. K. (2012). Toxicity and treatability of leachate: application of uasb reactor for leachate treatment from Okhla landfill, New Delhi. *Water Science and Technology,* 65, 1887-94.

Skiadas, I. and Lyberatos, G. (1998). The periodic anaerobic baffled reactor. *Water Science and Technology,* 38,401-408.

Smith, S. (2009). A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. *Environment International,* 35(1),142-156.

Speece, R. E. (1996). Anaerobic Biotechnology for Industrial Wastewaters. Archae Press, Nashville.

Sun, H., Peng, Y. and Shi, X. (2015). Advanced treatment of landfill leachate using anaerobic-aerobic process: organic removal by simultaneous denitritation and methanogenesis and nitrogen removal via nitrite. *Bioresource Technology,* 177, 337-345.

Tauseef, S. M., Abbasi, T. and Abbasi, S. A. (2013). Energy recovery from wastewaters with high-rate anaerobic digesters. *Renewable And Sustainable Energy Reviews,* 19, 704-741.

Tekerlekopoulou, A. G., Tsiflikiotou, M., Akritidou, L., Viennas, A., Tsiamis, G., Pavlou, S., Bourtzis, K. and Vayenas, D. V. (2013). Modelling of biological cr(vi) removal in draw-fill reactors using microorganisms in suspended and attached growth systems. *Water Research,* 47, 623-636.

Thanh, P.M., Ketheesan, B., Yan, Z., Stuckey, D. (2016). trace metal speciation and bioavailability in anaerobic digestion: A review. *Biotechnology Advances,* 34 ,122–136.

Tiew, K. G., Ahmad Basri, N.E., Watanabe, K., Abushammala, M. F. M. and Ibrahim, M. T. (2015). Assessment of the sustainability level of communitywaste recycling program in Malaysia. *Journal of Material Cycles and Waste Management*, 17 , 598-605.

Timur, H. and Özturk, I. (1997). Anaerobic treatment of leachate using sequencing batch reactor and hybrid bed filter. *Water Science And Technology,* 36, 501-508.

Tisa, F., Abdul Raman, A. A. and Wan Daud, W. M. A. (2014). Applicability of fluidized bed reactor in recalcitrant compound degradation through advanced oxidation processes: A review. *Journal Of Environmental Management,* 146, 260-275.

Trzcinski, A. P. and Stuckey, D. C. (2016a). Effect of sparging rate on permeate quality in a submerged anaerobic membrane bioreactor (SAMBR) treating leachate from the organic fraction of municipal solid waste (OFMSW). *Journal Of Environmental Management,* 168, 67-73.

Trzcinski, A. P. and Stuckey, D. C. (2016b). Inorganic fouling of an anaerobic membrane bioreactor treating leachate from the organic fraction of municipal solid waste (OFMSW) and a polishing aerobic membrane bioreactor. *Bioresource Technology,* 204, 17-25.

Tsarpali, V., Kamilari, M., Dailianis, S., (2012). Seasonal alterationsof landfill leachate composition and toxic potency insemi-arid regions. *Journal of Hazardous Materials*, 233-234, 163–171.

Uyanik, S., Sallis, P.J. and Anderson, G.K. (2001a). The effect of polymer addition on granulation in an anaerobic baffled reactor (ABR). Part 1: process performance. *Water Research,* 36, 933-943.

Uyanik, S., Sallis, P.J. and Anderson, G.K. (2001b). The effect of polymer addition on granulation in an anaerobic baffled reactor (ABR).Part II: compartmentalization of bacterial populations. *Water Research,* 36, 944-955.

Uggetti, E., Hughes-Riley, T., Morris, R. H., Newton, M. I., Trabi, C. L., Hawes, P., Puigagut, J. and García, J. (2016). Intermittent aeration to improve wastewater treatment efficiency in pilot-scale constructed wetland. *Science Of The Total Environment,* 559, 212-217.

Wang, B. and Shen, Y. (2000). Performance of an anaerobic baffled reactor (ABR) as a hydrolysis-acidogenesis unit in treating landfill leachate mixed with municipal sewage. *Water Science and Technology*, 42 (12),115-121.

Wang, K., Yin, J., Shen, D., Li, N., (2014). Anaerobic digestion of food waste for volatile fatty acids (VFAs) production with different types of inoculum: effect of pH. *Bioresour. Technol*. 161, 395–401.

Wang, X., Han, J., Chen, Z., Jian, L., Gu, X. and Lin, C.J. (2012). Combined processes of two-stage fenton-biological anaerobic filter–biological aerated filter for advanced treatment of landfill leachate. *Waste Management,* 32, 2401-2405.

Widziewicz, K., Kalka, J., Skonieczna, M. and Madej, P. (2012). The comet assay for the evaluation of genotoxic potential of landfill leachate. *The Scientific World Journal*,435239, 1-8.

Wu, Y., Wang, C., Liu, X., Ma, H., Wu, J., Zuo, J. and Wang, K. (2016). A new method of two-phase anaerobic digestion for fruit and vegetable waste treatment. *Bioresource Technology,* 211, 16-23.

Xu, S. Y., Lam, H. P., Karthikeyan, O. P. Wong, J. W. C. (2011). Optimization of food waste hydrolysis in leach bed coupled with methanogenic reactor: Effect of pH and bulking agent. *Bioresource Technology,* 102, 3702-3708.

Ye, J., Mu, Y., Cheng, X. and Sun, D. (2011). Treatment of fresh leachate with high-strength organics and calcium from municipal solid waste incineration plant using uasb reactor. *Bioresource Technology,* 102, 5498-5503.

Yokoyama, S. and Matsumura, Y. (2008). *Biochemical Conversion of Biomass*, *Part 5*, Japan,The Japan Institute of Energy:The Asian Biomass Hanbook.

Yoshida, M., Ahmed, S., Nebil, S. and Ahmed, G. (2002). Characterization of leachate from Henchir El Yahoudia closed landfill. *Water Environment Research*, 1(2), 129-42.

Yu, H. and Anderson, G.K. (1996). Performance of a combined anaerobic reactor for municipal wastewater treatment at ambient temperature. *Resources, Conservation, and Recycling*, 17, 259-271.

Yu, J.J., Chen, H., Guo, Q., Zhang, Z.Z., Guo, L.X. and Jin, R.C. (2015). Response Of Performance of an anammox Anaerobic Baffled Reactor (ABR) to changes in feeding regime. *Ecological Engineering,* 83, 19-27.

Zainol, N. A., Aziz, H.A., and Yusoff, M. S. (2012). Characterization of leachate from kuala sepetang and kulim landfills: A comparative study. *Energy and Environment Research*, 2(2), 45-52.

Zayen, A., Mnif, S., Aloui, F., Fki, F., Loukil, S., Bouaziz, M. and Sayadi, S. (2010). Anaerobic Membrane bioreactor for the treatment of leachates from jebel chakir discharge in Tunisia. *Journal Of Hazardous Materials,* 177, 918-923.

Zayen, A., Schories, G. and Sayadi, S. (2016). Incorporation of an anaerobic digestion step in a multistage treatment system for sanitary landfill leachate. *Waste Management,* 53, 32-39.

Zhang, R.,El-Mashad, H. M., Hartman, K., Wang, F., Liu, G., Choate, C. and Gamble, P. (2007). Characterization of food waste as feedstock for anaerobic digestion. *Bioresource technology*, 98, 929-35.

Zhao, J., Shi, Y.S. and Lu, Q.J. (2012). Experimental study for ABR to treat the domestic sewage, *Advanced Materials Research*, 393, 1217-1223.

Zhao, H., Zhong, C., Chen, H., Yao, J., Tan, L., Zhang, Y. and Zhou, J. (2016). Production of bioflocculants prepared from formaldehyde wastewater for the potential removal of arsenic. *Journal Of Environmental Management,* 172, 71-76.

Zhu, G., Zou, R., Jha, A.K., Huang, X., Liu, L. and Liu, C. (2015). Recent developments and future perspectives of anaerobic baffled bioreactor for wastewater treatment and energy recovery. *Critical Reviews in Environmental Science and Technolog*y, 45(12), 1243-76.

# APPENDIX A

## Operational problems and subsequent precautions

In this study, there have several operational problems that occurred throughout the experimental phase. The problems that should be kept in mind and the precautionary measures that should be taken to avoid any unavoidable problems are discussed in this section.

1. Calibrate the pump for different values of HRT before starting the experiment as it is not possible to calibrate during the experiment.

2. At the junction of lid and reactor, examine the leakage carefully on daily basis to avoid any leakage and subsequent infiltration of oxygen.

3. Use the timer for the operation of heater to maintain the temperature in the mesophilic range if the heating is continuous than there are chances of overflow because of overheating.

4. Intermittently check the inflow and outflow pipes because sometimes the clogging of pipes takes place due to thickened wastewater or sludge which may hinder the flow leading to overflow of the reactor.

5. The pH should be monitored on a continuous basis and if the pH of the feed is dropping from the value of 7 then we can add NaOH to stabilize the pH.

6. Empty the effluent tank according to HRT otherwise it can cause spillage in the lab.

7. Make sure that there is enough feed every time because if it finishes in the absence air can go inside the reactor causing problems as it is an anaerobic reactor.

8. Intermittently check the water in the bubble counter and note down the bubbles produced every day.

9. Make sure to use centrifuge in the preparation of samples for COD.

10. From gas collection ports there should be a single pipe connected to tedlar bag as the connectors in between can cause losses.

11. The stock solution for the synthetic wastewater (meat extract) must be shaken properly before being used as the thick content settles at the bottom.

12. After filling the reactor with the sludge the reactor should be purged with nitrogen gas to eliminate the oxygen present in the reactor.

13. GC or FTIR should be used in the measurement of gas because gas analyzers are not efficient and accurate for experiments.

14. The collected leachate sample should be avoided to be kept under direct sunlight as the material of the container together with the heat may change the characteristics of the leachate.

# APPENDIX B

**International Journal of Civil Engineering and Technology (IJCIET)**
Volume 9, Issue 5, May 2018, pp. 336–348, Article ID: IJCIET_09_05_038
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=5
ISSN Print: 0976-6308 and ISSN Online: 0976-6316



# A REVIEW OF MUNICIPAL SOLID WASTE (MSW) LANDFILL MANAGEMENT AND TREATMENT OF LEACHATE

**Imran Ahmad, Shreeshivadasan Chelliapan*, Norazli Othman, Roslina Mohammad, Samira Albati Kamaruddin**
Department of Engineering, UTM Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100, Kuala Lumpur, MALAYSIA

## ABSTRACT

*Solid Waste Management (SWM) has become an issue of concern ever since humans began to build communities within a concentrated area. The greater the population density the more important is a proper waste management system. The main objective of the disposal system was to take care of the sanitation and health of the community. However, with the development of modern civilization, simply removing waste became an insufficient solution because waste disposal dumps became major sources of regional environmental contamination due to emissions of leachate and gas into groundwater and surface water; dumps were soon recognized as unsuitable and unsustainable disposal practices. Therefore, various strategies have been introduced to improve the concepts of waste management and sustainable landfilling is a necessary part of an efficient integrated waste management system. The degradation of the organic fraction of the wastes in combination with percolating rainwater leads to the production of a dark coloured, highly polluted liquid called "leachate". If not treated and carefully disposed the movement of leachate into the surrounding soil, ground water, or surface water, may lead to severe pollution. This paper highlights the landfill management, landfill leachate generation and its characterization, and treatment methods available for landfill leachate.*

**Keywords:** Municipal Solid Waste, Landfill Leachate, Treatment of Leachate, Management of Leachate

**Cite this Article:** Imran Ahmad, Shreeshivadasan Chelliapan, Norazli Othman, Roslina Mohammad, Samira Albati Kamaruddin, A Review of Municipal Solid Waste (MSW) Landfill Management and Treatment of Leachate, International Journal of Civil Engineering and Technology, 9(5), 2018, pp. 336–348.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=5

# APPENDIX C














FINAL
DISCHARGE POINT