WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.074
Volume 8, Issue 7, 211-237. Review Article ISSN 2277– 7105

THE SIGNIFICANCE OF MICROBIAL TECHNIQUES AS A TOOL FOR BIOLOGICAL REMEDIATION OF LANDFILL LEACHATE: MINI REVIEW

Rahanatu Adamu Kakudi[1], Abdullahi Hadiza Ari[2,4] and Adamu Yunusa Ugya*[2,3]

[1]Department of Integrated Sciences, Federal College of Education, Kano, Kano State, Nigeria.
[2]College of New Energy and Environment, Jilin University, Changchun, China.
[3]Departments of Environmental Management, Kaduna State University, Kaduna, Nigeria.
[4]Faculty of Sciences, National Open University, Abuja, Nigeria.

Article Received on
07 April 2019,

Revised on 28 April 2019,
Accepted on 19 May 2019

DOI: 10.20959/wjpr20197-15102

***Corresponding Author**
Adamu Yunusa Ugya
Departments of
Environmental Management,
Kaduna State University,
Kaduna, Nigeria.

ABSTRACT

Landfill is the common method of waste management in most part of the world particularly developing countries due to low technology know-how. This method of solid waste disposal is meant to better the living standard of mankind but the unplanned production of landfill leachate reverse the same standard by impacting negatively to the environment which in turn affect mankind. Different method of treating landfill leachate have been develop, but most of this method are not easily accessible, the use of microbe for biological treatment of landfill leachate has gained the attention of researchers since the potentiality of many microbe has been attested for high pollutant reduction efficiency from landfill leachate but the onsite application of this method remains a problem owing to the lack of genomic, metabolomic and proteomic details to prove the efficiency of this microbes to effectively degrade pollutants from landfill leachates. This mini-review is aimed at evaluating the contribution of microbe towards the success of landfill leachate treatment and the role of molecular genomics in achieving the onsite treatment of landfill leachates. The mini-review report the role of metanogenic and acetogenic bacteria in the formation of landfill leachate, current trend in biological treatment of landfill leachate, the role of mycoremediation, phycoremediation and bioremediation (bacteria) in landfill leachates treatment and current contribution and the future of molecular tool in increasing the efficiency of microbe in landfill leachates treatment. The molecular genomics of microbe used in the treatment of landfill leachates need to be further studied to attest the role of genomics, proteomics and metabolomic constituent for efficient onsite application.

KEYWORDS: Proteomic, Organic Pollutants, Phycoremediation, Mycoremediation, Underground water.

INTRODUCTION

Landfill is the common method use for solid waste management in most part of the world particularly developing countries due to low technology know-how (Aftab, Shin, & Hur, 2018; Bautista-Ramirez et al., 2018; Cingolani, Fatone, Frison, Spinelli, & Eusebi, 2018). This method of waste disposal has recorded high efficiency in the reduction of the mass accumulation of solid waste (Cingolani et al., 2018; Inglezakis et al., 2018; Szymanski, Siebielska, Janowska, & Sidelko, 2018). The mixture of water originating from either rain or drainage water lead to the formation of landfill leachate, Many researchers including (D. Wu, Ma, Wei, Yang, & Xie, 2018) and (Aftab et al., 2018) have reported that landfill leachate contain organic and inorganic pollutants (Mingjun Deng et al., 2018; Jambers Scandelai et al., 2018; Ramaswami, Behrendt, & Otterpohl, 2018).

Landfill is meant to better the standard of living of man but ironically the production of leachate reverse the same standard thereby leading to the pollution of underground water and sometimes surface water (Fernandes et al., 2018; Xiang Li et al., 2018; Tigini & Varese, 2018). The effect attributed to landfill leachate has instigated researches from all over the field of environmental sciences to performed researchers on how to effectively treat landfill leachates among which include chemical coagulation/ flocculation (Verma & Kumar, 2018), Membrane bioreactor (Azzouz, Boudjema, Aouichat, Kherat, & Mameri, 2018), natural coagulation (Aziz, Agamuthu, & Fauziah, 2018) and Bioremediation (Andrea Paskuliakova, Ted McGowan, Steve Tonry, & Nicolas Touzet, 2018) to mention just a few.

The biological remediation of landfill leachate using microorganism is gaining acceptance owing to the fact that most researchers have reveal the potentiality of some microorganism to effectively remediate leachates with high organic and inorganic pollutants removal if match up to other biological and conventional methods (El-Fadel et al., 2018; Kalita & Joshi, 2017; Miao et al., 2018). The inquisitiveness of researchers towards the mechanism involve in the biological remediation of pollutants by microorganism is on the increase (X. Li, Tang, & Lu, 2018; Saez, Saavedra, Hebert, & Zarate, 2018; Sah et al., 2018). These questioning has lead to the molecular characterization of some microorganism use for the biological remediation of petrochemical wastewater in which quantification of molecular cellular component such as Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) with little or no studies on protein and metabolites (Oppong-Anane, Quinones, Harris, Townsend, & Bonzong, 2018; Subasinghe et al., 2018; S. Wu et al., 2018). Characterization of bacteria in landfill leachate will give a better picture of how biological remediation could be efficiently utilized to remove pollutants from landfill leachates (Hu et al., 2018; Syed-Ab-Rahman et al., 2018; Tabssum, Ahmad, & Qazi, 2018). This review thereby aimed at establishing the contribution of microorganisms towards the success biological treatment of landfill leachate and also to predict the future prospect of the use of microorganism in eradication of ground water pollution resulting from pollution by landfill leachate. The mini-review is particularly interested in the role of microorganism and mechanism involve in the remediation of landfill leachate.

Formation of Landfill Leachate

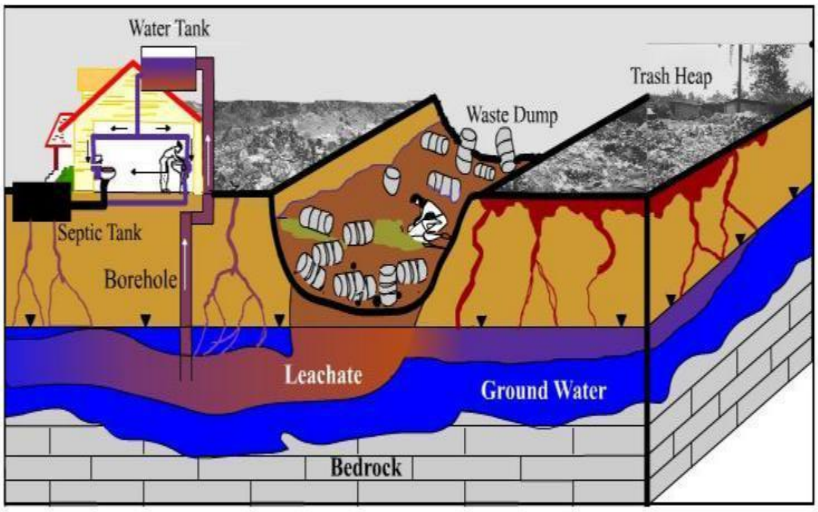

Figure. 1: Process of Landfill Formation.

Landfill leachate is formed when precipitation resulting from rainfall, surface runoff or groundwater recharge comes in contact degradading waste as shown in fig (1) (Ding et al., 2018; Salim & Evin, 2014; Szymanski et al., 2018). The process of decomposition as shown in Figure (1) is aided by bacteria; the decomposition of the landfill for the formation of leachate is divided into some sequential pathways which include aerobic pathway (hydrolysis and fermentation), anaerobic acetogenic pathway, anaerobic methanogenic pathway and maturation pathway (Bashir, Lim, Abu Amr, Wong, & Sim, 2019; Camano Silvestrini, Maine, Hadad, Nocetti, & Campagnoli, 2019).

Aerobic Pathway (Hydrolysis and Fermentation)

This process of leachate production relies on moisture content for water contribution, although, rainfall may partake in the contribution of water (Aftab & Hur, 2019; Su, Wang, Xia, & Xie, 2019). The process of degradation by aerobic condition involves two processes which are fermentation and hydrolysis. Figure (2) shows an illustration of how bacteria used oxygen to bring about the degradation of organic substances by hydrolysis and fermentation respectively(Gunes, Demir, Gunes, & Hanedar, 2019). Aerobic process of landfill leachate formation is utilized by researchers for a treatment process refered to as activated sludge. This process provides microbial organisms with oxygen to enable the microbe to actively utilized organic matter in landfill leachates thereby degrading them into CO_2 and H_2O as shown by figure (2). Other aerobic process based treatment method of landfill leachate includes Sequencing Batch Reactor (SBR), Aerated Lagoon (AL) and Rotating Biological Contractor (RBC) (Augusto et al., 2019; Mohammad-pajooh et al., 2018).

Anaerobic Acetogenic Pathway

During this path way, acetogenic bacteria are the dominant bacteria. The bacteria catalysis the continuation of the hydrolysis process of solid waste thereby leading to the formation of carboxylic acid of high concentration, a condition that lead to low hydrogen concentration which favours the growth of metanogenic bacteria which act on the carboxylic acid and convert it to methane and carbon (IV) is given off. These processes lead to low pH of below 4 due to the dissolution of other compounds, Hence, the reason why heavy metals, alkaline earth metals and alkaline earth metals are present in leachates (Aleya, Grisey, Bourioug, & Bourgeade, 2019; Camano Silvestrini et al., 2019; Shu, Guo, Zhang, He, & Wei, 2019).

Anaerobic Methanogenic Pathway

As concentration of methane increase so does the pH until the pH settled at between 7-8. This phase is also accompanied by drop in temperature to settle for between 20-65^{0}C so that the dominant bacteria will be mesophilic and thermophilic bacteria. Most researchers are silent about what happen in this stage (but the fact that the biodegradation potentiality of mesophilic and thermophilic bacteria signify the continuation of hydrolysis and fermentation in the decomposition of organic compounds). Anaerobic acetogenic and metanogenic pathway is utilized by researchers for the treatment of landfill leachate in a treatment process refered to as Upflow Anaerobic Sludge Blanket (UASB) (Banihani, Sierra-Alvarez, & Field, 2009; Eldyasti, Chowdhury, Nakhla, & Zhu, 2010; Taneja, Kumar, Raghav, & Mittal, 2010).

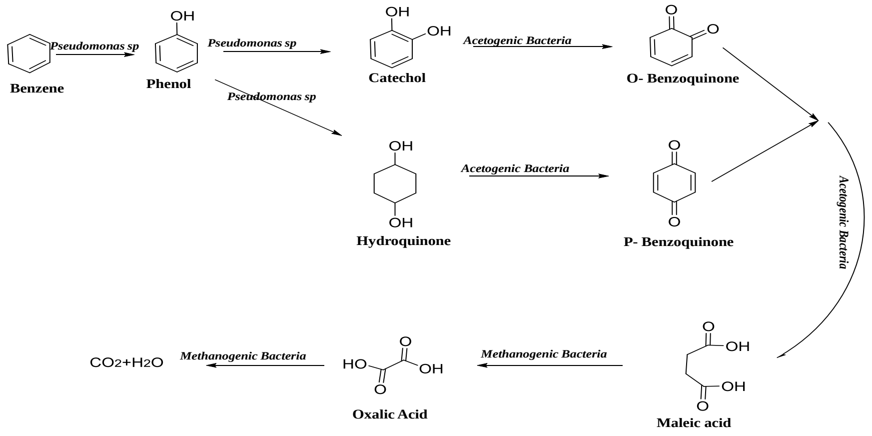

Figure. 2: Showing the Conversion of Organic Substances into Leachate (Ugya, Hua, Agamuthu, & Ma, 2019).

Maturation Pathway

Maturation pathway is also refered to as the landfill stabilization stage owing to the fact that the process involves the drastic reduction in methane production which is due to completion of decomposition of biodegradable parts of the landfill except for persistence compound leading to the limiting of nutrient availability which correlate positively with bacteria diversity in the leachate (Cheng et al., 2018; Fu et al., 2019; Guo et al., 2019).

Characteristics of Landfill Leachate and Effect

Landfill leachate contains organic and inorganic pollutants, some pollutants find include heavy metals such as cobalt, gallium, selenium, rubidium, strontium, caesium, barium, bismuth uranium and others as summarized in table (1) below.

Table. 1: Characteristics of Landfill Leachate.

S. No.	Constituent of Leachate	Environmental Impact	References
1	Biochemical Oxygen Demand, Chemical Oxygen Demand	Deplete dissolved oxygen in aquatic environment	(Coppini, Palli, Fibbi, & Gori, 2018)
3	Total Solid	Both dissolved and suspended tend to increase the turbidity of water body which inturn reduce productivity of aquatic body	(Boateng, Opoku, & Akoto, 2018; Ding et al., 2018)
4	Nitrogen, Phosphorus and Nitrate, Ammonia	They contribute immensely to eutrophication which lead to algae blooms which is associated with death of aquatic life. High toxicity has been reported in human. nitrate causes methemoglobinemia while phosphorus limit vegetative productivity	(Andrade Filho et al., 2018; Leite, Paredes, de Sousa, Lopes, & de Sousa, 2018)
7	Heavy metal (Hg, Cr, Ag, Ar)	Heavy metals are generally persistence so are toxic in soluble or elemental form. Cu, Mn, Fe, Zn are essential element to both plants and animals but can be toxic at higher concentration. Pb causes haemorrhagic and sloughing of human mucosa, Ni, Cr and Cd are highly carcinogenic compounds.	(G. Lu et al., 2018)
8	Organophosphorus flame retardants (OPFRs)		(Mingjun Deng et al., 2018; M. Deng et al., 2018)
9	Sulphate and Chloride		(Fudala-Ksiazek, Pierpaoli, & Luczkiewicz, 2018)
10	Turbidity	Reduce aquatic environment productivity due to sunlight penetration obstruction	(Dia, Drogui, Buelna, & Dube, 2018)
11	Phenol	Causes muscles tremor resulting into walking difficulty and gastrointestinal damage and even death	(Aziz et al., 2018; L. Wang et al., 2018)
12	Polycyclic Aromatic Hydrocarbons (PAHs)	Cancer causing pollutant	(Wojciechowska, 2013)
13	Total Petroleum Hydrocarbon	Causes nervous, reproductive, liver and kidney disorder, also causes teratogenic effect	(Gong, Wei, Li, & Huang, 2017; Kalmykova, Moona, Stromvall, & Bjorklund, 2014)

Emerging Pollutants Native to Nigeria Landfill Leachates

Pollutant which poses great threat to the environment but unregulated because they are either new or not easily detected are refers to as emerging pollutants. These pollutants are recently discovered but scanty or no literature exists with respect to the health implication of such pollutants (Lei et al., 2015; Masoner et al., 2014). Nigeria is a developing country which is located on the Gulf of Guinea in Africa continent (Fig 3). Nigeria is the country with the highest population of about 190.9 million people as at 2017. Nigeria produce more than 32 million tons of solid waste yearly, majority of the waste are poorly disposed leading to the blockage of drainage network, sewers and choking of water bodies. The 20-30 percent of waste collected is dumped in landfill and other open places without proper treatment.

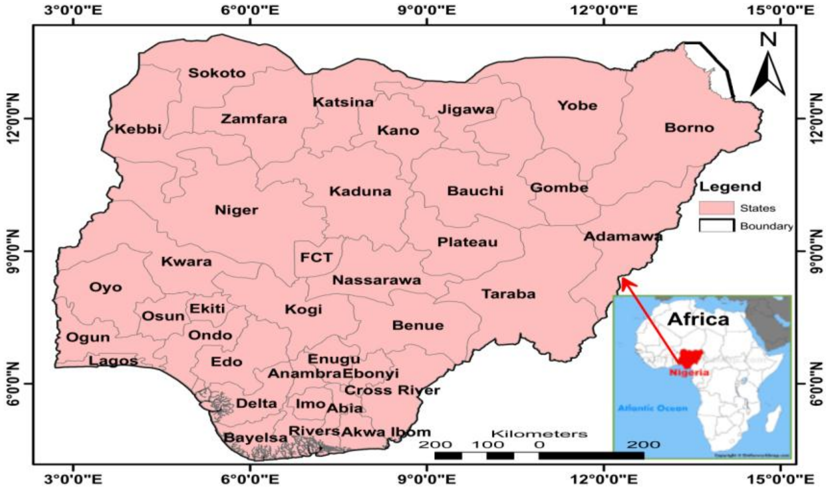

Figure. 3: Map Showing the Location of Nigeria.

The types of emerging contaminants in Nigeria can be categorized into four different types including domestic pollutants, industrial pollutants, agricultural pollutants and pharmaceutical pollutants (Geissen et al., 2015). Domestic pollutants are pollutants produce as a result of household use of organic materials, emerging domestic pollutants in Nigeria include N,N-diethyltoluamide resulting from the used of insect repellents, triclosan resulting from the use of antimicrobial disinfectant, acetophenone and camphor, menthol, limonene, galaxolide resulting from the use of fragrance and flavorant, benzophenone resulting from the use of perfumes and soap, ethyl citrate resulting from the use of food etc using (Masoner et al., 2014) as a guide. Industrial Pollutants are pollutants associated with industrial actions, emerging pollutants resulting from industrial from industrial action in Nigeria include Phenol, Tripheny phosphate, para-cresol, pentachlorophenol, naphthalene, isopropylbenzene, isophorone, anthracene, 1-methylnapthalene, 2- methylnaphthalene, 1,4-dichlorobenzene etc using (Masoner et al., 2014) as a guide. Emerging pollutants resulting from agricultural activities in Nigeria include atrazine resulting from the use of herbicide, carbaryl resulting from the use of insecticide etc using (Masoner et al., 2014) as a guide, Pharmaceutical emerging pollutants in Nigeria include1,7 dimethylxanthine, acetaminophen, caffeine, chloroxylenol, dextromethorphan, n icotine, pseudoephedrine etc using (Masoner et al., 2014) as a guide.

Biological Treatment of Landfill Leachate: The biological methods employed in the treatment of landfill leachate have been grouped into aerobic method, anaerobic method, natural system and combined treatment method (Kurniawan, Lo, Chan, & Sillanpaa, 2010). Aerobic method of landfill leachate treatment which is commonly called activated sludge involves the degradation of organic and some inorganic compounds present in landfill leachate in the presence of oxygen (K. Wang, Li, Tan, & Wu, 2018). This method of landfill leachate is employed in Sequencing Batch Reactor (SBR), Aerated Lagoon (AL) and Rotating Biological Contractors (RBC) (Kurniawan et al., 2010).

Anaerobic method of landfill leachate treatment involves the breakdown of inorganic and organic compound by microbe in the absence of oxygen, These method have been employed in Upflow Anaerobic Sludge Blanket (UASB) and Anaerobic Membrane Bioreactor (AMBR) (Klimiuk & Kulikowska, 2006). The treatment of landfill leachate using natural system is an emerging treatment method which depends on renewable energy sources such as wind and solar energy for the degradation of pollutants present in landfill leachate. Example of natural system used in landfill leachate treatment includes constructed wetland and Leachate Recirculation (LR) (Kamaruddin, Yusoff, Aziz, & Hung, 2015). Biological treatment of landfill leachate holds a promising start owing to it efficiency in the effective removal of organic and inorganic pollutant such as nitrogen and phosphorus compound from leachates. The use of biological method in leachate is mostly employed in the combine state with physiochemical method due to the higher pollutant concentration of leachate (M. Deng et al., 2018).

SBR is a type of activated sludge process of landfill leachates treatment involving the bubbling of oxygen into the landfill leachate thereby aiding the degradation of pollutants present in the wastewater particularly the reduction of organic compounds. SBR have been successfully used in the removal of organic and inorganic compound from landfill leachate. The pollutants removed from landfill leachate by SBR include Total Ammonium Nitrogen (Ren, Ferraz, & Yuan, 2018), Chemical Oxygen Demand (COD) (Ganjian et al., 2018), Total Organic Carbon (TOC), Total Suspended Solid (TSS) (Pastore et al., 2018), Biochemical Oxygen Demand (BOD), Total Coliform (TC), Fecal Coliform (FC), Ni, Cr, Pb, Cd (Hashemi, Hoseini, & Ebrahimi, 2018), Nitrogen (Miao et al., 2018), Total Kjehldahl Nitrogen (TKN), Total Nitrogen (Remmas, Ntougias, Chatzopoulou, & Melidis, 2018), Colour, Ammonia Nitrogen, As, Zn, Se, Mn, Ba, Ni (Yong, Bashir, Ng, Sethupathi, & Lim, 2018). RBC is another type of activated sludge process that involves the removal of grit, sand and coarse material via a screening process then the use of settling method to remove sediment from landfill leachate. RBC has been successfully used in the removal of organic and inorganic compound from landfill leachate. The pollutants removed from landfill leachate by RBC include TOC, Nitrate (Cortez, Teixeira, Oliveira, & Mota, 2011), Ammonia (Kulikowska, Jozwiak, Kowal, & Ciesielski, 2010), Vanadium, Pb, Cd, Ni, TC, Nitrate (Al-Muzaini & Thiem, 2004). AL is a type of activated sludge landfill leachate treatment technology that have a pond and an artificial aeration which is meant to promote biological oxidation in the landfill leachate and eventually lead to the degradation of organic and inorganic pollutants presents in the landfill leachates. AL has been successfully used in the removal of organic and inorganic compound from landfill leachate. The pollutants removed from landfill leachate by AL include citalopram, fluoxetine, sertaline, fluvoxamine, desmethylcitalopram, didesmethylcitalopram, norfluoxetine (Bergersen, Hanssen, & Vasskog, 2015), COD (Govahi, Karimi-Jashni, & Derakhshan, 2012; Silva, Fonseca, Saraiva, Vilar, & Boaventura, 2013), Ammonia (Govahi et al., 2012) and Ammonium Nitrogen (Kurniawan et al., 2010).

MBR is a type of anaerobic treatment process that involves the use of two membrane process like microfiltration and activated sludge process making it to be rich in microorganisms and activated sludge leading to the reduction of organic and inorganic pollutants in landfill leachates (An, Tan, & Meng, 2006). This method have recorded high efficiency in the removal of pollutants from landfill leachates, The pollutants removed from landfill leachate by MBR include BOD (H. Li, Gu, Zhao, & Wen, 2010; Pi, Gao, Fan, Gong, & Wan, 2009), COD (Koc-Jurczyk & Jurczyk, 2017), Phenol, Phthalates, Carbamazepine (CBZ), N, N-diethyl-m-Toluamide (DEET), Diclofenac (DCF) (Boonnorat, Techkarnjanaruk, Honda, & Prachanurak, 2016), Ammonia Nitrogen (Zhang, Qin, Meng, Fan, & Wu, 2013), Phosphate, sulphate, sulphide, chloride, TSS (Nivya & Pieus, 2016), TN (Wei, Song, Meng, & Pic, 2015; Zhang et al., 2013). UASB is a form of anaerobic method of landfill leachate treatment technology that is a methanogenic digester because it is a methane producing bioreactor. The principle of operation involves the use of anaerobic process to form a blanket of granular sludge which is place in a tank. The pollutant present in the landfill leachate is eventually degraded when the landfill leachate is made to pass through the blanket due to the biodegradatory role played by anaerobic methanogenic organisms as shown in figure 2. UASB have recorded high efficiency in the removal of pollutants from landfill leachates, the pollutants removed from landfill leachate by UASB include COD (He, Geng, & Yu, 2015; T. Lu, George, Zhao, & Liu, 2016; B. Wang, Li, Liu, & Huang, 2016), Nitrate, Ammonium Nitrogen (Baati, Benyoucef, Makan, El Bouadili, & El Ghmari, 2018; Du et al., 2017; Liu et al., 2015; Yang, Zhang, & Xian, 2017), TN (L.-n. Wu et al., 2016; L. Wu et al., 2015), BOD (Akgul, Aktan, Yapsakli, & Mertoglu, 2013).

Microbial World and Leachate Treatment

Microorganisms are unicellular organisms which are either prokaryotic or eukaryotic microscopic organisms that are grouped into major groups such as algae, bacteria, fungi and protest. These organisms have shown great importance to man and other organisms in many ways including fermentation of food, clinical importance, veterinary importance, treatment of sewages, production of biofuel, production of enzymes, production of bioactive compounds, wastewater treatment and an landfill leachates treatment. The process by which microorganism are used for biological treatment of landfill leachate includes bioremediation (bacteria), mycoremediation (Fungi) and phycoremediation (microalgae). Recently, an emerging biological process of treatment of wastewater is the use of algae biofilm which is a complex assemblage of algae, bacteria and fungi that multiply by forming thick submerged mats in an aquatic environment and terrestrial surfaces under suitable condition.

Fungi (Mycoremediation)

Mycoremediation of landfill leachates is the form of landfill remediation that involves the remediation of pollutants presents in landfill leachate by fungi. This method is very cheap and has been proved to have high efficiency in the removal of both organic and inorganic pollutants as summarized in table (2). The ability of fungi to mycoremediate inorganic substances such as heavy metals have been proved to be due to the high hyperaccumulating potentials of this organisms and the ability of this organisms to tolerate heavy metals due to their high adsorption potential. Mycoremediation of compounds such as dye (congo dye, azo dye, malachite dye, nigrosin dye, Trypan blue dye etc), pesticides (insecticide endosulfan, imazalil, thiophanate methyl, ortho-phenylphenol, diphenylamine, chlorpyrifos) and organic compounds (BTEX benzene, toluene, ethylbenzene and xylene) (Colborne et al., 2019), PAH (polycyclic aromatic hydrocarbon) (Chen, Zhou, Hu, Tian, & Zhang, 2019), MTBE (methyl tert-buthyl ether) etc) have been proved to be due to the ligninolytic enzyme such as laccase, manganese peroxidase etc released by fungi, These enzymes bring about the degradation of these compounds.

Table. 2: Fungi Effectively used in the Mycoremediation of Landfill Leachate.

SN	Fungi	Pollutants Removed	Removal Efficiency (%)	Reference
1	Ganoderma austral	BOD COD NH_4-N	50 32 40	(Noorlidah, Wan Razarinah, Noor, & Rosna, 2013)
2	Prostereum spadiceum	COD	NA	(Valeria, Federica, Alice, Valeria, & Giovanna, 2013)
3	Penicillium brevicompactum Pseudallescheria boydi Phanerochchate sanguine Flammulina velutipes Pleurotus Ostreatus Porostereum spadiceum Trametes pubescens Bjerkandera adusta	COD	NA	(Spina, Tigini, Romagnolo, & Varese, 2018)
4	Scenedesmus quadricauda	COD	NA	(Szylak-Szydlowski, 2011)
5	Trametes menziesii	COD BOD	2.11 89.14	(Wan Razarinah, Noor Zalina, & Abdullah, 2015)
6	Dichomitus squalens	Dissolved Organic Carbon (DOC) COD	44 61	(Kalcikova, Babic, Pavko, & Gotvajn, 2014)
7	Phanerochaete chrysosporium	COD NH_4-N Colour	4.7 72 25	(Kim, Park, & Kim, 2003)
8	Bjerkandera adusta	COD	63	(A. Bardi et al., 2017)
9	Bjerkandera adusta	COD Colour	61 49	(Alessandra Bardi et al., 2017)
10	Saccharomyces cerevisiae	COD TKN	76 82	(Wichitsathian, Sindhuja, Visvanathan, & Ahn, 2004)

Micro Algae (Phycoremediation)

Phycoremediation of landfill leachate is the process by which both macro and micro algae bring about the transformation of pollutant present in landfill leachates. The mechanism involve in the phycoremediation of landfill leachate is based on the fact that algae are autotrophic organism so are able to perform photosynthesis, during the process of photosynthesis, algae produces reactive oxygen species (ROS) such as hydrogen peroxide (H_20_2), super oxide (O_2^-) and hydroxide (OH^-) radicals. The table below show how micro and macro algae have been used to treat landfill leachate. Many researchers have shown the ability of the ROS produced by algae to be the reason why algae bring about the degradation of organic compounds and also bring about reduction of metal oxide which is in turn used by the algae for biomass production since the process of phycoremediation is also based on the ability of algae to use pollutants for biomass production. This biomass is then used for bio fuel production, many researchers have used both micro and macro algae in the removal of pollutants from leachate.

Table. 3: Micro Algae Effectively Used in the Remediation of Landfill Leachate.

SN	Microalgae	Pollutants Removed	Removal Efficiency (%)	Reference
1	Chlorella sp	Total Organic Carbon COD Turbidity Boron	60 68 98 98	(El Ouaer, Kallel, Kasmi, Hassen, & Trabelsi, 2017)
2	Nanochloropsis gaditana Pavlova lutheri Tetraselmis chuii Chaetocerous muelleri	BOD COD TOC Lathanium Barium Iron Aluminium Cerium Manganese	NA	(Richards & Mullins, 2013)
3	Clamydomonas sp Scenedesmus sp Chlorella sp Nitzschia sp Euglena sp Rodella sp Bracchiomas sp Pediastrum sp	NH4-N PO_4^{3}-P Nitrate	83 98 54	(Paskuliakova, Tonry, & Touzet, 2016)
4	Chlorella vulgaris	Cr Ni NH3-N BOD COD	70 68 53.91 52.78 51.05	(Sarunporn & Raymond, 2014)
5	Clamydomonas sp	PO_4^{3-}-P TON TAN CL^- SO_4^{2-} Orthophosphate	NA	(Andrea Paskuliakova et al., 2018)
6	Chlorella vulgaris	N-NO_3^- N-NH_4^+ P-PO_4^{3-} S-SO_4^{2-}	NA	(Pereira et al., 2016)
7	Chlorella vulgaris	N P	99.1 and 77.5 100 and 100	(Chang et al., 2018)
8	Clamydomonas sp	TAN Phosphate		(A. Paskuliakova, T. McGowan, S. Tonry, & N. Touzet, 2018)
9	Chlorella sp	NO_3^-	NA	(Nordin, Yusof, &

	Scenedesmus sp Oscillatoria sp			Samsudin, 2017)
10	Chlorella vulgaris Scenedesmus quadricauda Euglena gracilis Ankistrodesmus convolutus Chlorococcum oviforme	COD NH_4-N Orthophosphate	91 99.9 86.0	(Mustafa, Phang, & Chu, 2012)

Bacteria (Bioremediation)

The potentiality of bacteria in the remediation landfill leachate is on the raise with different bacteria consortia used for the treatment of landfill leachate by either converting the pollutants into non toxic substances or by acting as a catalyst in the degradation of pollutants into non harmful substances. The mechanism involve in the bioremediation of organic and inorganic pollutants by bacteria is a redox reaction in which an electron must be donated by one substance and accepted by a different substance for degradation to occur. During bioremediation process, the specie that usually accept electron include oxygen, manganese (III and IV), sulphate, nitrate etc while substances such as glucose, fatty acid and glycerol, amino acids, PAH etc act as electron donors. The ability of bacteria to bioremediate inorganic substances such as heavy metals have been proved to be due to the ability of the bacteria to tolerate heavy metals due to their high adsorption potential. Many researchers have used indigenous and non indigenous bacteria in the treatment of landfill leachate as summarized in table (4) below.

Table. 4: Bacteria Effectively used in the Bioremediation of Landfill Leachate.

SN	Bacteria Strain	Pollutants Removed	Removal Efficiency (%)	Reference
1	Brevibacillus panacilium	Magnesium Vanadium Manganeses Nickel Cobalt Copper Gallium Arsenic Selenium Robidium Strontium Caesium Barium Cadmium Lead Bismuth	74 15 40 35 5 60 28 10 52 5 20 7 30 40 25 44	(Er, Seow, Lim, Ibrahim, & Sarip, 2018)

		Uranium COD Ammonia	8 37 47	
2	Pseudomonas aureginosa Staphylococcus sp Enterobacter cloacae Escherichia coli Micrococcus luteus Proteus vulgaris Bacillus cereus Bacillus subtilis	Copper Lead Nickel Silver	NA NA NA NA	(Adebisi, Oluwatosin, & Olumayowa, 2015)
3	Leutococcus messenteroides Streptococcus parauberis Lactobacillus plantarum Lactococcus garvieae Enterococcus sp Lactococcus lactis Escherichia coli Lactobacillus paracasei	COD BOD NH^4 NO_2^- NO_3^-	NA NA NA NA NA	(MELANIA et al., 2014)
4	Chloroflexi, Planktomycetes and Proteobacteria	Ammonia Nitrogen	NA NA	(Miao et al., 2018)

CONCLUSION

Molecular characterization of the component of microbe use in landfill leachate treatment involves the investigation of how this microbe are able to habit landfill leachate despite it high pollution load studies. Involving the use of microbe in the treatment of landfill leachate is diverse but little knowledge is available for the characterization of how the molecular component of the microbe interfere with it's role during treatment. The little literature available focus on the genomic characterization with no or scarce literature involving proteomic, metabolomic and enzyme assay characterization. There is no doubt that the recalcification ability of landfill leachate is making it impossible to treat with ease but with the knowledge of molecular characterization of microbe used in treating of landfill leachate, the dream of eradicting the menance caused by landfill leachate will be realized because the approach will lead to the identification of the best microbial consortium that will be highly effective in the remediation of landfill leachate, the properties will also be utilized to create biological non toxic and environmental friendly material for landfill pollution control. Molecular approach is centered towards microbial genetic structure, genomic evolution, genomic mapping, genomic editing, metabolic intermediate hormone, signaling molecule, secondary metabolites, metaproteomics etc.

REFERENCES

1. Adebisi, M. S., Oluwatosin, O. A., & Olumayowa, T. A. Resistance of Bacteria Isolated from Awotan Dumpsite Leachate to Heavy Metals and Selected Antibiotics. International Journal of Research in Pharmacy and Biosciences, 2015; 2(9): 8-17.
2. Aftab, B., & Hur, J. Unraveling complex removal behavior of landfill leachate upon the treatments of Fenton oxidation and MIEX (R) via two-dimensional correlation size exclusion chromatography (2D-CoSEC). Journal of Hazardous Materials, 2019; 362: 36-44. doi: 10.1016/j.jhazmat.2018.09.017.
3. Aftab, B., Shin, H.-S., & Hur, J. Exploring the fate and oxidation behaviors of different organic constituents in landfill leachate upon Fenton oxidation processes using EEM-PARAFAC and 2D-COS-FTIR. Journal of Hazardous Materials, 2018; 354: 33-41. doi: 10.1016/j.jhazmat.2018.04.059.
4. Akgul, D., Aktan, C. K., Yapsakli, K., & Mertoglu, B. Treatment of landfill leachate using UASB-MBR-SHARON-Anammox configuration. Biodegradation, 2013; 24(3): 399-412. doi: 10.1007/s10532-012-9597-y.
5. Al-Muzaini, S., & Thiem, L. Comparison of leachate treatment between Rhode Island and Kuwait. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering, 2004; 39(2): 507-514. doi: 10.1081/ese-120027541.
6. Aleya, L., Grisey, E., Bourioug, M., & Bourgeade, P. Performance assessment of Etueffont (France) lagooning treatment system: Report from a 16-year survey. Science of the Total Environment, 2019; 648: 518-529. doi: 10.1016/j.scitotenv.2018.08.177.
7. An, K. J., Tan, J. W., & Meng, L. Pilot study for the potential application of a shortcut nitrification and denitrification process in landfill leachate treatment with MBR. In G. H. Chen, C. Shang & X. R. Zhang (Eds.), Leading-Edge Strategies and Technologies for Sustainable Urban Water Management, 2006; 6: 147-154.
8. Andrade Filho, J., Dias, N. d. S., Batista, R. O., Santos Junior, J. A., Santos, A. G. D., & Lima, A. L. F. Landfill leachate as nutritional source in castor bean cultivation under semi-arid conditions. Revista Brasileira De Engenharia Agricola E Ambiental, 2018; 22(6): 378-382. doi: 10.1590/1807-1929/agriambi.v22n6p378-382.
9. Augusto, P. A., Castelo-Grande, T., Merchan, L., Estevez, A. M., Quintero, X., & Barbosa, D. Landfill leachate treatment by sorption in magnetic particles: preliminary study. Science of the Total Environment, 2019; 648: 636-668. doi: 10.1016/j.scitotenv.2018.08.056.
10. Aziz, A., Agamuthu, P., & Fauziah, S. H. Effective removal of p-tert-Butylphenol and

Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)- from landfill leachate using locust bean gum. Waste Management & Research, 2018; 1-11.

11. Azzouz, L., Boudjema, N., Aouichat, F., Kherat, M., & Mameri, N. Membrane bioreactor performance in treating Algiers' landfill leachate from using indigenous bacteria and inoculating with activated sludge. Waste Management, 2018; 75: 384-390. doi: 10.1016/j.wasman.2018.02.003.
12. Baati, S., Benyoucef, F., Makan, A., El Bouadili, A., & El Ghmari, A. Influence of hydraulic retention time on biogas production during leachate treatment. Environmental Engineering Research, 2018; 23(3): 288-293. doi: 10.4491/eer.2017.200.
13. Banihani, Q., Sierra-Alvarez, R., & Field, J. A. Nitrate and nitrite inhibition of methanogenesis during denitrification in granular biofilms and digested domestic sludges. Biodegradation, 2009; 20(6): 801-812. doi: 10.1007/s10532-009-9268-9.
14. Bardi, A., Yuan, Q., Siracusa, G., Chicca, I., Islam, M., Spennati, F., . . . Munz, G. Effect of cellulose as co-substrate on old landfill leachate treatment using white-rot fungi. Bioresour Technol, 2017; 241: 1067-1076. doi: 10.1016/j.biortech.2017.06.046.
15. Bardi, A., Yuan, Q., Tigini, V., Spina, F., Varese, C. G., Spennati, F., . . . Munz, G. Recalcitrant Compounds Removal in Raw Leachate and Synthetic Effluents Using the White-Rot Fungus Bjerkandera adusta. Water, 2017; 9(11). doi: 10.3390/w9110824.
16. Bashir, M. J. K., Lim, J. H., Abu Amr, S. S., Wong, L. P., & Sim, Y. L. Post treatment of palm oil mill effluent using electro-coagulation-peroxidation (ECP) technique. Journal of Cleaner Production, 2019; 208: 716-727. doi: 10.1016/j.jclepro.2018.10.073.
17. Bautista-Ramirez, J. A., Gutierrez-Hernandez, R. F., Najera-Aguilar, H. A., Martinez-Salinas, R. I., Vera-Toledo, P., Araiza-Aguilar, J. A., . . . Rojas-Valencia, M. N. AGED REFUSE FILLED BIOREACTOR (ARFB), AS A PRETREATMENT FOR LANDFILL LEACHATE. Revista Mexicana De Ingenieria Quimica, 2018; 17(2): 561-571. doi: 10.24275/uam/izt/dcbi/revmexingquim/2018v17n2/Bautista.
18. Bergersen, O., Hanssen, K. O., & Vasskog, T. Aerobic treatment of selective serotonin reuptake inhibitors in landfill leachate. Environmental Sciences Europe, 2015; 27: 1-9. doi: 10.1186/s12302-014-0035-0.
19. Boateng, T. K., Opoku, F., & Akoto, O. Quality of leachate from the Oti Landfill Site and its effects on groundwater: a case history. Environmental Earth Sciences, 2018; 77(12). doi: 10.1007/s12665-018-7626-9.
20. Boonnorat, J., Techkarnjanaruk, S., Honda, R., & Prachanurak, P. Effects of hydraulic retention time and carbon to nitrogen ratio on micro-pollutant biodegradation in

membrane bioreactor for leachate treatment. Bioresource Technology, 2016; 219: 53-63. doi: 10.1016/j.biortech.2016.07.094.

21. Camano Silvestrini, N. E., Maine, M. A., Hadad, H. R., Nocetti, E., & Campagnoli, M. A. Effect of feeding strategy on the performance of a pilot scale vertical flow wetland for the treatment of landfill leachate. Science of the Total Environment, 2019; 648: 542-549. doi: 10.1016/j.scitotenv.2018.08.132.
22. Chang, H., Quan, X., Zhong, N., Zhang, Z., Lu, C., Li, G., . . . Yang, L. High-efficiency nutrients reclamation from landfill leachate by microalgae Chlorella vulgaris in membrane photobioreactor for bio-lipid production. Bioresour Technol, 2018; 266: 374-381. doi: 10.1016/j.biortech.2018.06.077.
23. Chen, H., Zhou, Y., Hu, X., Tian, K., & Zhang, J. Effects of chlortetracycline on biological nutrient removal from wastewater. The Science of the total environment, 2019; 647: 268-274. doi: 10.1016/j.scitotenv.2018.07.436.
24. Cheng, W., Quan, X., Huang, X., Cheng, C., Yang, L., & Cheng, Z. Enhancement of micro-filtration performance for biologically-treated leachate from municipal solid waste by ozonation in a micro bubble reactor. Separation and Purification Technology, 2018; 207: 535-542. doi: 10.1016/j.seppur.2018.07.005.
25. Cingolani, D., Fatone, F., Frison, N., Spinelli, M., & Eusebi, A. L. Pilot-scale multi-stage reverse osmosis (DT-RO) for water recovery from landfill leachate. Waste Management, 2018; 76: 566-574. doi: 10.1016/j.wasman.2018.03.014.
26. Colborne, S. F., Maguire, T. J., Mayer, B., Nightingale, M., Enns, G. E., Fisk, A. T., . . . Mundle, S. O. C. Water and sediment as sources of phosphate in aquatic ecosystems: The Detroit River and its role in the Laurentian Great Lakes. The Science of the total environment, 2019; 647: 1594-1603. doi: 10.1016/j.scitotenv.2018.08.029.
27. Coppini, E., Palli, L., Fibbi, D., & Gori, R. Long-Term Performance of a Full-Scale Membrane Plant for Landfill Leachate Pretreatment: A Case Study. Membranes, 2018; 8(3). doi: 10.3390/membranes8030052.
28. Cortez, S., Teixeira, P., Oliveira, R., & Mota, M. Mature landfill leachate treatment by denitrification and ozonation. Process Biochemistry, 2011; 46(1): 148-153. doi: 10.1016/j.procbio.2010.07.033.
29. Deng, M., Kuo, D. T. F., Wu, Q., Zhang, Y., Liu, X., Liu, S., . . . Zhang, H. Organophosphorus flame retardants and heavy metals in municipal landfill leachate treatment system in Guangzhou, China. Environmental Pollution, 2018; 236: 137-145. doi: 10.1016/j.envpol.2018.01.042.

30. Deng, M., Kuo, D. T. F., Wu, Q., Zhang, Y., Liu, X., Liu, S., . . . Zhang, H. Organophosphorus flame retardants and heavy metals in municipal landfill leachate treatment system in Guangzhou, China. Environ Pollut, 2018; 236: 137-145. doi: 10.1016/j.envpol.2018.01.042.
31. Dia, O., Drogui, P., Buelna, G., & Dube, R. Hybrid process, electrocoagulation-biofiltration for landfill leachate treatment. Waste Management, 2018; 75: 391-399. doi: 10.1016/j.wasman.2018.02.016.
32. Ding, J., Wang, K., Wang, S., Zhao, Q., Wei, L., Huang, H., . . . Dionysiou, D. D. Electrochemical treatment of bio-treated landfill leachate: Influence of electrode arrangement, potential, and characteristics. Chemical Engineering Journal, 2018; 344: 34-41. doi: 10.1016/j.cej.2018.03.043.
33. Du, R., Cao, S., Niu, M., Li, B., Wang, S., & Peng, Y. Performance of partial-denitrification process providing nitrite for anammox in sequencing batch reactor (SBR) and upflow sludge blanket (USB) reactor. International Biodeterioration & Biodegradation, 2017; 122: 38-46. doi: 10.1016/j.ibiod.2017.04.018.
34. El-Fadel, M., Sleem, F., Hashisho, J., Saikaly, P. E., Alameddine, I., & Ghanimeh, S. Impact of SRT on the performance of MBRs for the treatment of high strength landfill leachate. Waste Management, 2018; 73: 165-180. doi: 10.1016/j.wasman.2017.12.003.
35. El Ouaer, M., Kallel, A., Kasmi, M., Hassen, A., & Trabelsi, I. Tunisian landfill leachate treatment using Chlorella sp.: effective factors and microalgae strain performance. Arabian Journal of Geosciences, 2017; 10(20): 457. doi: 10.1007/s12517-017-3241-4.
36. Eldyasti, A., Chowdhury, N., Nakhla, G., & Zhu, J. Biological nutrient removal from leachate using a pilot liquid-solid circulating fluidized bed bioreactor (LSCFB). Journal of Hazardous Materials, 2010; 181(1-3): 289-297. doi: 10.1016/j.jhazmat.2010.05.010.
37. Er, X. Y., Seow, T. W., Lim, C. K., Ibrahim, Z., & Sarip, S. H. M. Biological treatment of closed landfill leachate treatment by using Brevibacillus panacihumi strain ZB1. IOP Conference Series: Earth and Environmental Science, 2018; 140(1): 012012.
38. Fernandes, A., Pastorinho, M. R., Sousa, A. C., Silva, W., Silva, R., Nunes, M. J., . . . Lopes, A. (2018). Ecotoxicological evaluation of electrochemical oxidation for the treatment of sanitary landfill leachates. Environmental science and pollution research international. doi: 10.1007/s11356-018-2650-6.
39. Fu, D., Kurniawan, T. A., Li, H., Wang, L., Chen, Z., Li, W., . . . Li, Q. Applicability of HDPC-supported Cu nanoparticles composite synthesized from anaerobically digested wheat straw for octocrylene degradation in aqueous solutions. Chemical Engineering

Journal, 2019; 355: 650-660. doi: 10.1016/j.cej.2018.08.188.

40. Fudala-Ksiazek, S., Pierpaoli, M., & Luczkiewicz, A. Efficiency of landfill leachate treatment in a MBR/UF system combined with NF, with a special focus on phthalates and bisphenol A removal. Waste Management, 2018; 78: 94-103. doi: 10.1016/j.wasman.2018.05.012.
41. Ganjian, E., Peyravi, M., Ghoreyshi, A. A., Jahanshahi, M., Khalili, S., & Rad, A. S. Effects of perlite and caustic soda on microorganism activities of leachate in a sequence batch reactor. Environmental Technology, 2018; 39(18): 2321-2334. doi: 10.1080/09593330.2017.1354923.
42. Geissen, V., Mol, H., Klumpp, E., Umlauf, G., Nadal, M., van der Ploeg, M., . . . Ritsema, C. J. Emerging pollutants in the environment: A challenge for water resource management. International Soil and Water Conservation Research, 2015; 3(1): 57-65. doi: https://doi.org/10.1016/j.iswcr.2015.03.002.
43. Gong, W., Wei, Y., Li, B., & Huang, Z. Resource utilization and treatment of landfill leachate using supercritical water gasification. Desalination and Water Treatment, 2017; 87: 249-256. doi: 10.5004/dwt.2017.21037.
44. Govahi, S., Karimi-Jashni, A., & Derakhshan, M. Treatability of landfill leachate by combined upflow anaerobic sludge blanket reactor and aerated lagoon. International Journal of Environmental Science and Technology, 2012; 9(1): 145-151. doi: 10.1007/s13762-011-0021-7.
45. Gunes, E., Demir, E., Gunes, Y., & Hanedar, A. Characterization and treatment alternatives of industrial container and drum cleaning wastewater: Comparison of Fenton-like process and combined coagulation/oxidation processes. Separation and Purification Technology, 2019; 209: 426-433. doi: 10.1016/j.seppur.2018.07.060.
46. Guo, R., Meng, Q., Zhang, H., Zhang, X., Li, B., Cheng, Q., & Cheng, X. Construction of Fe2O3/Co3O4/exfoliated graphite composite and its high efficient treatment of landfill leachate by activation of potassium persulfate. Chemical Engineering Journal, 2019; 355: 952-962. doi: 10.1016/j.cej.2018.08.168.
47. Hashemi, H., Hoseini, M., & Ebrahimi, A. A. Flat Sheet Membrane Sequencing Batch Bioreactor for the Removal of Coliforms and Heavy Metals from Stabilized Composting Leachate. Journal of Environmental Engineering, 2018; 144(4). doi: 10.1061/(asce)ee.1943-7870.0001339.
48. He, Y., Geng, J., & Yu, P. The Effect of Operating of A modified Upflow Anaerobic Sludge Blanket for Landfill Leachate Treatment. In M. Liu & X. Zhang (Eds.),

Proceedings of the International Conference on Advances in Mechanical Engineering and Industrial Informatics, 2015; 15: 1884-1889.

49. Hu, Y., Lu, Y., Liu, G., Luo, H., Zhang, R., & Cai, X. Effect of the structure of stacked electro-Fenton reactor on treating nanofiltration concentrate of landfill leachate. Chemosphere, 2018; 202: 191-197. doi: 10.1016/j.chemosphere.2018.03.103.
50. Inglezakis, V. J., Amzebek, A., Kuspangaliyeva, B., Sarbassov, Y., Balbayeva, G., Yerkinova, A., & Poulopoulos, S. G. Treatment of municipal solid waste landfill leachate by use of combined biological, physical and photochemical processes. Desalination and Water Treatment, 2018; 112: 218-231. doi: 10.5004/dwt.2018.22252.
51. Jambers Scandelai, A. P., Cardozo Filho, L., Campos Martins, D. C., Formicoli de Souza Freitas, T. K., Garcia, J. C., & Granhen Tavares, C. R. Combined processes of ozonation and supercritical water oxidation for landfill leachate degradation. Waste Management, 2018; 77: 466-476. doi: 10.1016/j.wasman.2018.04.031.
52. Kalcikova, G., Babic, J., Pavko, A., & Gotvajn, A. Z. Fungal and enzymatic treatment of mature municipal landfill leachate. Waste Manag, 2014; 34(4): 798-803. doi: 10.1016/j.wasman.2013.12.017.
53. Kalita, D., & Joshi, S. R. Study on bioremediation of Lead by exopolysaccharide producing metallophilic bacterium isolated from extreme habitat. Biotechnology reports (Amsterdam, Netherlands), 2017; 16: 48-57. doi: 10.1016/j.btre.2017.11.003.
54. Kalmykova, Y., Moona, N., Stromvall, A.-M., & Bjorklund, K. Sorption and degradation of petroleum hydrocarbons, polycyclic aromatic hydrocarbons, alkylphenols, bisphenol A and phthalates in landfill leachate using sand, activated carbon and peat filters. Water Research, 2014; 56: 246-257. doi: 10.1016/j.watres.2014.03.011.
55. Kamaruddin, M. A., Yusoff, M. S., Aziz, H. A., & Hung, Y.-T. Sustainable treatment of landfill leachate. Applied Water Science, 2015; 5(2): 113-126. doi: 10.1007/s13201-014-0177-7.
56. Kim, Y. K., Park, S. K., & Kim, S. D. Treatment of landfill leachate by white rot fungus in combination with zeolite filters. J Environ Sci Health A Tox Hazard Subst Environ Eng, 2003; 38(4): 671-683.
57. Klimiuk, E., & Kulikowska, D. Organics removal from landfill leachate and activated sludge production in SBR reactors. Waste Manag, 2006; 26(10): 1140-1147. doi: 10.1016/j.wasman.2005.09.011.
58. Koc-Jurczyk, J., & Jurczyk, L. THE EFFECT OF KALDNES BIO FILTER MEDIA PACKING VOLUME ON THE EFFICIENCY OF MUNICIPAL LANDFILL

LEACHATE TREATMENT. Carpathian Journal of Earth and Environmental Sciences, 2017; 12(1): 77-82.

59. Kulikowska, D., Jozwiak, T., Kowal, P., & Ciesielski, S. Municipal landfill leachate nitrification in RBC biofilm - Process efficiency and molecular analysis of microbial structure. Bioresource Technology, 2010; 101(10): 3400-3405. doi: 10.1016/j.biortech.2009.12.050.
60. Kurniawan, T. A., Lo, W., Chan, G., & Sillanpaa, M. E. Biological processes for treatment of landfill leachate. J Environ Monit, 2010; 12(11): 2032-2047. doi: 10.1039/c0em00076k.
61. Lei, M., Zhang, L., Lei, J., Zong, L., Li, J., Wu, Z., & Wang, Z. Overview of Emerging Contaminants and Associated Human Health Effects. BioMed Research International, 2015; 12. doi: 10.1155/2015/404796.
62. Leite, V. D., Paredes, J. M. R., de Sousa, T. A. T., Lopes, W. S., & de Sousa, J. T. Ammoniacal Nitrogen Stripping From Landfill Leachate at Open Horizontal Flow Reactors. Water Environment Research, 2018; 90(5): 387-394. doi: 10.2175/106143017x15131012152942.
63. Li, H., Gu, Y., Zhao, Y., & Wen, Z. Leachate treatment using a demonstration aged refuse biofilter. Journal of Environmental Sciences, 2010; 22(7): 1116-1122. doi: 10.1016/s1001-0742(09)60226-6.
64. Li, X., Tang, Y., & Lu, X. Insight into Identification of Acinetobacter Species by Matrix-Assisted Laser Desorption/Ionization Time of Flight Mass Spectrometry (MALDI-TOF MS) in the Clinical Laboratory. Journal of the American Society for Mass Spectrometry, 2018; 29(7): 1546-1553. doi: 10.1007/s13361-018-1911-4.
65. Li, X., Yuan, Y., Wang, F., Huang, Y., Qiu, Q.-T., Yi, Y., & Bi, Z. Highly efficient of nitrogen removal from mature landfill leachate using a combined DN-PN-Anammox process with a dual recycling system. Bioresource Technology, 2018; 265: 357-364. doi: 10.1016/j.biortech.2018.06.023.
66. Liu, M., Yang, Q., Peng, Y., Liu, T., Xiao, H., & Wang, S. Treatment performance and N2O emission in the UASB-A/O shortcut biological nitrogen removal system for landfill leachate at different salinity. Journal of Industrial and Engineering Chemistry, 2015; 32: 63-71. doi: 10.1016/j.jiec.2015.07.017.
67. Lu, G., Yue, C., Qiu, G., Guo, M., Chen, F., & Zhan, M. High mercury leachate containing HgS22- complex ion: Detoxifying solidification and high efficiency Hg extraction. Journal of Environmental Sciences, 2018; 73: 177-184. doi: 10.1016/j.jes.2018.01.026.

68. Lu, T., George, B., Zhao, H., & Liu, W. A case study of coupling upflow anaerobic sludge blanket (UASB) and ANITA (TM) Mox process to treat high-strength landfill leachate. Water Science and Technology, 2016; 73(3): 662-668. doi: 10.2166/wst.2015.536.
69. Masoner, J. R., Kolpin, D. W., Furlong, E. T., Cozzarelli, I. M., Gray, J. L., & Schwab, E. A. Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States. Environmental Science-Processes & Impacts, 2014; 16(10): 2335-2354. doi: 10.1039/c4em00124a.
70. MELANIA, S., AMANDA, L., ADRIANA, L., JOSÉ, M. G., BALTASAR, M., & MARIO, D. Approaches for Microbiological Characterization of a Landfill Leachate Treatment. Journal of Residuals Science & Technology, 2014; 11(2): 39-44.
71. Miao, L., Zhang, Q., Wang, S., Li, B., Wang, Z., Zhang, S., . . . Peng, Y. Characterization of EPS compositions and microbial community in an Anammox SBBR system treating landfill leachate. Bioresource Technology, 2018; 249: 108-116. doi: 10.1016/j.biortech.2017.09.151.
72. Mohammad-pajooh, E., Turcios, A. E., Cuff, G., Weichgrebe, D., Rosenwinkel, K.-H., Vedenyapina, M. D., & Sharifullina, L. R. Removal of inert COD and trace metals from stabilized landfill leachate by granular activated carbon (GAC) adsorption. Journal of Environmental Management, 2018; 228: 189-196. doi: 10.1016/j.jenvman.2018.09.020.
73. Mustafa, E.-M., Phang, S.-M., & Chu, W.-L. Use of an algal consortium of five algae in the treatment of landfill leachate using the high-rate algal pond system. Journal of Applied Phycology, 2012; 24(4): 953-963. doi: 10.1007/s10811-011-9716-x.
74. Nivya, T. K., & Pieus, M. T. Comparison of Photo ElectroFenton Process(PEF) and combination of PEF Process and Membrane Bioreactor in the treatment of Landfill Leachate. In C. Viswanathan & R. S. Kumar (Eds.), International Conference on Emerging Trends in Engineering, Science and Technology, 2016; 24: 224-231.
75. Noorlidah, A., Wan Razarinah, W. A. R., Noor, Z. M., & Rosna, M. T. Treatment of Landfill Leachate Using Ganoderma Australe Mycelia Immobilized on Ecomat. International Journal of Environmental Science and Development, 2013; 4(5): 483-487. doi: 10.7763/IJESD.2013.V4.399.
76. Nordin, N., Yusof, N., & Samsudin, S. Biomass Production of Chlorella sp., Scenedesmus sp., and Oscillatoria sp. in Nitrified Landfill Leachate. Waste and Biomass Valorization, 2017; 8(7): 2301-2311. doi: 10.1007/s12649-016-9709-8.
77. Oppong-Anane, A. B., Quinones, K. Y. D., Harris, W., Townsend, T., & Bonzong, J.-C. J. Iron reductive dissolution in vadose zone soils: Implication for groundwater pollution in

landfill impacted sites. Applied Geochemistry, 2018; 94: 21-27. doi: 10.1016/j.apgeochem.2018.05.001.

78. Paskuliakova, A., McGowan, T., Tonry, S., & Touzet, N. Microalgal bioremediation of nitrogenous compounds in landfill leachate - The importance of micronutrient balance in the treatment of leachates of variable composition. Algal Research-Biomass Biofuels and Bioproducts, 2018; 32: 162-171. doi: 10.1016/j.algal.2018.03.010.
79. Paskuliakova, A., McGowan, T., Tonry, S., & Touzet, N. Phycoremediation of landfill leachate with the chlorophyte Chlamydomonas sp. SW15aRL and evaluation of toxicity pre and post treatment. Ecotoxicol Environ Saf, 2018; 147: 622-630. doi: 10.1016/j.ecoenv.2017.09.010.
80. Paskuliakova, A., Tonry, S., & Touzet, N. Microalgae isolation and selection for the treatment of landfill leachate. Proceedings of the 13 International th Conference on Modelling, Monitoring and Management of Water Pollution (WP 2016), 2016; 209: 65-78.
81. Pastore, C., Barca, E., Del Moro, G., Di Iaconi, C., Loos, M., Singer, H. P., & Mascolo, G. Comparison of different types of landfill leachate treatments by employment of nontarget screening to identify residual refractory organics and principal component analysis. Science of the Total Environment, 2018; 635: 984-994. doi: 10.1016/j.scitotenv.2018.04.135.
82. Pereira, S. F. L., Gonçalves, A. L., Moreira, F. C., Silva, T. F. C. V., Vilar, V. J. P., & Pires, J. C. M. (2016). Nitrogen Removal from Landfill Leachate by Microalgae. International journal of molecular sciences, 17(11): 1926. doi: 10.3390/ijms17111926.
83. Pi, K. W., Gao, L. X., Fan, M. X., Gong, W. Q., & Wan, D. J. Two-stage biodegradation coupled with ultrafiltration for treatment of municipal landfill leachate. Process Safety and Environmental Protection, 2009; 87(5): 336-342. doi: 10.1016/j.psep.2009.07.002.
84. Ramaswami, S., Behrendt, J., & Otterpohl, R. Comparison of NF-RO and RO-NF for the Treatment of Mature Landfill Leachates: A Guide for Landfill Operators. Membranes, 2018; 8(2). doi: 10.3390/membranes8020017.
85. Remmas, N., Ntougias, S., Chatzopoulou, M., & Melidis, P. Optimization aspects of the biological nitrogen removal process in a full-scale twin sequencing batch reactor (SBR) system in series treating landfill leachate. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering, 2018; 53(9): 847-853. doi: 10.1080/10934529.2018.1455375.
86. Ren, Y., Ferraz, F. M., & Yuan, Q. Biological leachate treatment using anaerobic/aerobic

process: suspended growth-activated sludge versus aerobic granular sludge. International Journal of Environmental Science and Technology, 2018; 15(11): 2295-2302. doi: 10.1007/s13762-017-1633-3.

87. Richards, R. G., & Mullins, B. J. Using microalgae for combined lipid production and heavy metal removal from leachate. Ecological Modelling, 2013; 249: 59-67. doi: 10.1016/j.ecolmodel.2012.07.004.
88. Saez, G. D., Saavedra, L., Hebert, E. M., & Zarate, G. Identification and biotechnological characterization of lactic acid bacteria isolated from chickpea sourdough in northwestern Argentina. Lwt-Food Science and Technology, 2018; 93: 249-256. doi: 10.1016/j.lwt.2018.03.040.
89. Sah, S., Bordoloi, P., Vijaya, D., Amarnath, S. K., Devi, S. C., Indumathi, V. A., & Prashanth, K. Simple and economical method for identification and speciation of Staphylococcus epidermidis and other coagulase negative Staphylococci and its validation by molecular methods. Journal of Microbiological Methods, 2018; 149: 106-119. doi: 10.1016/j.mimet.2018.05.002.
90. Salim, S. N., & Evin, N. Assessing the Impacts of Seasonal Variations on Predicting Leachate Generation in Gumushane Open Dump Using Water Balance Method. Polish Journal of Environmental Studies, 2014; 23(35): 179-1901659-1901668.
91. Sarunporn, T., & Raymond, J. R. Using Chlorella vulgaris to Decrease the Environmental Effect of Garbage Dump Leachates. Journal of Bioremediation & Biodegradation, 2014; 5(5): doi: 10.4172/2155-6199.1000239.
92. Shu, D., Guo, J., Zhang, B., He, Y., & Wei, G. rDNA- and rRNA-derived communities present divergent assemblage patterns and functional traits throughout full-scale landfill leachate treatment process trains. Science of the Total Environment, 2019; 646: 1069-1079. doi: 10.1016/j.scitotenv.2018.07.388.
93. Silva, T. F. C. V., Fonseca, A., Saraiva, I., Vilar, V. J. P., & Boaventura, R. A. R. Biodegradability enhancement of a leachate after biological lagooning using a solar driven photo-Fenton reaction, and further combination with an activated sludge biological process, at pre-industrial scale. Water Research, 2013; 47(10): 3543-3557. doi: 10.1016/j.watres.2013.04.008.
94. Spina, F., Tigini, V., Romagnolo, A., & Varese, C. G. Bioremediation of Landfill Leachate with Fungi: Autochthonous vs. Allochthonous Strains. Life, 2018; 8(3). doi: 10.3390/life8030027.
95. Su, Y., Wang, J., Xia, H., & Xie, B. Comparative network analysis revealing the

mechanisms of antibiotic resistance genes removal by leachate recirculation under different hydraulic loadings. Science of the Total Environment, 2019; 649: 318-326. doi: 10.1016/j.scitotenv.2018.08.361.

96. Subasinghe, R. M., Samarajeewa, A. D., Meier, M., Coleman, G., Clouthier, H., Crosthwait, J., . . . Beaudette, L. A. Bacterial and fungal composition profiling of microbial based cleaning products. Food and Chemical Toxicology, 2018; 116: 25-31. doi: 10.1016/j.fct.2017.12.006.
97. Syed-Ab-Rahman, S. F., Carvalhais, L. C., Chua, E., Xiao, Y., Wass, T. J., & Schenk, P. M. (2018). Identification of Soil Bacterial Isolates Suppressing Different Phytophthora spp. and Promoting Plant Growth. Frontiers in Plant Science, 9. doi: 10.3389/fpls.2018.01502.
98. Szylak-Szydlowski, M. Szylak-Szydlowski, M. Assessing Toxicity Variations in Landfill Leachates during Biological Treatment. Ochrona Srodowiska, 2011; 33(2): 65-68.
99. Szymanski, K., Siebielska, I., Janowska, B., & Sidelko, R. Variations in physical and chemical parameters of landfill leachates over time. Desalination and Water Treatment, 2018; 117: 149-155. doi: 10.5004/dwt.2018.22201.
100. Tabssum, F., Ahmad, Q.-U.-A., & Qazi, J. I. DNA sequenced based bacterial taxonomy should entail decisive phenotypic remarks: Towards a balanced approach. Journal of Basic Microbiology, 2018; 58(11): 918-927. doi: 10.1002/jobm.201800319.
101. Taneja, R., Kumar, M., Raghav, A. K., & Mittal, A. K. (2010). ON SITE INTEGRATED LANDFILL LEACHATE TREATMENT: RECIRCULATION AND UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR (UASBR).
102. Tigini, V., & Varese, G. C. Biosorption with autochthonous and allochthonous fungal biomasses for bioremediation and detoxification of landfill leachate. Environmental Earth Sciences, 2018; 77(9). doi: 10.1007/s12665-018-7519-y.
103. Ugya, A. Y., Hua, X., Agamuthu, P., & Ma, J. MOLECULAR APPROACH TO UNCOVER THE FUNCTION OF BACTERIA IN PETROCHEMICAL REFINING WASTEWATER: A MINI REVIEW. Applied Ecology and Environmental Research, 2019; 17(2): 3645-3665. doi: 10.15666/aeer/1702_36453665.
104. Valeria, T., Federica, S., Alice, R., Valeria, P., & Giovanna, C. V. Effective Biological Treatment of Landfill Leachates by means of Selected White Rot Fungi European Journal of Clinical Microbiology and Infectious Diseases, 2013; 32: 265-270.
105. Verma, M., & Kumar, R. N. Coagulation and electrocoagulation for co-treatment of stabilized landfill leachate and municipal wastewater. Journal of Water Reuse and

Desalination, 2018; 8(2): 234-243. doi: 10.2166/wrd.2017.102.

106. Wan Razarinah, W. A. R., Noor Zalina, M., & Abdullah, N. Utilization of the White-rot Fungus, Trametes menziesii for Landfill Leachate Treatment. Sains Malaysiana, 2015; 4(3): 309-316.
107. Wang, B., Li, W., Liu, L., & Huang, G. H. Influence of sludge reflux ratios on biodegradation performance in a coupled landfill leachate treatment process based on UASB and submerged MBR. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering, 2016; 51(9): 701-706. doi: 10.1080/10934529.2016.1170428.
108. Wang, K., Li, L., Tan, F., & Wu, D. Treatment of Landfill Leachate Using Activated Sludge Technology: A Review. Archaea, 2018; 10. doi: 10.1155/2018/1039453
109. Wang, L., Lv, Q., An, M., Liu, Z., Song, Y., Zhou, Y., . . . Xu, J. Identification of toxic substances in phenol-acetone wastewater on activated sludge and selective toxicity removal performance with ferrous pretreatment. Environmental Science and Pollution Research, 2018; 25(20): 19628-19634. doi: 10.1007/s11356-018-2035-x.
110. Wei, J., Song, Y., Meng, X., & Pic, J.-S. Combination of Fenton oxidation and sequencing batch membrane bioreactor for treatment of dry-spun acrylic fiber wastewater. Environmental Earth Sciences, 2015; 73(9): 4911-4921. doi: 10.1007/s12665-015-4091-6.
111. Wichitsathian, B., Sindhuja, S., Visvanathan, C., & Ahn, K. H. Landfill leachate treatment by yeast and bacteria based membrane bioreactors. J Environ Sci Health A Tox Hazard Subst Environ Eng, 2004; 39(9): 2391-2404.
112. Wojciechowska, E. Removal of persistent organic pollutants from landfill leachates treated in three constructed wetland systems. Water Science and Technology, 2013; 68(5): 1164-1172. doi: 10.2166/wst.2013.316.
113. Wu, D., Ma, R., Wei, H., Yang, K., & Xie, B. Simulated discharge of treated landfill leachates reveals a fueled development of antibiotic resistance in receiving tidal river. Environment International, 2018; 114: 143-151. doi: 10.1016/j.envint.2018.02.049.
114. Wu, L.-n., Liang, D.-w., Xu, Y.-y., Liu, T., Peng, Y.-z., & Zhang, J. A robust and cost-effective integrated process for nitrogen and bio-refractory organics removal from landfill leachate via short-cut nitrification, anaerobic ammonium oxidation in tandem with electrochemical oxidation. Bioresource Technology, 2016; 212: 296-301. doi: 10.1016/j.biortech.2016.04.041.
115. Wu, L., Zhang, L., Zhang, S., Shi, X., Peng, Y., & Zhang, J. CO-TREATMENT OF MATURE LANDFILL LEACHATE AND DOMESTIC WASTEWATER WITH

COMBINED PARTIAL NITRIFICATION AND ANAEROBIC AMMONIUM OXIDATION. Fresenius Environmental Bulletin, 2015; 24(8): 2426-2433.

116. Wu, S., Jiang, Y., Lou, B., Feng, J., Zhou, Y., Guo, L., . . . Man, C. Microbial community structure and distribution in the air of a powdered infant formula factory based on cultivation and high-throughput sequence methods. Journal of Dairy Science, 2018; 101(8): 6915-6926. doi: 10.3168/jds.2017-13968.
117. Yang, L., Zhang, J., & Xian, P. Optimization of key factors affecting biogas production from synthetic wastewater by anaerobic granular sludge. Environmental Progress & Sustainable Energy, 2017; 36(1): 11-20. doi: 10.1002/ep.12390.
118. Yong, Z. J., Bashir, M. J. K., Ng, C. A., Sethupathi, S., & Lim, J.-W. A sequential treatment of intermediate tropical landfill leachate using a sequencing batch reactor (SBR) and coagulation. Journal of Environmental Management, 2018; 205: 244-252. doi: 10.1016/j.jenvman.2017.09.068.
119. Zhang, G., Qin, L., Meng, Q., Fan, Z., & Wu, D. Aerobic SMBR/reverse osmosis system enhanced by Fenton oxidation for advanced treatment of old municipal landfill leachate. Bioresource Technology, 2013; 142: 261-268. doi: 10.1016/j.biortech.2013.05.006.