Experimental Survey on Microbial Bioremediation of Food Wastewaters

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Abstract- Wastewater from food industries is increasingly becoming more toxic in recent times. The concentrations of pollutants like organic matters, fats, oil and grease (FOGS) in food wastewater have been observed to increase in wastewater bodies with increasing adverse effects on the environment. These adverse effects on the environment result from the increasing use of wastewater effluents in food restaurants and industries and indiscriminate discharge of wastewater into the water drains by industries and household. This dissertation aim to study in details the experimental breakthroughs in microbial bioremediation of food wastewaters across the globe, effects of current wastewater treatment techniques employed in the removal of pollutants from restaurants and food industries wastewaters. This survey shows that the concentration of waster effluents on the environment are of great negative impact and thus need to be given desired attention in applying experimental achievements in the field for future purpose. In achieving this, the paper has extensively carried out its study through observation of recent experimental works and other related sources in examining the success and challenges in microbial bioremediation. Findings show that a lot of successes have been achieved in the course of laboratory experimentation and little has been achieved in field application of these findings. the paper compare and contrast in details diverse works in relation to composition of wastewaters, microbial diversity, microbes remediation ability, success rate in different environmental conditions as well as the effect of microbial consortium in bioremediation process. The paper recommends the application of these findings in laboratory experimentation in the field for future purpose as a way for more attention and appreciation to be given to microbes in remediation process of food waste polluted waters.

Index Terms- Bioremediation; Wastewater; Oil; Microorganisms, Pollutants

I. Introduction

Food wastewater is water that has been used for cleaning meats and vegetables, washing dishes and cooking utensils, or cleaning the floor [51]. The effluent is mostly the leftovers of food, soup, detergents, fats, oil and grease which generates unpleasant odor when discharged into drains without proper on-site treatment process

Water bodies are continually polluted by pollutants resulting from human activities. These activities of the population are increasing every year, and along with this increase are wastes that are produced and released into the environment, either in the form of solid waste, liquid or gas [62]. Water bodies are naturally able to carry out cleansing of natural contaminants, but these natural contaminants are coupled with artificial pollutants, which are a result of human activities, the pollution load becomes too much for the water body to handle [60]. One of the major pollutants of these water bodies are wastewater effluents from food waste. Ever increasing industrialization and rapid urbanization have considerably increased the rate of water pollution [63]. The rapid economic development and the increasing living standard of people have led to rapid increase in the number of food industries around the globe. Food wastewater come from places such as restaurants, catering services companies, domestic or household waste and beverage and dairy industries. These industries have been linked with pollutions resulting from the indiscriminate discharge of untreated wastewater into the environment. The Volume of domestic or household waste has increased by 5 millions meter cubic per year, with an increase in the average content of up to 50% [62]. The dairy industry generates huge amount of wastewaters, approximately 0.2–10 L of waste per liter of processed milk [10]. Milk production In Poland has increased by 58.9% over 2000–2010. The yearly milk production now is almost 12milliard liters [34]. More than 400.000 tons of lipid-containing wastewater is discharged each year in Japan, and about 75% of this wastewater is from food industries and restaurants [29]. Given oily wastewater pollution background, China provides the maximum allowable emission of oily wastewater concentration of 10 mg/L. Therefore, oily wastewater treatment is urgently needed in today's field of environmental engineering problems [66]. But according statistics, the food industries in china every year release millions of tons of waste water into the environment. This Increase in food production and processing activities are continuously leading to increase in wastewater release into the environment. Rapid growth of industries has not only enhanced the productivity, but also resulted in release of toxic substances into the environment, creating health hazards and other related problems. Food wastewater contains toxic substances such as

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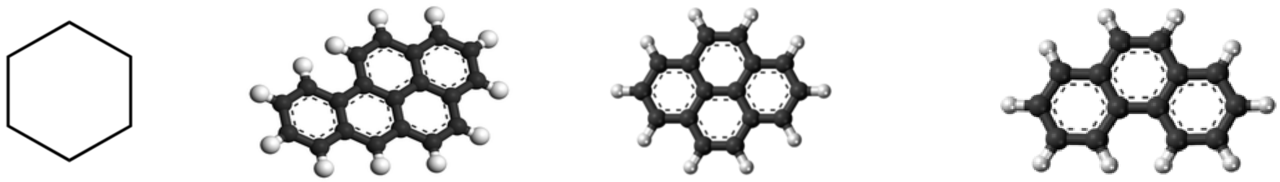
heavy organic matter, fats, oil & grease, fatty acids; nitrogenous compounds etc [17]. These compounds are inhibitory to plant and animal growth as well as harmful to human being .Food wastewater contains high oil contents. The usage of vegetable oil in food industries has resulted in the discharge of oil effluent and oily sludge into the environment without treatment or in a condition below the standard discharge limits [1].Wastes Containing Oil and grease generated from vegetable oil are hazardous pollutants particularly when injected into the aquatic environments where they pose high toxicity to the aquatic organisms and other ecology damages to the water bodies [54].

Recently, focus has shifted from physicochemical method of wastewater remediation to microbial bioremediation due to its numerous advantages when compare to physical and chemical method in carrying out remediation of food wastewater. A lot of microbial bioremediation research has been conducted in view of finding lasting solution to this global menace.

This review study focuses on food wastewater from restaurants, food catering services, domestic waste and other food manufacturing and processing industries.

II. Constituents of Food Wastewater

The main constituents of food wastewater are organic maters, fats, oil and grease (FOGS). The main components of oil are alkanes (e.g. hexane), aromatic hydrocarbons (e.g. benzene, toluene and xylene) and polycyclic aromatic hydrocarbons (e.g. Pyrene and Phenanthrene) [22].



Cyclohexane **Benzo-a-Pyrene** **Pyrene** **Phenanthrene**

Fig.1 Typical oil composition (Adapted from [22])

Food wastewater also has high concentrations of biochemical oxygen demand (BOD) and suspended solids (SS). The constituents of food and wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, milk and meat products and due to the seasonal nature of food processing and post harvesting. Water-phase and the nature of the oil-phase in oily wastewater are different from one case to another [1]. Studies have shown that the concentration of COD, animal and vegetable oils and SS are 16 times higher in restaurants wastewaters than domestic wastewater

Table 1.Characteristic of untreated wastewater from food industries

NO	Pollution indicators	Units of measurement	Mean values
1	COD	mg L^{-1}	6835.6
2	BOD	mg L^{-1}	643.8
3	Total suspended solids	mg L^{-1}	439.5
4	pH	Unit.pH	6.6
5	Chlorides	mg L^{-1}	161.15
6	Phosphorus	mg L^{-1}	7.4

This table was plotted using the work of [2, 4, 17, 63, and 43].

The constituents of food wastewater also differ from place to place. However, Constituent of pollutants of all restaurants wastewater is comparatively the same but variations exist in composition among them Due to differences in cuisines. The wastewater composition of Chinese food wastewater differs from that of Western, Europe and other countries restaurant wastewater. This can be attributed to the fact that the food served in these countries differs from that of china. It can also be attributed to differences in culture and way of life. Studies have shown that differences exist in composition of food wastewater pollutants among places and countries. According Xueming Chen et al [65] research study, the highest COD, oil and grease values are found in wastewater discharged by an American and western food restaurant wastewater, respectively. The highest suspended solid content was found from student canteen serving Chinese as well as Western fast foods. Table 2 shows the various constituent of food wastewater from different places.

Table 2
Composition of varieties of food wastewater

NO	Restaurant	Number of samples	PH	COD (mg/l)	BOD5 (mg/l)	Oil and grease (mg/l)	SS (mg/l)	Conductivity (uS/cm)
1	Chinese restaurant	10	6.62–7.96	292–3390	58–1430	120–172	13.2–246	227–661
2	Western restaurant	10	6.94–9.47	912–3500	489–1410	52.6–2100	152–545	261–452
3	American fast-food	11	6.30–7.23	980–4240	405–2240	158–799	68–345	254–706
4	Student canteen	14	6.82–8.76	900–3250	545–1630	415–1970	124–1320	233–1570
5	UC bistro	13	6.03–8.22	1500–1760	451–704	140–410	359–567	341–514

Adapted from the work of [65].

III. Sources of Food Wastewater Pollutants

Food Wastewaters come from various different sources which include restaurants, catering services companies and beverage and dairy industries. Food wastewaters which are predominantly dominated by heavy organic matter, fats, oil & grease, fatty acids; nitrogenous compounds have various sources which are of significant. Fats, oil and grease (FOGS) which are major pollutants of wastewater are mainly sourced from oil seeds like soya bean, sunflower, safflower, cottonseed, rapeseed, and peanut and oil palm. The cultivation and demand for oil seeds in recent times have increased. Oil seeds particularly soya bean and oil palm are usually processed to obtain the oil contents which are subsequently processed for human consumption and industrial applications [53]. The consumption of vegetable oil which is a major product of these oil seeds has increased (3.5%) rapidly nearly twice more than the world population increased (1.6%) between 1980 and 2000 [1]. The dairy industry is generally considered to be the largest source of food processing wastewater in many countries. As awareness of the importance of improved standards of wastewater treatment grows, process requirements have become increasingly stringent. The dairy industry is characterized by the multitude of products and production lines. Plants can have as few as one or two production lines or all of them (pasteurized milk, cheese, butter, etc.).The pollution potential of meat-processing is due to dissolved pollutants accumulated over a long period of time. Wastewater from meat industry also contains high concentrations of suspended solids (SS), including pieces of fat, grease, hair, feathers, flesh, manure, grit, and undigested feed [43].

IV. Effects of Food Wastewater

Wastewater demonstrates a complicated system containing different components, including pollutants coming from the processed raw materials, chemicals and residues of technological additives used in individual operations. World water bodies are increasingly polluted with food wastewaters, its effects can be irreversible for aquatic living organisms as it threatens their survival, and the consequences of these effects are transferred indirectly or directly to humans, as they are also involve in the food chain of the ecosystem [1]. The high pollutant content of this wastewater has led to the depletion of the DO (dissolve oxygen) level of the receiving water bodies and become the propagation place for mosquitoes and flies carrying malaria and other perilous disease such as dengue fever, yellow fever and chicken guinea which are detrimental to human health. Water sources heavily polluted with toxic chemicals can cause sexual mutations and long-term cancers [47]. FOGS present in food wastewater creates oil layer which prevents or reduce light penetration and photosynthesis. According to [54], Oil and grease containing wastes generated from vegetable oil origin are generally classified as serious types of hazardous pollutants particularly when injected into the aquatic environments where they pose high toxicity to the aquatic organisms and other ecology damages to the water bodies. [63], Reported that dissolved organic components can seriously affect normal operations of ecosystems, flora and fauna. Wastewater also causes blockage of drains in the environment.

V. Treatment Processes for Remediation of Food Industries Wastewaters

Various test techniques has been used to ascertain the level of pollutant constituent in food wastewater. The American Public Health Association (APHA)'s Methods for the Examination of Water and Wastewater [8] has been used by a lot of researchers to analyze food wastewater. This method along with methods for chemical analysis of water and waste gave detailed explanation on the experimentation on determination of total dissolved and suspended solids, total solids, chemical oxygen demand, biochemical oxygen demand, pH, turbidity and conductivity. Another technique is the use of Partition-Gravimetric Method (503A) which involves the extraction of dissolved and emulsified oil and grease using trichlorotrifluoroethane. Other provisions are the Partition-Infrared Method (503B) which uses an extraction process identical to the 503A method together with Infrared Detection Methods and the Soxhlet Extraction Method (503C) which is based on an acidification of the sample, separating the oils from the liquid through filtration and extraction using trichlorotrifluoroethane.

Food industries wastewaters are remediated by various accepted techniques and the selection of the required equipment depends on the condition of the pollution. At present, domestic and foreign wastewater treatment methods are mainly physical treatment and chemical treatment method. Physicochemical techniques that have been studied for their applicability in treatment of wastewaters include sedimentation, screening, aeration, filtration, flotation, degasification, chlorination, ozonation, neutralization, coagulation, sorption, ion exchange, etc. nanofiltration and reverse osmosis membranes has been studied in detail for remediation of dairy industries wastewater

Table 3; Highlights of common wastewater treatment process

chemical	biological
1. Chemical precipitation 2. Coagulation/flocculation 3. Chemical oxidation 4. Ion exchange, 5. Solvent extraction	1. Onsite treatment processes- pit latrine, composting latrines, pour flush toilets, septic tanks 2. Offsite treatment processes- trickling filters, aerated lagoons, waste stabilization ponds, constructed wetlands, activated sludge system

Adapted from the work of (**[10]**, **[18] – [3]**).

Though physicochemical treatment process has some advantages which includes; Mineralization of non biodegradable compound and Small reactor volume , Physicochemical treatment methods in dealing with wastewater pollution has some limitations including partial treatment, higher cost, generation of secondary pollutants; higher quantity solids and use of chemicals agents make the biological methods a favorable alternative for the removal of pollutants because of its simplicity, low processing costs, high efficiency and lack of secondary pollutions.

Microbial degradation of oil wastewater involving the application of variety of microorganisms such as bacteria, molds, and yeasts, and fungi which have demonstrated effective degradability of oil-wastewater has attracted attention in recent times. Microbial populations have an amazing and extensive capacity to degrade variety of organic compounds. Naturally occurring microorganisms thrive on many of the complex compounds contained in wastewater. Small size, high surface area-to-volume ratio and large contact interfaces with their surrounding environment, are some of the ideal features of microorganisms as bioindicators of pollutants. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site.

VI. Isolation and Identification of Microbes in Bioremediation Process

The identification of microorganisms involves comparison of an unknown microbe with similar microbes that are already known, thus eventually the former unknown is named [33]. Biodiversity which has been defined as the range of significantly different types of organisms and their relative abundance in an assemblage or community [59] is another factor to consider in isolation and identification process. Due to the enormous biodiversity of microbes and inability to culture most of them, only a limited fraction has been fully characterized and named. The morphological characteristics such as cell shape, cell wall, movement, flagella, Gram staining, etc. per se may not be adequate for establishing a detailed classification of microbes [31]. Advancement in molecular and chemical ecology has provided promising alternatives. Conventional and Biochemical Methods, Plate counts, Sole-carbon-source Utilization (SCSU), Phospholipid fatty acid (PLFA) analysis, Molecular Methods to Study Microbial Diversity, Nucleic acid hybridization, Mole percentage guanine +cytosine (mol% G+C), DNA Reassociation, Restriction fragment length polymorphism (RFLP), Terminal restriction fragment length polymorphism (T-RFLP)., Ribosomal intergenic spacer analysis (RISA)/ Automated ribosomal intergenic spacer analysis (ARISA) /Amplified ribosomal DNA restriction analysis (ARDRA) DNA microarrays, Denaturant gradient gel electrophoresis (DGGE)/Temperature gradient gel electrophoresis (TGGE), Single strand conformation polymorphism (SSCP), Metagenomic analysis of microbial communities, Community genomics analyzing methods, Statistical methods for assessing functional diversity of microbial communities, and Nucleic acid reassociation and hybridization [31,19] are some of the methods used for identification and characterization of microbes in recent times.

The major microorganisms found in wastewater influents are viruses, bacteria, fungi, protozoa and nematodes [3]. These organisms enhance degradation of pollutants as well as nutrient recycling like phosphorus and nitrogen. But in wastewaters bacteria have been the most studied microbes therefore are considered the most efficient organisms in degrading organic matters. Madigan et al. [58] reported that there are usually large amount of heterotrophic microorganisms (bacteria) which belong to the following species:*Pseudomonas fluorescens, Pseudomonas aeruginosa*, *Bacillus cereus*, *Bacillus subtilis*, *Enterobacter*, *Streptococcus faecalis*, *Escherichia coli* etc. while yeasts belonging to genus *Saccharomyces*, *Candida*, *Cryptococcus*, are frequently found in dairy wastewaters. Mupit Datusahlan [32] stated that certain types of bacteria are resistance to toxicity degradation in waste water, e.g. *Bacillus sp,Clostridium sp*, *Staphylococcus*, *Mycobacterium*, *Escherichiacoli*, *Providences*, *Erwinia*, *Proteus vulgaris*, *Pseudomonas aeruginosa and Acinetobacter radioresistens*, and therefore show good potential wastewater treatment . Fungal isolates like *Aspergillus terreus, Aspergillus niger, Rhizopus nigricans* and *Cunninghamella sp* are common isolates for wastewater degradation process [4]. Kanu et al. [25] gave detailed report on the isolation, identification and analysis of bacteria "*Pseudomonas aeruginosa sp*" in waste water and the same bacteria shows good potential for use in waste water treatment, biochemical oxygen demand (BOD) and lipid degradation.

In activated sludge, bacteria isolates like *Achromobacter, Alcaligenes, Arthrobacter, Citromonas, Flavobacterium, Pseudomonas, Zoogloe and Acinetobacter* ([28]-[44]) has been discovered to be important microbes in carrying out wastewater bioremediation. Activated sludge usually has a lot of microbes because of it constant aeration, agitation and recirculation. Bacteria, fungi, rotifers, viruses, nematodes and protozoa are commonly found in the activated sludge.

VII. Microbial isolates and Microbial consortium in bioremediation process

The importance of microbes in the remediation of wastewater around the world has attracted enormous attention in recent times. This has prompt a lot of research work to be carried out in pursue of finding best and adaptable biodegradable microbes for bioremediation purpose. In treating the harmful effects of wastewater, three solutions usually arise: (i) Incineration, (ii) Hiding in discharge and (ii) Recovery. However, the first and the third solutions are very expensive, whereas the second causes many environmental problems [2] hence the need for microbes. Lot of microbes have been isolated and studied in relation to their level of occurrence as well as their biodegradable ability in both single and consortium form. Some organisms are more in numbers than the others. Odeyemi et al. [40] isolated hundred and twenty fungal isolates from wastewater with the highest occurring organism as *Fusarium moniliforme* (19.2% occurrence), followed by *Fusarium oxysporium* (14.2%) and the least occurred organism *Aspergillus versiculor* (0.8%). And also, among the lipolytic fungal isolates, *Aspergillus spp*. showed the highest occurrence of 79.5%, followed by 5.1% occurrence of *Penicillium spp., Fusarium spp*. and *Rhizopus spp*. while *Absidia spp*. and *Thermophillus spp*. showed the least occurrence (2.6%). Wmf Wan Ishak et al. [61] reported isolation of eight strains of bacteria from municipal sludge under aerobic or anaerobic conditions at 37°C, one strain was identified as belonging to *Bacillus megatherium* and two strains were tentatively identified as *Nitrosomonas sps*. and *Nitrobacter sp.* Based on the result obtained, Bacillus family which is *Bacillus Megatharium* and *Bacillus Licheniformis* was identified .The results showed that gram-negative bacilli with a yellow pigment was considered as a major group of the population. Some microbes show more degradable ability than the others. Ayodhya Dattatray Kshirsaga [4] used fungal isolates *Aspergillus terreus, Aspergillus niger, Rhizopus nigricans* and *Cunninghamella sp* in the treatment of wastewater. *Spergillus terreus* and *Aspergillus niger* showed excellent pollutant removal capabilities. *Spergillus terreus* showed the best removal capability of nitrate and BOD while and *Aspergillus niger* showed best removal of phosphate and COD capacity from wastewater. Qu [48] found that *pseudomonas spp*. (isolated from activated sludge) was very effective in removing phenol from industrial wastewater compared to the nonaugmented one. Tuo [57] found *Bacillus spp.* have high ability for quinoline removal.

Consortium of microbes always seems to be the one with the best biodegradable capability in areas where it is use even in the degradation of petroleum hydrocarbons in wastewater [68]. Hesnawia [49] Studied TOC removal efficiencies of *B. subtilis, B. laterosponus and P. aeruginosa*, in synthetic and real wastewater and discovered that the mixed bacteria culture of selected strain of *B. subitlis and P. aeruginosa* increased treatment performance by 6 to 16% higher than other strains. *Porwal H.J. et al* [17] used aerobic microbial isolates of yeast and two bacterial isolates in the bioremediation of dairy effluent, while all the isolates show efficiency in the bioremediation, there consortium was highest by 47.52% in bioremediation efficiency. Mixed bacterial culture comprising *Pseudomonas aeruginosa* LP602, *Bacillus sp*. B304 and *Acinetobacter calcoaceticus* LP009 were used in the treatment of lipid-rich wastewater. The BOD value and lipid content were reduced from ∼3500 and 20 000 mg L^{-1}, respectively, to 120 mg L^{-1} within 12 days under aerobic conditions [64]. *Prasad Mp and Manjunath K.* [45] Studied the biodegradation effect of *bacillus subtilis, B. licheniformis, B.amyloliquefaciens, pseudomonas aeruginosa* and *staphylococcus aureus* in the bioremediation of fat and oil in waste water. *Ngo Thanh Phong et al* [35] isolated 102 isolates and discovered the lipid degrading abilities of 61 strains belonged to the class *Bacilli* (18.18%) and *Gamma-Proteobacteria* occupied 81.82% composing of genus *Acinetobacter* (55.55%), *Aeromonas* (22.22%), *Pseudomonas* (11.11%) and *Stenotrophomonas* (11.11%). *Oumaima Naili et al* [39] used pure strains of *Acinetobacter junii, Pseudomonas aeruginosa, Moraxella lacunata, and Alcaligenes denitrificans* in the removal of phosphate from wastewater and concluded that mixed bacterial culture containing mostly isolated strains can be used successfully for removing phosphate wastewater.

Table 4 below shows the highlights of some isolated microbes that have been identified for food wastewater pollutants bioremediation;

Table 4
Highlights of some isolated microbes that have been identified for food wastewater pollutants bioremediation

Types of microorganisms	Examples	References
bacterial	*Acinetobacter junii, A. calcoaceticus, A. radioresistens, Achromobacter sp, Alcaligenes sp, Arthrobacter sp, Aeromonas sp, bacillus subtilis, B. licheniformis, B.amyloliquefaciens, B. laterosponus, B. megatherium ,B.*	([39],[35], [45],[64], [49],[58],

	cereus, B. Licheniformis , B. laterosponus ,Clostridium sp, Citromonas sp, Cryptococcus sp, Enterococcus sp, Erwinia sp, Enterobacter sp, Escherichia Coli, Flavobacterium, Klebsiella sp, Lueconostoc lactis ,Mycobacterium, Moraxella lacunata, Nitrosomonas sp, Nitrobacter sp, Pseudomonas aeruginosa, P. fluorescens, , Providences, Proteus vulgaris, Raoultella planticola , Stenotrophomonas sp, staphylococcus aureus, Streptococcus faecalis ,Serratia sp, Zoogloe sp.	[25],[44], [28],[61], [48],[57], [30],[16], [36]- [12]).
yeast	*Candida, Saccharomyces*	[58]-[32]
Fungal	*Aspergillus sp., Absidia spp., Cunninghamella sp , , Fusarium moniliforme , Fusarium oxysporium, Penicillium spp., Rhizopus spp, Thermophillus spp. Alternaria sp, Trichoderma sp and Thermoactinomyces sp*	[4],[38]-[27]

VIII. Optimizing microbial bioremediation performance

The quality of restaurant wastewater varies with the type of food served, for example, Japanese, European buffet, Western and Chinese. Both the pollutant load and in particular oil content increase in the order of the food listed. Furthermore, wastewater quality can also vary greatly over the course of a day. Hence, a biological system intended for use to treat such wastewater, must be able to withstand different magnitudes of quality and quantity spike loading [11]. Generally, microbes especially bacterial have good adaptability to harsh environmental conditions because of their ability not to follow the elevational diversity patterns of plants and animals ([9],[20], [37], [21]-[55]). The isolation of bacteria and the study of their identification have been hampered by the unreliability of conventional microbiological techniques. This is largely due to their morphological variations and inconsistent characteristics and different biochemical characteristics. To fully understand their role in promoting activated sludge process, bacteria need to be characterized [60]. To combat the excess environmental wastewater, efficient and environmentally friendly waste treatment technologies are also needed. The bioengineered technologies adapted for each type of organic and toxic wastes are required to achieve high treatment efficiencies. To enhance better performance of biological remediation process, bioaugmentation of one or more species of specialized microorganisms are needed ([52], [14] - [26]). Bioaugmentation is when a versatile microorganism or an efficient consortium is added to the initial indigenous microbial community of a contaminated medium to enhance biopurification abilities [5]. Microbial growth and activity are readily affected by pH, temperature and moisture [42]. Although, microorganisms have been isolated in extreme conditions, most of them grow optimally over a narrow range, so it is important to achieve optimal conditions [40] during microbe's growth and isolation. Various species of fungi involved in the decomposition of wastewater include species of *Rhizopus, Aspergillus, Alternaria, Trichoderma* and *Thermoactinomyces*, and grows best at low pH level and optimal temperature between –60℃ to 50℃ for optimal biological activities [27]. Substrate concentration and enzyme allocation can affect rates of microbial decomposition of waste [15 and 50]. Enzymes like cellulase, pectinase, lipase etc have been isolated for wastewater degradation purpose. Moataza Saad M et al ., *Hala, M. R et al* ([30]-[16]) reported the exceptional ability of *Fusarium oxysporum* to produce quality and enormous lipase. The fluoresce diacetate (FDA) hydrolysis assay measures the enzyme activity of microbial populations and can provide an estimate of overall microbial activity in an environmental sample. *jianliang Xue et al* [23] used this method in examining the activity of microbes in the soil. Nilu¨fer Cihangir1 and Elif Sarikaya [36] isolated a strain of *Aspergillus* from Turkish soil samples incubated at pH5.5, temperature 30℃ in 96 hours to obtain a lipase activity. Abundance of biodegradable can also to be enhancing through a suitable growth medium. *Anderson CR* et al [6] used biochar to study the increase in abundance of certain bacterial like: *Bradyrhizobiacea, Hyphomicrobiaceae, Streptosporangineae* and *Thermomonosporaceae* which are also effective in phosphate solubilization and reduction of nitrate to ammonia. To get an efficient biological wastewater treatment, it is very important to know the wastewater microbiota composition and biochemical properties correlated to the origin of pollutants, as well as the optimum metabolic activity and physical-chemical conditions. . Pepper IL et al [46] stated that, the bioavailability of compounds in a given system is a very important factor in determining biodegradability of the system. Hesnawia R. [49] suggested the need for highly specialized strains for efficient treatment of wastewater. Abdelali Fadile et al [2] emphasized the importance of adaptable microbes and consortia in the bioremediation of grease from waste water. When they used adapted and non adapted consortium of microbe's biomass in aerobic treatment of lipid-rich of restaurant wastewater and discovered that the adapted biomass allowed a rate of abatement of 84.28 and 93.3% of the COD and greases removal respectively against 51.88 and 66.6% by the non adapted biomass. Indeed, it is desirable to adopt species that are Generally Regarded as Safe (GRAS). Furthermore, it is preferable that the species have limited nutritional requirements and have the ability to antagonize the growth of pathogenic species as well as the capacity to adapt to stringent environmental conditions (i.e. low temperatures and water activity, high concentrations of toxic substances) [40]. Microorganisms like *Pseudomonas fragi, Staphylococcus aureus, Geotrichum candidum, Candid lipolytica, Penicillium roqueforti,* and *Penicillium sp.* are the organisms reported to produce lipases which are active even at very low temperatures [7]. Prakashveni R. and Jagadeesan M. [65] studied 18 bacterial genera isolated from the Thanjavur Co-operative Milk Products dairy effluent and discovered *Alcaligens faecalis, Lueconostoc lactis* survive in all seasons. Sugimori D. [13] isolated a strain of bacterium *Raoultella planticola* strain 232-2 that is capable of efficiently catabolozing lipids under acidic conditions such as in grease traps in restaurants and food processing plants. They also isolated two bacterial strains with high degradation abilities at an alkaline pH from Japanese soil, as *Acinetobacteria sp*. strain SS-192 and *Pseudomonas aerunosa* strains SS-219.

IX. Oil degradation in food wastewater

Oily wastewaters are generated in many industrial processes, such as petroleum refining, petrochemical, food, leather and metal finishing [24]. The presence of high-strength oil and grease (O&G) in wastewater poses serious challenges for environment [67]. Oil-water mixture with droplets greater than or equal (≥) to 150 microns is classified as free oil while oil-water mixture with droplets size ranging between 20 and150 microns, are classified as dispersed oil mixture. Emulsified oil mixture are oil-water mixture with droplet sizes smaller than 20 microns and oil-water mixture with droplet sizes smaller than 5 microns are classified as soluble oil mixture. The oily wastewater often contains lipid such as edible oil and long-chain fatty acid [12]. Biological treatment has been found to be the most efficient method for removing fat oil and grease by degrading them into miscible molecules [41]. Oil-rich wastewaters were used to be treated physically, which has proven ineffective especially when the fat is in its dispersed form [38]. Oil degrading microbes produce enzymes that tend to hydrolyze the oil content of wastewater. They secrete wide varieties of enzymes such as cellulase, pectinase, lipase which assist them in degrading organic matters in wastewater. Odeyemi A. T. et *al* [40] reported that bacteria associated with dietary oil-rich wastewater are the novel source of environmental enzymes for possible commercial applications and may play an important role in enzyme-catalyzed organic matter cycling in domestic environments. *Prasad Mp. et al* [45] reported the ability of organisms to produce highly-efficient lipases which degraded lipid-rich wastewater both individually and when used as a consortium. According to [16], among the lipolytic microorganisms that are significant in wastewater are aerobic and anaerobic bacteria of the genera: *Pseudomonas*, *Clostridium* and also *fungi* of the genera; *Penicillium, Aspergillus, and Fusarium. . Odeyemi A. T. et al* [40] revealed the potency of genera of *Klebsiella, Pseudomonas and Staphylococcus spp* in oil degradation process. *Ngo Thanh Phong et al* [35] Identified 11 lipid-degrading bacterial strains with two groups: *Gammaproteobactera and Bacilli*. *Gammaproteobacteria* composed of *Acinetobacteria*, *Pseudomonas*, *Aeromonas and Stenotrophomonas* with high ratio in comparison to *Bacilli* with two species (*Bacillus cereus* and *Bacillus pumilus*).

X. CONCLUSIONS

The use of physicochemical method for wastewater remediation has been replaced by microbial bioremediation method. Utilizing the potential of bacteria, fungi and even yeasts for remediation purpose is eco-friendly. Microbes have been use for reduction of wastewater pollutants to acceptable economy level. Microbes synthesize a lot of enzymes which are instrumental in degrading oil pollutants which are major constituent of food wastewater. Microbes possess some distinctive advantage over other form of organisms due to ease in handling, mass cultivation ability to withstand various environmental conditions and high degradable capabilities. Their extreme small size and large surface area relative to their volume makes them applicable in many areas of wastewater remediation. Thus, the use of microbes in bioremediation of food wastewater is a development in the right direction

Recommendations

Numerous breakthroughs have been recorded in using microbes for wastewater remediation. Lot of microbial isolates has been studied by various researchers. Their biodegradable abilities have been describe as amazing. However most of this experimental research reports are yet to be applied in the field. Thus, the continuous experimental research on microbial degradation ability could play a crucial role in large scale application in bioremediation of food wastewater constituents in the future

ACKNOWLEDGMENT

This work was supported by the Projects of Science and Technology Support of Gansu province (1504FKCA015), the Projects of Science and Technology Support of Lanzhou City (2015-3-68), the National Natural Science Foundation of China (31260135). We are grateful for the editors and the anonymous reviewers for their valuable comments and help.

References

[1] *Abass O. Alade, Ahmad T. Jameel, Suleyman A. Muyubi, Mohamed I. Abdul Karim, Zahangir Alam Md , 2011. Removal of Oil and Grease as Emerging Pollutants of Concern (Epc) In Wastewater Stream. IIUM Engineering Journal, 12(4).*

[2] *Abdelali Fadile, Fatima Zahra El Hassani, Halah Aissam, Mohammed Merzouki, Mohamed Benlemli , 2011. Aerobic Treatment of Lipid-Rich Wastewater by a Bacterial Consortium. African Journal of Microbiology Research, 5(30): 5333-5342.*

[3] *Akpor O. B., Muchie M., 2010. Bioremediation of Polluted Wastewater Influent: Phosphorus and Nitrogen Removal. Scientific Research and Essays, 5(21): 3222-3230.*

[4] *Ayodhya Dattatray Kshirsaga , 2013. Application of Bioremediation Process for Wastewater Treatment Using Aquatic Fungi. International Journal Of Current Research, 5:1737-1739*

[5] *Samer Semranya, Lidia Faviera, Hayet Djelala, , Samir Taha,, Abdeltif Amrane , 2012. Bioaugmentation: Possible solution in the treatment of Bio-Refractory Organic Compounds (Bio-ROCs). biochemical engineering journal, 69:75-86*

[6] *Anderson CR Condron LM, Clough TJ, Fiers M, Stewart A, Hill RA, Sherlock RR., 2011. Biochar Induced Soil Microbial Community Change: Implications for Biogeochemical Cycling Of Carbon, Nitrogen and Phosphorus. Pedobiologia journal, 54 (5-6): 309-320*

[7] *Alford, J.A., Pierce, D.A., Frank G., 1964. Activity of Microbial Lipase on Nature Fats and Synthetic Triglycerides. Journal of Lipid Research, 5: 390-394.*

[8] *Apha, Standard Methods for the Examination of Water and Wastewater, 20th Edn. American Public Health Association.*

[9] *Jianjun Wang, Janne Soininen, Yong Zhang, Beixin Wang, Xiangdong Yang and Ji Shen* , 2012. *Patterns of elevational beta diversity in micro- and macro organisms. Global Ecology and Biogeography*, 21(7):743-750.

[10] *Balannec B., Vourch M., Rabiller-BaudryM., Chaufer B., 2005. Comparative Study Of Different Nanofiltration And Reverse Osmosis Membranes For Dairy Effluent Treatment By Dead-End Filtration. Separation And Purification Technology, 42(2): 195–200.*

[11] *Chih-Kuei Chen and Shang-Lien Lo, 2006. Treating Restaurant Wastewater Using a Combined Activated Sludge-Contact Aeration System. Journal of Environmental Biology, 27(2): 167-183.*
[12] *Sugimori D., Utsue T., 2013. A Study of the Efficiency of Edible Oils Degraded In Alkaline Conditions by Pseudomonas Aeruginosa Ss-219 and Acinetobacter Sp. Ss-192 Bacteria Isolated From Japanese Soil. World J. Microbiol. Biotechnol., 28(3):841-848.*
[13] *Sugimori D., Watanabe M., Utsue T., 2013.Isolation and Lipid Degradation Profile Of Raoultella Planticola Strain 232-2 Capable Of Efficiently Catabolozing Edible Oils under Acidic Conditions. Appl. Microbiol. Biotechnol., 97(2):871-880*
[14] Erdogan E.E., Sahin F., Karaca A., 2011. *Determination of petroleum-degrading bacteria isolated from crude oil-contaminated soil in Turkey*. African Journal of Biotechnology, 11(21): 4853-4859.
[15] *Donovan P. German, Stephany S. Chacon, and Steven D. Allison, 2011. Substrate Concentration and Enzyme Allocation Can Affect Rates of Microbial Decomposition. Ecology, a publication of the ecological society in America, 92(7): 1471-1480.*
[16] *Hala, M. R., Adel, A. E., Hassaan, A. E. And Samah, A. D., 2010. Production, Optimization and Partial Purification of Lipase from Fusarium Oxysporium. Journal of Applied Science in Environmental Sanitation, 5(1): 39-53.*
[17] *H.J. Porwal , A.V. Mane , S.G. Velhal , 2015. Biodegradation Of Dairy Effluent By Using Microbial Isolates Obtained From Activated Sludge. Water Resources And Industry 9: 1-15*
[18] Ivanna Kyrychuk, Yuriy Zmievskii, Valeriy Myronchuk, Ivanna Kyrychuk, Yuriy Zmievskii, Valeriy Myronchuk, 2014.treatment *of dairy effluent model solutions by nano filtration and reverse osmosis. Ukrainian Food Journal,* 3(2):281-288.
[19] *Jennifer L, Kirk, Lee A, Et Al., 2004. Methods of Studying Soil Microbial Diversity. Journal of Microbiological Methods. 58 (2): 169-188*
[20] *Jessica A. Bryant, Christine Lamanna, Helene Morlon, Andrew J. Kerkhoff, Brian J. Enquist , Jessica L., 2008. Green. Microbes on mountainsides. Contrasting elevational patterns of bacterial and plant diversity. Proceeding Of National Academy Of Sciences Of The United States of America.*
[21] *Jianjun Wang, Janne Soininen. Etal , 2011. Contrasting Patterns in Elevational Diversity between Microorganisms and Microorganism .Journal Of Biogeography,38: 595-603*
[22] *jianliang Xue, Linao Zheng, Hongsheng Lu, Blin Guo, Yanan Wu, Nenghu Qiao Bingqi Yan., 2014. Treatment Of Oil Polluted Marine Environment Through Multi-Functional Material. Journal Of Chemical And Pharmaceutical Research, 6(5):1504-1509*
[23] *Johan Schnürer , Thomas Rosswall. Fluorescein Diacetate, 1982. Hydrolysis as a Measure of Total Microbial Activity in Soil and Litter. Applied and Environmental Microbiology, 43(6):1256.*
[24] *José Coca, Gemma Gutiérrez, Josém Benito., 2010. Treatment Of Oily Wastewater, Water Purification and Management, Part of the series NATO Science for Peace and Security Series C: Environmental Security, 1-55*
[25] *Kanu, Ijeoma, Achi , O.K., 2011. Industrial Effluent and Their Impacts on Water Quality of Receiving River in Nigeria. Journal of Applied Technology in Environmental Sanitation, 75-86.*
[26] Karamalidis A., Evangelou A., Karabika E., Koukkou A., Drainas C., Voudrias E., 2010. Laboratory scale bioremediation of petroleum contaminated soil by indigenous microorganisms and added Pseudomonas aeruginosa strain Spet. Bioresource Technology, 101(16): 6545–6552
[27] *Maire, R. M., Pepper, I. L., Gerba C. P., 2003. Important Constituent in Wastewater. Journal of Environmental Microbiology, 3: 149-173.*
[28] Environment Protection Agency 1996
[29] *Yada M., Kawakuchi K., Mihara Y., "Haikibutsu No Bioconversion,"Bioconversion of Wastes, Chijin Shokan, Tokyo, 2001.*
[30] Moataza Saad M., Amany, Kansoh L., Gadallah M.A., 2005. Optimization of extracellular lipase production by Fusarium oxysporum, Arab J. Biotech, 8 (1): 19-28.
[31] *Fakruddin md., Khanjada Shahnewaj Bin Mannan*, 2013. *Methods for Analyzing Diversity of Microbial Communities in Natural Environments. Ceylon Journal of Science (Bio. Sci.), 42(1): 19-33.*
[32] Mupit Datusahlan, W. M. F. Wan Ishak, and Essam A. Makky , 2013. *Biodegradation of Wastewater Oil Pollutants, Identification and Characterization: A Case Study – Galing River, Kuantan Pahang, Malaysia*. International Journal of Bioscience, Biochemistry and Bioinformatics, 3(6): 2013
[33] *Mohammad kazem Sharifi-Yazdi, Cyrus Azimi,, Khalili Mb., 2001. Isolation and Identification of Bacteria Present In the Activated Sludge Unit, In the Treatment of Industrial Waste Water. Iranian J. Publ. Health, 30(3-4):91-94.*
[34] *Marek Gugała1, Krystyna Zarzecka1, Anna Sikorska , 2015.Wastewater Management in Food Processing Enterprises – A Case Study of the Ciechanów Dairy Cooperative. Journal Of Ecological Engineering , 16(1):178-183*
[35] *Ngo Thanh Phong,, Nguyen Thanh Duyen , Cao Ngoc Diep , 2014. Isolation And Characterization Of Lipid-Degrading Bacteria In Wastewater Of Food Processing Plants And Restaurants In Can Tho City, Vietnam. American Journal Of Life Sciences, 2(6): 382-388*
[36] *Nilu¨fer Cihangir1 , Elif Sarikaya, 2004. Investigation of lipase production by a new isolate of Aspergillus sp. World Journal of Microbiology & Biotechnology*, 20: (2):193–197
[37] *Noah Fierer, Christy M. Mccain, Patrick Meir, Michael Zimmermann, Joshua M. Rapp, Miles R. Silman, and Rob Knight, 2011. Microbes do not follow the elevational diversity patterns of plants and animals. Ecological Society of America, 92(4):797–804*
[38] *Odeyemi, A.T, Adebayo, A.A., Omoboye, O.O., Ajayi, S.S., 2013.Incidence of Lipolytic Mycoflora In Domestic Wastewater. Journal of Natural Sciences Research, 3(8).*
[39] *Oumaima Naili1, Messaoud Benounis, Leyla Benammar , 2015. Screening Of Bacteria Isolated From Activated Sludges For Phosphate Removal From Wastewater. Journal of Applied Environmental and Biological Sciences. 5(5)1-5*
[40] *Odeyemi A. T., Aderiye B. I., Bamidele O. S, 213. Lipolytic Activity of Some Strains Of Klebsiella, Pseudomonas And Staphylococcus Spp. From Restaurant Wastewater and Receiving Stream. Journal Of Microbiology Research, 3(1): 43-52*
[41] *Odeyemi, A.T., Dada, A.C., Ogunbanjo, O.R. , Ojo, M.A., 2010. Bacteriological, Physicochemical and Mineral Studies on Awedele Spring Water and Soil Samples in Ado Ekiti, Nigeria. African Journal of Environmental Science and Technology. 4(6): 319-327.*
[42] *Odeyemi, A.T., Aderiye, J.B. , Adeyeye, E.I., 2011. Changes In The Microflora And Chemical Components Of Domestic Oil-Rich Wastewater. Journal of Microbiology, Biotechnology and Food Sciences, 1(1): 126-147.*
[43] *Oneţ Cristian , 2010. Characteristics of the Untreated Wastewater Produced By Food Industry. Analele Universităţii Din Oradea, Fascicula:Protecţia Mediului , 15 (10):709-714.*
[44] *Water Environment Association, 1987*
[45] *Prasad Mp , Manjunath K.., 2011. Comparative Study on Bioremediation of Lipid-Rich Wastewater Using Lipase Producing Bacterial Species. Indian Journal Of Biotechnology, 10: 121-124*
[46] . Pepper IL, Gerba CP, Brusseau ML, 1996. Pollution Science. San Diego, Calif, USA: Academic Press
[47] *Oberholster, P.J., Botha,. A.M., Cloete, T.E., 2008. Biological and chemical evaluation of sewage Water Pollution in the Rietvlei Nature Reserve Wetland Area, South Africa, Environmental pollution, 156(1):184-192*
[48] Qu Y., Zhang R., Ma F., Zhou J., Yan B., 2011. *Bioaugmentation with a novel alkali-tolurent psuedomonas strain for alkaline phenol wastewater treatment in sequencing batch reactor. World Journal of Microbiology and Biotechnology, 27: 1919-1926*
[49] Hesnawia,R., Dahmani,K., Al-Swayah A., Mohamed S., Mohammed S.A., 2014. *Biodegradation of municipal wastewater with local and commercial bacteria. 12th International Conference on Computing and Control for the Water Industry, CCWI2013, Procedia Engineering, 70: 810 – 814*
[50] *Jagadamma, S., Mayes, M.A., Steinweg, J.M., Schaeffer S.M., 2014. Substrate quality alters the microbial mineralization of added substrate and soil organic carbon.* Biogeosciences, 11:4665–4678.
[51] *Zulaikha, S., Lau W.J., Ismail A.F., Jaafar J.,* 2014.*Treatment of restaurant wastewater using ultrafiltration and nanofiltration membranes*. Journal of water processing engineering, 2 58–62

[52] *Schneider I.D., Topalova Y.I., 2011. Effect of bioaugmentation on anarobic wastewater treatment in the dairy industry. Journal of Dairy Science, 94:4389-4397.*

[53] *Shahrakbah Yacob , 2008. Progress and Challenges in Utilization Of Palm Biomass, Advanced Agriecological Research Sdn. Bhd.*

[54] *Mendiola S., Achutegui J.J., Sanchez F.J., San M.J., 1998. Polluting Potential Wastewater from Fish-Meal and Oil Industries. Grasa Aceites , 49:30–33, 1998*

[55] *Shen C, Xiong J, Zhang H, Etal, .2013. Soil Ph Drives The Spatial Distribution Of Bacterial Communities Along Elevation On Changbai Mountain. Soil Biology & Biochemistry, 57: 204-211.*

[56] *Kiran GS, Shanmughapriya S, Jayalakshmi J, Selvin J, Gandhimathi R, Sivaramakrishnan S, Arunkumar M, Thangavelu T, Natarajaseenivasan K.,* 2008. *Optimization of Extracellular Psychrophilic Alkaline Lipase Produced By Marine Pseudomonas Sp． (Msi057). Bioprocess And Biosystems Engineering, 31(5): 483 -492*

[57] *Tuo B.H., Yan B., Fan B.A., Yang Z.H., Liu J.Z., 2011. Biodegradation characteristics and bioaugmentation potential of a novel quinolinedegrading strain of Bacillus spp. isolated from petroleum –contaminated soil.* Bioresource Technology 107:55-60.

[58] *Michael T. Madigan , John M. Martinko , Jack Parker ,2000. Brock Biology of Micro-Organisms. Prenticehall, Inc, 1–29*

[59] *Torsvik, V, Daae, F.L., Sandaa, R.A., Ovreas, L., 1998. Review Article: Novel Techniques for Analysing Microbial Diversity in Natural and Perturbed Environments. Biotechnol, 64: 53–62.*

[60] *Vishakha S.,Shivsharan , Minal P. Wani , Suhas W. Kulkarani. , 2013. Isolation Of Microorganism From Dairy Effluent For Activated Sludge Treatment" International Journal Of Computational Engineering Research, 3(2):2250 -3005*

[61] *Wmf Wan Ishak, Jamek S., Jalanni NA., Nf Mohd Jamaludin., 2011. Isolation and Identification of Bacteria from Activated Sludge and Compost for Municipal Solid Waste Treatment System. International Conference on Biology, Environment and Chemistry, 24*

[62] *Wibowo Mangunwardoy, Tony Sudjarwo, Mufti Petala Patria , 2013. Bioremediation Of Effluent Wastewater Treatment Plant Bojongsoang Bandung Indonesia Using Consorsium Aquatic Plants And Animals. Mangunwardoyo & Al. Bioremediation of Effluent Wastewater Plant. 14 (1)*

[63] *Wael Qasim , Mane A.V., 2013. Characterization and Treatment of Selected Food Industrial Effluents by Coagulation and Adsorption Techniques. Water Resources And Industry, 4:1–12*

[64] *Wiyada Mongkolthanaruk , Saovanee Dharmsthiti , 2002. Biodegradation Of Lipid-Richwastewater By A Mixed Bacterial Consortium. International Biodeterioration & Biodegradation 50 (2):101–105*

[65] *Xueming Chen, Guohua Chen, Po Lock Yue 2000. Separation of pollutants from restaurant wastewater by electro coagulation. Separation and Purification Technology* ,19: 65–76

[66] Li Yu, Mei Han, Fang He, 2013. A *review of treating oily wastewater*. Arabian Journal of Chemistry.

[67] *Zhang Hz，Xiang H，Zhang Gl，Et A, 2009. Enhanced Treatment of Waste Frying Oil In An Activated Sludge System By Addition Of Crude Rhamnolipid Solution． Journal Of Hazardous Materials, 167(1-3):217－223*

[68] *Zulfiqar Ali Malik , Safia Ahmed , 2012. Degradation of Petroleum Hydrocarbons by Oil Field Isolated Bacterial Consortium. African Journal of Biotechnology, 11(3):650-658.*

[69] *Prakashveni R. and Jagadeesan M, 2012. Isolation identification and distribution of bacteria in Dairy Effluent. Advances in Applied Science Research, 3 (3):1316-1318*

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