Journal of Environment Protection and Sustainable Development
Vol. 6, No. 4, 2020, pp. 72-81
http://www.aiscience.org/journal/jepsd
ISSN: 2381-7739 (Print); ISSN: 2381-7747 (Online)

Environmental Pollutant of Palm Oil Effluent and Its Management in Okitipupa Area of Ondo State, Nigeria

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Abstract

In recent decades, Okitipupa area has been known as one of the leading producer area and exporters of palm oil products in ondo state. Every year, the number of palm oil mills increases rapidly, thus increasing the capacity of fresh fruit bunch waste or effluent discharge and the pollution caused by waste materials from the palm oil mills has become a major environmental concern. However, not much has been said about the negative effects of such a huge industry. This report reviews the environmental impacts of palm oil mill effluents generated from oil palm processing and how they can be efficiently managed through biological and environmental tools. The processing of oil palm generates three (3) major waste streams including gaseous (pollutant gases), liquid (palm oil mill effluent, POME) and solid (palm press fibre, chaff, palm kernel shell and empty fruit bunch) wastes. POME has been the most environmental problem, among all the others. It contains high pollution indicators such as oil and grease; it also impacts on the soil and water properties as well as climate changes. Discharging POME into the soil tampers with its pH, which is one of the major factors affecting nutrient availability to plants. POME also changes the soil appearance and properties in terms of vegetation, odour, colour and constitution, making the soil to lose its vegetative cover. It also interferes with the greenhouse effect emissions and also air pollution, biodiversity loss. The discharge of POME on the soil and surrounding lands can also contaminate the aquatic ecosystem during runoff, leading to acidification and eutrophication. The paper concludes by suggesting options for effective management such as the use of POME for microalgae cultivation, the use of pre-treated POME as fertilizer; focusing on phytoremediation, bioremediation and mycoremediation of POME-contaminated soil and water as options for the rehabilitation of POME-contaminated soils and waterbodies.

Keywords

POME, Biological & Environmental Tools, Phytoremediation, Bioremediation, Mycoremediation

Received: September 10, 2020 / Accepted: September 18, 2020 / Published online: November 6, 2020

1. Introduction

Environmental issues are increasingly becoming more important globally. Over the recent years, there has been an increasing concern for environmental risk of industrial activities associated with extraction, hydrocarbons, food processing, transportations and refining [1]. Industries have increased the threat of oil pollution to the environment and concomitant effluent discharged into the natural environment had created major ecological problem throughout the world. Discharge and indiscriminate dumping of palm oil mill effluent (POME) has led to alterations overtime on soil

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physicochemical characteristics [2]. Palm oil is one of the many vegetable oils widely consumed around the world. Oil palm production in Nigeria increases yearly [3]. Palm oil is one of the many vegetable oils widely consumed around the world. Nigeria is currently the 5th world's leading producer of palm oil [4]. The palm oil industry is a major agro based enterprise in Nigeria especially in the southern part of the country where palm oil trees are found both in the wild and plantations [5]. Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. About 43-45% of this is always a mill residue in the form of empty fruit bunches (EFB), shell, fibre and palm oil mill effluent (POME), which will continue to accumulate with increasing production [6]. The production of palm oil requires large volumes of water with concurrent generation of wastewater known as palm oil mill effluent (POME). The POME is a mixture of water, oil and natural sediments (solid particles and fibres), large quantities of which are generated annually during crude palm oil production [7] and is amenable to microbial degradation. It is estimated that for each tonne of crude palm oil (CPO) that is produced, 5-7.5 tons of water are required and more than 50% of this water (about 3.5 m^3) ends up as POME [8]. The solid waste products that result from the milling operation are empty fruit bunches, palm fibre, and palm kernel. In both traditional and modern milling settings, these solid waste products are all put to economically useful purposes such as fuel material and mulch in agriculture. It is the POME that is usually discharged into the environment, either raw or treated. Raw POME consisting of complex vegetative matter is thick, brownish, colloidal slurry of water, oil and solids including about 2% suspended soils originating mainly from cellulose fruit debris, that is, palm mesocarp [9]. The raw or partially treated POME has an extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil [10]. This highly polluting wastewater can, therefore, cause pollution of waterways due to oxygen depletion and other related effects as reported by [10] Thus, while enjoying a most profitable commodity, palm oil, the adverse environmental impact from the palm oil industry cannot be ignored. It has been observed that most of the POME produced by the small-scale traditional operators undergoes little or no treatment and is usually discharged into the surrounding environment. The local palm fruit processing method to produce palm oil is very long and laborious. Firstly, the palm bunches are quartered (cut into four) and left overnight for easy separation of nuts from the spikelet's. The fruits are boiled for 1-1½ h, pounded in a mortar or macerated with feet in a canoe-like container, water is added and it is well mixed up. All nuts are then carefully removed by hand. The fibres are well shaken over in the sludge, until oily foam comes up to the surface of the sludge. The foam is collected in a container until the operation is completed when there is no more foam formation. This foam is later boiled for about 30 to 40 min. The clean edible oil then collects on the surface leaving the sludge at the bottom. Sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire starting cake called flint. At other times, the sludge is poured onto the surrounding bushes and soil together with the liquid waste known as palm oil mill effluent (POME).

The management of agro industrial effluents such as palm oil mill effluent (POME) has been a major environmental concern in countries producing them. These effluents are land and aquatic pollutants when discharged untreated, due to the presence of high organic load. Also, their phytotoxic properties are serious nuisance when discharged untreated, as they have high levels of organic loads and some organic acids. These effluent streams are normally disposed of in drainage channels or stored in evaporation ponds or worse still discharged in arable lands to possibly avert the cost of treatment [11, 12]. This practice is predominant in developing countries where effluent discharge standards are not strictly adhered to. It has been observed that most of the POME produced by the small-scale traditional operators undergoes little or no treatment and is usually discharged into the surrounding environment. There is a dearth of information on these POME sediments. The characterization of these sediments and their effects on the land or water body into which they are dumped are important for future researches due to the fact that these properties have significant effects on the settling process that occurs either under natural gravity or by coagulations [13]

2. Palm Oil Industry / Enterprises in Okitipupa Area

Okitipupa Oil Palm Plc is an oil palm processing firm that manages oil palm estates in Southern Ondo State and processes raw materials from its plantation. The firm's estates located close to the town of Okitipupa in Ilutitun, Ikoya, Irele, Erinje, Iyansan, Igbotako and Apoi and other private owned plantation across the area. A Nucleus oil palm estate project was initiated by the Western Nigerian government under Adeyinka Adebayo as a way to boost the economy of small towns and rural areas. These oil palm estates were developed beginning in 1969 and additional acreage were to be developed between the years 1975 and 1983, initially planned to include 6,000 hectares of planted oil palm fruits and 4,000 hectares provided by small scale farmers. The expansion was to be financed by the Western State government and by multilateral loans. [14]. In 1974, an oil processing mill was installed at Okitipupa and in 1976, the firm was incorporated as a limited liability company. However, the planned expansion was inhibited by financial difficulties and reduced government interest in the project. [14] Another mill was installed in 1993 at Ipoke [15]. Presently, Okitipupa oil palm plantation and its small scale production is the biggest oil palm producer in Nigeria more than 12,474 hectares [16] (Figure 1).

Figure 1. Palm oil fruit.

Figure 2. Palm oil local processing plant.

3. Palm oil Mill Effluent

POME is a basic expression referring to the effluent from the last phases of palm oil manufacture in the mill. It incorporates different fluids, dirt, leftover oil and suspended solids.

POME in its untreated shape is a high quality waste, relying upon the operation of the procedure. POME is generated mainly from oil extraction, washing and cleaning processes in the mill, and these contain cellulosic material, fat, oil and grease, and so on [17]. POME also contains substantial quantities of solids; both suspended solids and total dissolved solids in the range of 18,000 and 40,500 mg/L, respectively (Figure 2). Oil palm is the most productive oil producing plant in the world, with 1 ha of oil palm producing between 10 and 35 tons of fresh fruit bunch (FFB) per year [17]. During processing of oil palm, more than 70% by weight of the fresh fruit brunch was left over as waste [18]. Usually, the harvested part is the fruit whereby oil is obtained from the fleshy mesocarp of the fruit. Despite the importance of the edible oil and fats extracted from the palm fruits, the POME contains residual oil which affects the environment cannot be ignored. Treatment and disposal of oily wastewater such as POME is presently one of the serious environmental problems. Palm oil mill wastes have existed for years but their effects on environment are at present more noticeable [17]. The oily waste has to be removed to prevent problems which are considered as hazardous pollutants particularly in the aquatic environments because they are highly toxic to the aquatic organisms. Discharging the effluents or by-products on the lands or release to the river may lead to pollution and might deteriorate the surrounding environment. In order to conserve the environment, an efficient management system in the treatment of these by-products is needed [19]. Treatment of POME is essential to avoid environmental pollution [20].

Figure 3. POME in the water.

Figure 4. POME in the soil.

4. Effect of POME on Soil Quality

The discharge of POME into the environment affects soil pH, which is one of the main factors that influence nutrient availability to plants [21]. Most plants grow and survive within a pH range of 6.5 – 7.5. POME being acidic constituent increases soil acidity. The soil can also be impacted through the leaching of heavy metals and other POME Physico-chemical properties into the soil (Figure 4). POME stimulate the increase of organic carbon, total nitrogen, phosphate, sulphate, phosphorus, sodium, potassium, calcium, magnesium, aluminium and hydrogen in the soil [22]. Ordinarily, availability of nutrients including sodium, phosphorus and potassium enhances plant growth. However, high nitrogen, potassium and phosphorus will not be able to perform their functions if the soil pH is outrageously high [21]. The high phosphorus in POME contaminated soil leads to high absorption of materials thereby delaying its effect on the soil, because POME biodegrades slowly [21]. Available Phosphorus in soil contaminated with POME is due to increase in pH level and other nutrient determinants available in the soil [22]. The solids in raw POME are good organic matter sources, organic matter being a good booster of soil productivity. However, it is also hindered by high pH of POME- contaminated soil. Several organisms invade and grow in soil contaminated with POME, biodegrading complex compounds into simple ones [21, 23]. The changes in the soil physicochemical properties and other vital nutrients due to POME discharge affects the soil texture and particulate size. POME discharged untreated on the soil increases the soil bulk density, and percentage of silt and clay.

The soil texture is usually dependent on the organic matter content. POME discharge on soil leads to water retention due to the presence of unrecovered oil and debris during processing.

Apart from changing the soil appearance, POME also affects some other properties including vegetation, colour, odour, and constitution. Despite the soil enrichment by POME, the soil loses its vegetation cover and becomes damp with humus. This leads to clogging and water logging of the soil pores and eventually result in death of vegetation [22]. Summarily, POME discharge leads to loss of agricultural lands as well as indigenous microorganisms in the soil such as earthworms, which play significant roles in soil aeration. [24].

5. Effect of POME on Water Quality

In mechanized mills, POME are produced in various processing lines including sterilizers, clarifying centrifuges and hydro cyclones, while in traditional/smallholder mills, they are produced during boiling, digestion and clarification. Most of the POME, especially the traditional small scale producer undergoes no treatment and is usually discharged into the surrounding environment [21] (Figure 3). This often leads to pollution of waterways due to oxygen depletion, reduced land use, and other related effects [24, 25]. During the rainy season, POME is a breeding habitat for mosquitoes and emits offensive odours. Its discharge into the aquatic ecosystem turns the water brown, smelly and slimy [25], which adversely affects aquatic life and water quality for domestic purposes. The discharge of untreated POME into soils also have serious impacts on surrounding water bodies during runoffs, leading to acidification and eutrophication of water bodies. POME can also alter potable water sources (surface and groundwater). POME increases water parameters such as temperature, pH, total alkalinity, total dissolved solids, total suspended solids, magnesium, calcium, sodium, potassium, chloride, sulphate, nitrate, phosphate, zinc, iron, manganese, dissolved oxygen, biological oxygen demand in a river or water body receiving POME. [25].

6. Effects of POME on Climate Change

POME is typically released into open-air holding ponds for remediation, thereby releasing carbon dioxide, methane, and hydrogen sulphide, all of which contribute to global climate change. Sources of greenhouse gas (GHG) emissions include the transportation of staff and fresh fruit bunches (FFBs) to the mill and the diesel generators used to power the mill.

7. Potential Management of Palm Oil Mill Effluent (POME)

The management of oil palm processing wastes is of great importance and should be given utmost priority. This will reduce its hazards associated with its processing while generating useful products. The various adverse impacts could be prevented through biotechnological techniques; this include the reuse for the liquid wastes. POME can be used to produce organic acids such as acetic and formic acids, citric acids, polyhydroxyalkonates, solvents such as actetonebutanol, bio-insecticides and antibiotics [26]. Others include bio- hydrogen and biogas production [27-29] through microbial fuel cells technology, composting, vermin compositing [30] and fertilizer production due to its ability to enrich the soil phosphorus, nitrogen and potassium content. When properly treated and packaged, POME can be used by farmers both in rural and urban areas to improve soil fertility thereby increasing the agricultural productivity for global, national and regional food demands [22]. The treatment reduces the initial harsh effects of POME on agricultural lands. The use of pre-treated POME for fertilizer is done through the process of valorisation. Valorisation is any chemical or biotechnological process aimed at recovering value-added products from by-products or wastes [31]. An example of a waste valorisation technology is the vermicompositing process. This is a process for transforming organic waste biologically into compost, which is a nutrient-rich fertilizer and soil conditioner [32]. Vermicompositing involves interactions between earthworms and organic compounds in the waste decomposition process. Earthworms condition and fragment the organic wastes, altering its biological activities for further biochemical decomposition by microorganisms. The potential of vermicompositing to manage a wide variety of biodegradable solid wastes is well documented, such as agro-industrial wastes [32; 33], industrial wastes [34], and municipal wastes [31]. The efficiency of vermicompositing process is characterized by earthworm growth, carbon to nitrogen ratio and available nutrients content. [35] investigated the evolution of enzyme activities such as dehydrogenase, cellulase, amylase, acid phosphatase, urease and protease during the vermicomposting of POME. The vermicomposting of POME gives the opportunity for resource recovery at lesser costs when compared to other treatment technologies. During the organic waste degradation process, microorganisms decompose organic wastes by producing hydrolytic extracellular enzymes that break down the large organic compounds into smaller fragments. The evolution of enzyme activities during the biodegradation of the organic wastes have been found to be dependent on the growth of the microbial communities present which increase with substrate concentrations. Earthworm activities are also crucial in the promotion of enzymatic activities through increase in substrate availability and activation of microbial metabolism. Therefore, earthworm biomass declines, as well as enzymes thereby resulting to stabilization of organic matters (which can now be used as fertilizer) [35]. The positive impact of earthworms on bacterial, fungal and Actinomycetes population has also been reported by [34] during the vermicomposting of cow dung and herbal pharmaceutical wastes. The microbes present in the organic wastes were not killed in the intestinal tract of the earthworms instead they increased in the ejected earthworm casts. [31] also suggested that earthworms are instrumental in increasing microbial colonization which leads to higher microbial activities and population. POME can also be used for microalgae production. Generally, the culturing of microalgae on a large scale requires high nitrogen and other related chemical fertilizers, which makes the process nonenvironmentally friendly. Culturing microalgae in wastewaters has proven to be a very efficient self-purification process for wastewaters [36]. In Malaysia, most palm oil millers favour the culture of microalgae as a tertiary treatment before the POME is released because of the low cost and high impact. The vast majority of the POME nutrients such as nitrates and phosphates that are not removed during the anaerobic digestion is used up in the microalgae pond, playing very important roles in the growth of the microalgae. The cultured microalgae can then be used as feed for livestock [37] Other minerals such as Iron, zinc, phosphorus, magnesium, calcium and potassium that are required for microalgae growth are also present in POME. Thus, the use of POME to grow microalgae for biomass production is a good and low cost option for POME management. Microalgae cultivation in POME also offers an alternative means to the conventional forms of tertiary wastewater treatment because it utilizes the organic compounds present in it to generate the microalgae for biomass production [36]. However, there are several environmental and operational factors that can affect the microalgae growth in order to make the cultivation fruitful. The colloidal, dark and viscous nature of effluent discarded from the palm oil mill are considered in media preparation for culturing the microalgae [37]. According to various researchers, 5% dilution of the raw POME is the best concentration for culture media preparation, due to the natural properties of the POME. This dilution will enhance light penetration into the media for the algal growth. Through these biotechnological advances, the environmental impact associated with oil palm processing wastes can be effectively managed. However, due to the increasing amount of POME generated, disposal has remained a challenge and this has created the need for the rehabilitation of POME polluted soils and water bodies through biotechnological approaches such as phytoremediation, bioremediation and mycoremediation.

7.1. Phytoremediation of POME-contaminated Water Bodies

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. There are several different types of phytoremediation mechanisms. These are; Rhizosphere biodegradation, Phytostabilization, Phytoaccumulation, Phytovolatilization. Phytoremediation is a green technology and an environmentally friendly approach that makes use of green plants and their associated microorganisms in the reduction of pollutants in water and wastewater. It is an emerging, cost-effective, aesthetically pleasing and low cost technology that directly uses green plants to degrade or render environmental contaminants harmless. These contaminants include organic compounds or heavy metals that the plants are able to take up and accumulate in their tissues [38]. The main application of phytoremediation is in lightly contaminated soils and waters, where the material to be treated is at a shallow or medium depth and the area to be treated large. This will make the technique economical and applicable for both planting and harvesting. Phytoremediation of POME-contaminated water bodies has so far involved the use of Constructed Wetlands (CW) also known as Artificial Wetlands. Constructed wetlands is a type of phytoremediation system that utilizes the functions of macrophytes and soil media in the domestic, municipal, agricultural and industrial wastewater treatment [39]. It is a wastewater system constructed to utilize natural processes and remove pollutants from contaminated water and over the years, the system has shown considerable organics and suspended solid removal in wastewater treatment [40]. Constructed wetlands also promote biodiversity because there is an involvement of soil, water and plant in one system. The selection of suitable plant species is the most important factor in constructed wetland systems. There are two types of constructed wetlands according to their hydrology; free water surface flow (FWS) and sub-surface flow (SSF) wetlands. Sub-surface flow systems are further divided into horizontal flow (HF) and vertical flow (VF) constructed wetlands according to their flow directions. A combination of two or more wetland systems also known as hybrid constructed wetlands have been shown to enhance treatment performance. Constructed wetlands forces the wastewater to move upwards through the aerobic zone (upper layer), down to the anoxic zone (middle layer) and finally the anaerobic zone (lower layer) [41]. Phytoremediation in constructed wetlands have been successfully used to remove heavy metals and organic contaminants. The system combines physical, chemical and biological processes to remove pollutants in wastewater. The main mechanisms involve phytoaccumulation, phytodegradation, phytovolatilization, phytofiltration, rhizodegradation and phytodesalination [42]. In the case of heavy metal contaminations, plants take up the contaminants through phytoaccumulation, filtering the metals from water through evatranspiration or phytovolatilization. For organic contaminants, plants take up the contaminants through rhizodegradation (degradation of organic matter in the rhizosphere through the release of enzymes) and phytodegradation (the buildup of organic carbon in the soil). Plants provide substrates such as roots, stems and leaves for microorganisms that can breakdown the pollutants in the POME-contaminated water, or they clean up the water through uptake of the nutrients and trace metals in the wastewater. In constructed wetland systems, substrates play a great role in the contaminant removal because they provide a suitable growth medium for the plants and also allow successful movement of the wastewater. Substrates are able to remove pollutants from the wastewater by ion exchange, adsorption and precipitation. Substrates also provide the surface area for microbial attachment. The selection of substrates depends on their hydraulic permeability and absorption capacity [43]. The absorption capacity influences the loading of the pollutants. Poor hydraulic capacity will result in the clogging of the system, therefore decreasing the effect of the pollutant removal. Clogged substrates are the biggest concern in POME phytoremediation as it can reduce the infiltration of oxygen in the growth media and cause the treatment to fail. The clogging would usually come from the accumulation of solids and oil and grease in the POME. The common substrate in constructed wetland systems may come from natural materials such as gravel, sand, clay, zeolite, limestone or bentonite, or from industrial by-products and agricultural wastes such as rice husk ash, oil palm ash and coal cinder, or artificial products such as activated carbon or compost from agricultural wastes. Gravel is the regularly used substrate in constructed wetland systems because they provide a surface area for the biomass to attach and they also have precipitation capacities. However, a combination of substrates can also be applied. The selection of suitable plant species is essential in the implementation of phytoremediation of POME contaminated water [44]. Suitable plant species for phytoremediation of water polluted by POME should have high uptake ability of organic and inorganic pollutants, fast growth rate, tolerance in polluted water, high adaptability to the climate, and be easily controlled in dispersion [45]. Also the plants should not only accumulate, degrade or volatilize contaminants, but should also grow favourably in different conditions and be easy to harvest. The efficiency of phytoremediation also depends on the specie of the plant and their characteristics, interaction of their root zone and environmental conditions. The key roles during implementation of phytoremediation are the rate of photosynthetic activity and the rate of plant growth during the pollutant removal process [44]. Plant age can also influence the ability of plants to take up the contaminants because young roots will grow faster and have higher nutrient uptake rates than older roots. Aquatic macrophytes are suitable for wastewater like POME because of their fast growth rate and large biomass and also their ability to take up contaminants in the wastewater [46]. The plants that are able to extract and accumulate pollutants are called Hyperaccumulators. The most common aquatic hyperaccumulators include water hyacinth (Eichhornia crassipes), duckweed (Lemna minor), water fern (Azolla filiculoides), water spinach (Ipomoea aquatica), water lettuce (Pistia stratiotes), Cyperus alternifolius, vetiver grass (Chrysopogon zizanioides) and bulrush (Typha latifolia and Scirpus maritimus). Indigenous aquatic species such as Cyperus alternifolius and Scirpus maritimus as emergent plants and Azolla filiculoides and Ipomoea aquatica as floating plants have been investigated for their potential in the removal of POME contaminants in water. Cyperus alternifolius has been found to be the best in phosphorus removal and also in the ability to tolerate unfavourable conditions. It has also been found to be easy to propagate. Most of the research on phytoremediation of POME to date have used floating plants using species such as water hyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes) and Vetiver grass (Chrysopogon zizanioides), either with diluted POME samples or pre-treated samples because the high organic and suspended solids content in the raw POME samples are a major problem. The high colloidal POME may clog the surface of the water. Therefore, pre-treatment is required to reduce the suspended solids, oil and grease before feeding into the treatment systems. The potential of emergent plants in the phytoremediation of water contaminated by POME is gradually being explored and Vetiver grass have shown great pollutant removing effects, therefore there is room for the use of other types of emergent plants in POME treatment, putting considerations on their capability to remove the pollutants, their survival rate and how much they tolerate the effluent water.

7.2. Vetiver Grass in Phytoremediation of POME-contaminated Water Bodies

Vetiver grass (Chrysopogon zizanioides) belongs to the same grass family as maize, sorghum, sugarcane and lemon grass. It is a perennial grass that grows two metres high and three metres deep into the ground. It has a strong dense and vertical root system. It can grow both in the abundance and in the absence of water. The leaves sprout from the bottom of the clumps and each blade is narrow, long and coarse. The leaf is 45-100cm long and 6-12cm wide. Vetiver grass is highly suitable for phytoremediation because it has some extraordinary features. They include a massive and deep root system, tolerance to extreme climatic variations such as prolonged drought, flood, submergence, fire, frost and heat waves. It also tolerates a wide range of soil acidity, alkalinity, salinity, elevated levels of aluminium, manganese and heavy metals such as arsenic, nickel, lead, zinc, mercury, selenium, copper etc. in soils. Application of the vetiver grass in phytoremediation of wastewater is still new. It is a green and environmentally friendly approach for treatment of wastewater as well as a natural recycling method. In the process of treatment, the vetiver grass absorbs essential plant nutrients such as nitrogen and phosphorus, and stores them for other uses. The end product of this system of POME treatment has generated high nutrient material for animal feed, mulch for gardens, roof thatching materials, handcrafts (ropes, hats, mats and baskets), raw material for making pulp and paper, and materials for organic farming [47]. In central China, vetiver grass was used to treat a river polluted with POME with percentage removal of total phosphorus at 93.7% after two weeks and more than 99% after three weeks [42]. According to the same research, the percentage removal of total nitrogen was 58% after two weeks and 71% after four weeks. Phosphorus is a very key element in water eutrophication. Thus, vetiver grass can be used for the rehabilitation of soils and water polluted with POME, which are often extremely acidic, high in heavy metals and high in plant nutrients (that cannot be adequately used by the vegetation due to abnormal pH).

7.3. Bioremediation of POME-polluted Soil

In natural conditions, pollutants in the environment are degraded slowly. This means that a lot of harm will be done to the ecosystem before such an environment recovers. Therefore, there is the need to speed up the rate of recovery of the polluted environment. Bioremediation is any process that uses microorganisms, their enzymes and green plants to return the altered contaminated environment to its original condition [48]. Microorganisms alter and break down the oil into other substances such as carbon dioxide, water and simpler compounds that do not affect the environment. The rate at which the soil recovers will depend on the type of contaminants present and how long they have been there. POME which contains long chain hydrocarbons in addition to unrecovered oil makes it necessary to hasten the period of recovery of the soil. Bioremediation has been used to successfully clean up petroleum hydrocarbon pollutants [49], refinery effluents [50], textile effluents [51] and wastewater [52]. The bioremediation of POME depends enormously on a combination of microbial activities that will use up the organic substances present in the POME as supplements for their own growth and eventually degrade the organic matters into simple by-products such as methane, carbon dioxide, hydrogen sulphide and water. The bioremediation process would require a large pond to hold the POME in place for effective biodegradation, which will regularly take a few days depending on the nature of the microorganisms [53]. A variety of microorganisms have been investigated and found to be capable of degrading oily waste water. Anaerobic and aerobic treatments have been the long-standing biological treatments for POME but the suspended and colloidal components are not usually effectively decomposed because their floating nature affects the microbial cycle. This usually causes failure of the treatment system, giving rise to the need for a more effective treatment mechanism for the liquid wastes. Apart from this, the presence of spores makes the microbial species present in POME to be inactive and highly resistant to the lethal effect of boiling, dry heating and ultra violet radiation, the spores also enable them to survive the high acidity of POME environment [54]. [55], detected the presence of various microorganisms such as Pseudomonas aeruginosa, Aspergillus, Penicillium and Candida in chicken droppings and cow dung with the ability to break down oil and this was found to speed up the bioremediation process in POME-polluted soil.

7.4. The Use of Fungi (Mycoremediation) in the Rehabilitation of POME-polluted Soil

The use of fungi in the bioremediation of POME has drawn the attention of researchers for some time now. This is because most of the previous works in the bioremediation of POME has so far involved only bacteria. Several fungi like Rhizopus, Mucor, Candida rugosa, Geotrichum candidum and Aspergillus have been studied for their abilities to produce lipolytic enzymes [56]. Lipolytic enzymes like lipase facilitate the hydrolysis of lipids, causing their breakdown into fatty acid and alcohol. The oily nature provides a good environment for lipolytic microorganisms to flourish due to the unrecovered oil present in the POME. Aspergillus niger and Aspergillus flavus have been especially distinguished for their ability to endure oily waste water such as POME. The presence of Penicillium, Fusarium and Mucor sp. in POME, have also shown that these fungi are able to survive in hostile environments [23, 56].

According to previous reports, these organisms can degrade oily water effectively. High population of fungi in POME may be attributed to poor sanitation in the traditional and smallholder mills. Biodegradation of POME by fungi has to do with the saprophytic ability of the fungi to grow on and degrade carbon sources in the POME and also reduce factors which could influence the environment. Therefore, the screening and isolation of fungi from POME dump sites provides an alternative and environmentally friendly way of cleaning up the pollutants because the microbes use the organic compounds present in the POME as supplements, thereby degrading them into simpler compounds. [57], in India, investigated selected fungal strains isolated from POME dump sites in the bioremediation of POME. The fungal isolates showed very high lipase producing activities. The reduction efficiency in the removal of oil and grease was highest with Emericella nidulans and lowest in Trichoderma reesei, indicating the potential of these indigenous fungal strains in the removal of oil and grease. The organisms were also found to be effective in the reduction of chemical oxygen demand (COD) and biological oxygen demand (BOD) from the POME. This is very important because high BOD and COD makes POME unsuitable for discharge into the environment, therefore recycling of POME by biological treatment using these organisms will make the POME safe for discharge and/or reuse. The use of other fungi such as Trichoderma viride and yeast such as Saccharomyces cerevisae and Yarrowia lipolytica for the treatment of POME has not been extended to the removal of oil and grease even though they have high potentials in the removal of chemical oxygen demand (COD) from POME [57]. This may be because these microorganisms are not indigenous to POME. The fact that physical or chemical treatment of the raw POME is not required is also an added advantage in the use of indigenous fungi for POME bioremediation.

8. Conclusion

The problem of palm oil mill effluent pollution is unique to okitipupa area and Nigeria at large for a number of reasons. No established control methods are effective because local palm oil mills located in the nooks and crannies of Okitipupa area are unlicensed and without quality control. Palm oil mill effluent treatment technology is non-existent and the prescribed environmental regulations on the allowable pollution loads are unenforceable. Minimization of effluent quantity is not pursued in the traditional palm oil mill and effluent utilization is also not practiced. Sound water quality objectives to reduce the level of pollutants in the effluents are not pursued due to lack of awareness of the severity of the pollution problem being created. This prevalent disregard for the environment in okitipupa area and Nigeria at large with regard to indiscriminate effluent discharge is far from the desired as most industries in developed countries strive for quality and environmental conservation through sustainable development and cleaner technology approaches. Some of the major obstacles to adoption of cleaner solutions in POME management in palm oil mills have been the total absence of sustainable technology and compelling economic arguments. There are reasons why POME has been treated and handled by millers as waste instead of resource. This report has suggested some options for effective POME management. Therefore, POME should be considered a valuable resource, and recovering it for other uses is a much more preferable environmental alternative than the current way it is treated and disposed of. However, as disposal and discharge has remained a challenge, phytoremediation, bioremediation and mycoremediation technologies have proved to be low cost, effective methods of removing the pollutants and making the polluted soil and water once again fit for domestic, agricultural and industrial uses.

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