I.J.S.N., VOL. 1(2), 2010: 127-132 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

Www.scienceandnature.org

MUSHROOM AS A PURIFIER OF CRUDE OIL POLLUTED SOIL

F.N. Emuh
Department of Agronomy Delta State University, Asaba Campus, P.M.B. 95074 Asaba, Nigeria

ABSTRACT
Crude oil serves as the mainstay and the bedrock of economy of Organization of Petroleum Exporting Countries (OPEC) and some other countries exporting crude oil. Crude oil pollution in the soil is a serious environment hazard, with attendant effects on soil, arable lands and in the petroleum industry and also in areas of which they are transported to and utilized. Crude oil blocks pore spaces and reduce/prevent infiltration of water and aeration into the soil, and thus unproductive/barren. These crude oil polluted soil and heavy metals in the polluted soil are broken down and adsorbed by mushroom hypha and mycelium through the secretion of enzymes into environmentally safe levels resulting in carbon (iv) oxide, water and perhaps biomass. Mushroom brings life to polluted barren land, thus, there is a resumption of active and a times luxuriant growth in the environment. Conclusively, mushroom is a purifier of oil contaminated soils.

KEYWORDS: Contaminants, crude oil, mushroom, pollution

INTRODUCTION

Pleurotus tuber regium (Fr.) Sing is a popular white rot fungi, found in the tropical countries of Africa, Asia, Australia and Pacific region of the world (Okhuoya *et al*, 1998; Isikhwemhen *et al*, 1998). It belongs to a heterogeneous group of about 7,000 species in the division Eumycota (fungi) in the kingdom Thallophyta (no embryo) in the plant kingdom. About 10% of the fungi is what is referred to as mushroom (Hawksworth, 2001). Mushroom is popular and generally accepted in Nigeria populace (Nwokolo, 1987; Oso, 1977). Mushroom constitutes a group of living organism incapable of manufacturing its own food, thus devoid of chlorophyll. It requires already made food. Mushroom has cellulose cell wall which is made up of calose, pectose and cellulose in different proportion. It also has false parenchyma cells and has reserve of food (carbohydrates) in the glycogen.

Mushrooms are unicellular, multi-cellular thalloid or filamentous in structure. It reproduces bisexually by spores production and sexually by production gamete.

Types of mushroom

Mushrooms are fungus, which depends on other organism in the ecosystem for their source of food. They possess no chlorophyll and may simply be referred to as saprophytic, parasitic and symbiotic nutritionally.

A. Saprophytic mushroom

This group in nature depend and grow in plant and animal remains and waste such as animal droppings, dead animals, twigs, fallen leaves, dead wood, stumps organic matter, etc (Agrodok, 2005), thus forming the first menu in the food chain or food web. Decomposers are the primary recyclers of soil nutrients in the planet earth which are the products of saprophytic nutrition. This group of mushrooms secretes acids and enzymes which degrade plant and animal remains, breaks down large and insoluble molecules such as carbohydrates, lipids and protein into smaller molecules that can be absorbed (Stamets, 2005).

These dead plants and animals are recycled by mushroom (fungus), to hydrogen, carbon, nitrogen and phosphorus and animals into nutrients for living organisms which utilize them in their ecological niche.

Saprophytes are primary, secondary and tertiary decomposers. Mushroom grows first either slowly or rapidly on dead plants and animals (primary decomposers), sends out mycelium, attaches, attack and decomposes the plant and animal remains (Stamets, 2005)). Secondary and tertiary decomposers rely on the activity and outcome `of the primary and secondary decomposers. Mushroom in conjunction with some bacteria, actinomycetes, yeast and other fungi acts as primary and secondary decomposers, which releases carbon (iv) oxide, heat, water, ammonia as by product of breaking down of plants and animal remain or composting. Tertiary decomposers may thrive longer in the habitat created by primary and secondary decomposers.

B. Parasitic mushroom

Mushroom which depends on other organisms for their existence are referred to as parasitic mushroom. They are either obligate or facultative. Parasitic mushroom such as honey mushroom destroys hectares of forest; and act as agents of habitat restoration. Honey mushroom (*Armilla bulbosa*) covered 37 acres in Michigan forest and was estimated to be 1500 years old (Stamets, 2005). Facultative mushroom are weak parasitic mushroom found in dying host plant. The deaths of these are caused by other organisms, or environmental stress. Oyster mushroom (*Pleurotus oestreatus*) is a good example of facultative parasitic mushroom and commonly found in dying oak and cotton.

C. Symbiotic or mutualistic mushroom

These are mushrooms which live in harmony with other organism and they derive mutual benefit from each other. They are referred to as symbiotic or mutualistic mushroom. The hypha/mycelium releases or delivers salt, water and produces antibodies to protect the host plant from pathogens and other fungi while the mushroom benefits carbohydrates and other nutrients.

Uses of mushroom

Mushroom (*Pleurotus tuber regium*) serves as an important source of food for a variety of animals ranging from insect to large mammalian herbivore such as Deer (Alexopolus *et al*, 1996). It is often used in thickening popular egusi-melon soup and serves as a substitute for egusi-melon (*Citrullus vulgaris*) in South Eastern Nigeria (Nwokolo, 1987; Okhuoya and Isikhwemhen, 1999). It is a good source of vitamins, minerals, low in sugar, lowers blood cholesterol (Kenada and Tokuda, 1966), and a selective medicinal for diabetic (Bano, 1976; Chang and Miles, 1982; Gupta, 1989) as well as contributes to longevity in human being (Flynn.1991).

Mushroom contains quality good protein, low fat content and contains vitamins B1, B2 and C. It also has effects on tumours, blood pressure and viruses. It has ability to degrade lignin and cellulose. Emuh (2009) reported that mushroom inoculated in locally sourced substrates showed promise in bioremediation of crude oil polluted soil.

Sources and influence of oil pollution

In different parts of the world and especially areas where oil exploitation and exploration are carried out, the environment is increasing exposed to changes. These changes result from natural and anthropogenic, could be drastic and have effects on the ecosystem. The sources of oil pollution include:

A. Blow out in oil locations. An accidental discharge at the stage of drilling of crude oil is referred to as blow out. This arises from well heads and well controls which lead to large barrels of crude oil spill into the environment. The environment includes fishing water, swamps, forests and arable lands. Example is the recent blow out in the Gulf of Mexico, USA in 2010.

B. Pipeline leakage. This results from crude oil or refined petroleum products transmission along the pipeline. The pipeline leakages results from rupture along the pipeline, corrosion along the pipelines, malfunctioning of the pipeline valves (Odu, 2000).

C. Sabotage. In Nigeria the Department of petroleum resources statistics showed that more than 60% of oil spilled resulted from sabotage. Saboteurs cut pipelines to steal crude oil or refined premium motor spirit or kerosene as the case may be. Recent cases in Nigeria are the famous Ejigbo of 2005 and Lagos of 2006 where a lot of human lives were lost. This deliberate means leads to oil pollution of the environment (Emuh, 2009).

D. Accidents. This arises from loading and unloading of vessels with discharge of crude oil and refined products into the environment. Tanker collision results from accidental discharge, which discharges petroleum product into the environment such as the Alaska oil spill of 1989.

E. Disposal of Brine and solid waste water. Some oil exploration companies dispose their brine, solid waste improperly that constitutes a significant source of pollution in the environment. Brine and water waste produced together with oil and solid waste consists of tank bottom cleaning and Sludge. Treatment clay and oil skimming discharged into the environment constitute pollutants and health hazard.

F. Air pollution. Of importance is the industrial activity resulting from the operations in the refining of petroleum products and gas glaring. Some of the major pollutants emitted are ammonia, chromium, organic acid and sulfides etc are discharged into the environment and causes contamination of in the environment.

Effects of oil pollution on soil

Blow out at oil locations, pipeline leakages, transportation and sabotage and disposal of brine, solid waste and waste water has adverse effects on bodies of surface water used by drinking household, industrial purposes aquatic life and vast tract of agricultural lands. These constitute environmentally pollutants and render the environment unproductive. Thus the inhabitants are impoverished and deprived. Generally the addition of oil to the soil decreases the water holding capacity of the soil (Schollenberger, 1930).Soil factors affected by oil pollution on land includes soil atmosphere (air in the soil), soil water availability and retention, exchangeable Mn, Fe, total N, available P, No_3 and the sulphur status of the soil (Udo and Oputa, 1984). The oil in the soil renders the soil hydrophobic thus reducing the presence and availability of water in the soil (Ogboghodo *et al*, 2001). Oil pollution in the soil leads to plant nutrients deficiency symptoms' (Schwendinger, 1968), resulting from droughty conditions as well as unavailability of plant growth resources. Oil in the soil affect microbes, oxygen contents of the soil and plant roots (Benka-Coker, 1995).

Crude oil pollution of the soil leads to nutrient availability that are toxic to plants, like manganese (Odu, 2000). Heavy pollution of crude oil in the soil leads to barrenness' of the soil (Amadi *et al*, 1993). However, Udo and Oputa (1984) reported that, the application of 0.25% volume by weight of oil in the soil improved the water holding capacity of the soil. Light pollution of 1% and below, benefits plant growth after 6 months of natural rehabilitation, while at high concentration of 5% and below, farmers can aerate or remediate the soil by hoeing (Odu, 2000). Barren soils resulting from crude oil pollution resumed active growth after years of natural remediation. Stebbling (1970), Amadi *et al* (1993), reported that heavy polluted soils remained barren for many years, resumed active growth and the plants were more luxuriant than the surrounding vegetation of un-polluted soils. Heavy metals are present in the soil and crude oil polluted soils. Odu (2000), reported that heavy metals are immobilized in crude oil contaminated soils, and are responsible for high level of metals after oil spillage or pollution in the affected soils. These metals result in nutrient imbalance, toxicity of the soils and unfavourable growth (if any) of plants in the ecosystem. However, some heavy metals stimulate growth. Vanadium was reported by Guegnov (1961), to stimulate the growth of lettuce.

Effects of oil on seed germination and in plants

Crude oil contaminated soils and polluted soils have effects on germination. It inhibits germination of seeds. This results from insufficient soil aeration and water in the soil leading to loss of viability (Udo and Fayemi, 1975; Rowell, 1977). Oil in the seed coats the seed surface thereby affecting the physiological functions within the seed (McGill and Nyborg, 1975). Oil in the soil injures or kills the seed embryo when they come in contact and enters the seed through the micropyle end of the seed, leading to germination failure (Atunuya, 1987; Ogbemudia, 1996). In germinated plants, oil in the soil results in growth retardation, wilting of the plant, defoliation of leaves, chlorosis resulting from deficiency of the soil (Gudin and Syratt, 1975).

Influence of mushroom in purifying the crude oil and heavy metals in polluted soils

Mushroom inclusive of fungi, are ubiquitous in the soil, and contributes to degradation of oil in the soil. Mushroom grows in hydro-carbon and non- hydro-carbon contaminated soils, secretes enzymes luccase, manganese dependent peroxidase and lignin peroxidase which are used for remediation (Barr and Aust, 1994; Aust *et al*, 2003; Mansur *et al*, 2005). Similarly, Oudot (1990), Stamets (2005), reported that mushroom grows optimally in harmful contaminants. Lau *et al*, (2003), reported the use of mushroom compost to degrade PAH contaminated soil. Mushroom exhibits extra ordinary abilities to transform recalcitrant pollutants and also degrades broad spectrum of structurally diverse toxic environmental pollutants (Lang et al, 195; Reddy 1998). Their extra cellular ability, access them to degrade non-soluable toxic compounds and non-popular compounds (Levin *et al*, 2003). Mushroom also exhibit low specificity of the enzymes produced which enables them degrades recalcitrant, anthropogenic compounds (Mendel *et al*, 1998). Similarly, Cajthaml *et al*, (2002), reported that enzymes of fungi (mushroom) degrade several PAH (anthracene, flouranthrene, phanathrene and pyrene) after 50 days of incubation to less than 1% anthracene, less than 5% of phanathrene and less than 7% of pyrene. In the same, Levin *et al*, 2003 reported that *Trametes trogii* metabolized and degraded 90 - 97% highly concentrated nitrobenzene and anthracaene. Mushroom utilizes different substrates and degrades them during the period of incubation as food (Wang, 1984; Barr and Aust, 1994). Mushroom exhibits different range of growth in remediation of contaminated soil (Nicolotti and Eglis, 1998; Emuh, 2009).The shows the different abilities of mushrooms species and strains to breakdown and adsorb or mineralizes the pollutants. Thomas *et al*, (1999) reported that Oyster mushroom, mineralized and metabolized 97% of oil similar to oil spilled at Exxon Valdez tanker of Alaska, USA after 8 weeks of incubation or mesocosm. Similarly, Bhatt *et al*, (2002), Sasek (2003),reported the use of mushroom to degrade hydrocarbons and its by-product as diesel, gasoline, oil and tar while Kondo *et al* (2003), Gadd (2004) reported the use of mushroom to degrade pesticides and preservatives. Mushrooms are particular proficient in breaking down many recalcitrant compounds, dissembles long chain molecules and harmful toxins to less but simpler chains (Stamets, 2005). Eggen and Sasek (2002) reported that Oyster mushroom compost significantly and effectively reduced toxin in polluted soil.

Effects of mushroom on heavy metals

Mushroom grows, breaks down and absorbs or mineralizes environmental pollutants into non-toxic form (Hamman, 2004). The presence of heavy metals and other harmful contaminants, which mushroom attacks extra-cellularly, digests led to increase in mushroom as opposed to inhibition of mushroom and subsequent removal of toxic metal in the environment by shiitake mushroom (Hitivani and Mecs, 2003; Stamets, 2005). The scavenging of metals from polluted sites by mushroom (Malik, 2004) are due to remediation and purifying abilities of mushrooms. Oudot (1990), Barr and Aust (1994), Stamets (2005), Emuh (2009), reported that mushroom grows in the presence of heavy metals, secretes enzymes and detoxified such contaminants. Similarly, mulligan and Galver-Cloutier (2003) reported that fungi, mushroom inclusive degraded metal contaminated soil. Stamets (2005) reported that mushroom channels heavy metals from land to fruity bodies for removal from the soil/ environment. This is first by denaturing the toxins and finally absorbing such heavy metals.

Mushroom are hyper accumulators of heavy metals and radioactive metals that are toxic to consume and are thus eliminated from the environment. These are bio-concentrated in solid forms in the mushroom (Wasser *et al*, 2003; Sasek, 2003). Similarly, Arica *et al*, (2003) reported, the use of turkey tail mushroom and phoenix oyster mushroom mycelia to eliminate 97% mercury ion from water. Similarly, Humer *et al*, (2004), reported that mushroom degraded copper and chromium in treated woods.

Mushroom hypha/mycelium thickness

Mushroom is a fungus, which feeds by secreting enzymes and digests food externally and absorb the nutrients in net like chain called hypha. The net like chain (hypha) is exposed to stimuli in their ecological niche and act as a conscious intellect and respond to stimuli. Dense and regular branching of hypha endows fungi with potentials to pervade any substrate thoroughly (Hudson, 1986). The higher the mycelium thickness, the higher the rate of mechanical penetration and breaking down of substrate. This culminates at the higher the rate of digestion of substrate through the secretion of extra-cellular enzymes. This shows the potentials of bioremediation capabilities of mushroom (Hudson, 1986; Bouchez *et al*, 1996; Juhaz and Naidu, 2002; Hamman, 2004).

These hypha/mycelium penetrates contaminated soils, thus placing a mat on them, is the process of breaking down and adsorption of toxic products or pollutants. Generally the bonds in hydro-carbon and petroleum products such as PMS and AGO are similar to bonds that hold the plant materials together. The enzymes produced by mushroom which are lignin perioxidase, manganese perioxidase and luccase penetrate, break and digest or mineralizes these hydrocarbon, petroleum products and pesticides to primary non-solid products and are liberated in the forms of water and carbon (iv) oxide (Schliphake *et al*, 2003; Stamets, 2005). These enzymes act singly or collectively in aiding mycelium to break down nature or human made resistant materials (Stamets, 2005). Similarly, Hitivani and Mecs (2003), reported that the mycelium of shiitake mushroom exposed to heavy metals of cadmium, copper, lead, mercury and zinc increased the production of enzymes luccase, decolourized them and subsequently absorbed the heavy metals.

SUMMARY AND CONCLUSION

In this paper, an attempt has been made to highlight mushroom and its type based on nutrition and its utility. Against the background of crude oil spillage/pollution which comes in the form of blowout, pipeline leakages, disposal of brine, solid waste, waste water and their effects on soil, seed germination and in plants, mushroom has a positive effect on purifying polluted/ contaminated soil and heavy metals in the soil.

It is pertinent to note that crude oil pollution/spillage is a major cause of environmental degradation especially in Niger-Delta area of Nigeria. This has impaired fishing in waters, soil fertility and reduction in arable lands, of which the host communities are now vociferous about their own plight (Emuh, 2009).

Apart from the economic uses of mushroom (food and medical purposes), it plays an important but a unique role in the purification and rehabilitation of crude oil polluted soils. Introduction of crude oil brings lifelessness into the soil, while the introduction of mushroom into polluted/contaminated soil brings synergy of life into the soil. The mushroom serves as an impetus for other micro-organism in the rehabilitation of oil polluted soils. Thus, the introduction of mushroom is a launching pad for other micro-organism in fostering microbial communities of which the population dynamics shift in response, of life into the soil. This papers ends by the importance of mushroom to bring life and rehabilitation of crude oil polluted soils.

REFERENCES

Alexopulus, C.J; Mims, C.W. and Bushwell, M. (1996). Introductory Mycology. Third Edition. John Wiley and Sons Inc. Publishers. 869pp.

Amadi, A.A.; Dickson, A. And Moate, G.O.(1993). Remediation of oil polluted oils Effects of organic supplements on the performance of maize (*Zea mays* L.). *Water, Air and Soil pollute* 66:59-76.

Aust, S.D.; Swaner, P.R. and Stahl, J.D.(2003). Detoxification and metabolism by white rot fungi. Pesticide decontamination and detoxification.

J.J.P.C Zhu; S.D. Aust and D.A.T. Lemly Gan (Editors.). Washington, D.C., Oxford University press, Pp 3-14.

Atunuya, E.I. (1987). Effect of waste engine oil on physical and chemical properties of the soil. A case of waste oil contaminated Delta soils in Bendel State. *J. Appli. Sci* 5:155-176.

Arica, M.Y.; Arpa, C.; Kaya, B.; Bektas, S.; Denizilli, A. And Gene, O. (2003).Comparative biosorption of mercuric ion from aquatic systems by immobilized live and heat-inactivated *Trametes versicolor* and *Pleurotus sajo-caju*. *Bioresource Technology* 89(2):145-154.

Bano, Z. (1976). The nutritive value of mushroom. *In*: Proceedings of first symposium on survey and cultivation of edible mushroom in India. *Reg. Lab. Sringer* 2: 148-150.

Barr, D.P. and Aust, S.D.(1994). Mechanisms of white fungi use to degrade pollution. *Crit. Rev. Environ. Sci. Technol.* 28 (2): 79 – 87.

Benka-Coker, M.O. and Ekundayo, J.A. F. (1995). The effect on an oil spill on some physico-chemical properties of a spill site in the Niger-Delta area of Nigeria. *Environ. Monitor. Assess* 36:93-104.

Bhatt, M.; Cajthaml, T. and Sasek, V. (2002). Mycoremediation of PAH- contaminated soil.47 (43);255 – 258.

Bouchez, M. Blanchet, D. Haeseler, F. and Vandec, J.P. (1996). Les hydrocarbures aromatique poly cycliques dans I environment. *Revue de I' institute cia' s du petrole* 51: 797 – 828.

Chang, S.T. and Miles, P.G. (1982). Introduction to mushroom science. *In*: *The tropical mushroom*. Biological nature and cultivation methods.

Chang, S.T. and Quimo, T.H. (eds.). The Chinese University press, Hong Kong, China.

Emuh, F.N. (2009). Bioremediation potentials of white rot fungi in the reclamation of crude oil polluted soil. Ph.D. Thesis submitted to Graduate School, Delta State University, Abraka, Nigeria, 180pp.

Eggen, T. and Sasek, V.(2002). Use of edible and medicinal oyster mushroom [(*Pleurotus oestreatus* Jacq.Fr.) Kimm] spent compost in remediation of chemically polluted soil. *International Journal of Medical mushroom* 4:225-261.

Flynn, V.T.(1991). Is the Shiitake mushroom an Aphrodisiac and a cause of longevity?. In: Science of cultivation of edible mushroom. M.J. Maher(ed.). Balkema, Rotterdam. The Netherlands. Pp 345-361.

Gadd, G.M.(2004). Mycotransformation of organic and inorganic substrates. *Mycologist* 18(2):60-70.

Guegnov, V.M.(1961). Use of new kind of fertilizer of petroleum origin. U.S. Dept. of commerce. *Office of Technical service.* 64pp.

Gupta, V.P.(1989). Mushroom yield. A rich food – a profitable commercial crop. Kisan world, December 1989. Pp37.

Hamman, S. (2004). Bioremediation capability of white rot fungi. B- 1570, Review article, spring 2004.

Hitivani, N. and Mecs, L. (2003). Effects of certain heavy metals, on the growth, dye decolouration and enzyme activity of *Lentinula edodes Ectoxicology and Environmental safety* 55(2):199-203.

Hudson, H.J.(1986).Fungal Biology. Edward Arnold publisher Ltd. 1st Edition. 298pp.

Humer, M.; Bokan, M; Amartey, S.A.; Sentijure, M. Kalan, P. and Pohleven, F. (2004). Fungal bioremediation of copper, chromium and boron treated wood as studied by electron pragmatic resonance. *International Biodeterioration and Biodegradation* 53:25-32.

Isikhuemhen, O.S.; James, T.Y.; Monoalvo, J.; Nerud, M. and Vilgalys, R.R. (1998). Breeding behaviour, progeny and cultivation biology of *Pleurotus tuber regium.* Sixth International mycological congress held in August 23rd - 28th, 1998 in Jerusalem, Isreal.

Juhasz, A.L. and Naidu, R.(2002). Bioremediation of high molecular weight polycyclic aromatic hydrocarbon: a review of microbial degradation of Benzo[(a)]pyrene. *International Biodeterioration and Biodegradation* 45:57-88.

Kondo, R.; Sasek, K. And Wakao, K. (2003).White rot fungi and methods of decomposing dioxins using them. Bioremediation technologie. Inc. (JP), U.S. Patent 6,653, 119, November 25, 2003.

Lang, F.; Kleeberg, I.; Martens, R. and Zadrazil, F. (1995).Interaction of white rot fungi and micro organisms leading to biodegradation of soil pollutants. In: Proceedings of the 5th International conference on contaminated soil held on 30th Oct. to 5th Nov., 195 in Manstrict, The Netherlands. Pp 1277- 1278.

Lau, k. L.; Tsang, Y.Y. and Chiu, S.W.(2003). Use of spent mushroom compost to bioremediate PAH contaminated samples. *Chemosphere* 52 (9)1539 -1548.

Levin, L,; Viale, A. and Forchiassin, A.(2003). Degradation of organic pollutants by white rot basidomycetes, *Trametes trogii*. *International Biodeterioration and Biodegradation* 52:1-5.

Malik, A. (2004). Metal biodegradation through growing cells. *Environmental International* 30 (2) 1261- 1278.

Mandal, T.K.; Balden, P.; Gabriel, J.; Nerud, F. and Zadrazil, F. (1998). Effects of mercury on the growth of wood rottening basidomycetes.

Mansur, M.M.; Arias, E.; Copa-Patino, J.H.; Flardh, M. and Gonzalez, A.E.(2003).The white rot fungi *Pleurotus oestreatus* secretes luccase isoezyzmes with different specificities. *Mycologia* 95 (6):1013- 1020.

McGill, W.B. and Nyborg, M.P. (1975). Reclamation of wet forested soils subjected to oil spills report on contract No. Osp 3-8073 for Northern forest research centre, Edmonton. Dip Publication No. G75-1, University of Alberta, Canada.

Moder, M.; Cajthaml, T.; Schrader, S. and Sasek, V. (2002). Solid phase micro extraction (SMPE) used for direct fruit body sampling in comparism to describe PAH partitioning in mushroom cultures. *Fresnius Environmental Bulletin* 16 (5):284-288.

Mulligan, C.N. and Galver- Cloutier, R. (2003). Bioremediation of metal contaminants. *Environmental monitoring assessment* 84 (1-2): 45-60.

Nicolotti, G. And Eglis, S. (1988). Soil contamination by crude oil: Impact on the mycorrhisphere and on the revegetational potential of forest trees. *Environmental pollution* 99 (1):37-43.

Nwokolo, E. (1987). Composition of nutrients in the sclerotia of mushroom (*Pleurotus tuber regium*) . *Plant food for human Nutrition* 37:133-139.

Odu, C.T.I. (1981). Nitrogen accretions in oil polluted soils. In: Current perspectives in nitrogen fixation. Australian Academy of Science, Camberra, Australia. 520pp.

Odu, C.T.I. (2000).Rehabilitation of soils after oil spills. In: Agronomy in Nigeria. Published by Agronomy Department, University of Ibadan, Nigeria. Pp 223-227.

Ogbemudia, F.O.(1996). Effects of Ogini crude oil on the seed germination of *Glycine max, Vigna unguiculata, pennisetum tyhpoides and Sorghum bicolour*. Unpublished B.Sc. project submitted to Department of Botany, University of Benin, Benin City, Nigeria. 18pp.

Ogboghodo, I.A.; Irufa, E.K.; Osemwota, I.O. and Chokor, J.U.(2001).An assessment of the of the effect of crude oil pollution on soil properties, germination and growth of maize (*Zea mays*) with crude types, Forcados and Escarovos light. In: *Proceedings of the 27th Annual conference of Soil society of Nigeria,* held in Calabar between 5th - 9th November, 2001. Pp 299-308.

Okhuoya, J.A. and Isikhuemhen, O.S.(1999). Mushroom cultivation: on the Nigerian experience. In: *Proceedings of the third (3rd) International conference on mushroom biology and mushroom products and Acims of the 26th*

National mushroom industry conference held in Sidney, Australia between 12th - 16th October, 1999.

Okhuoya, J.A.; Isikhuemhen, O.S. and Evue, G.A.(1998). *Pleurotus tuber regium* (Fr.) Sing: Sclerotia and sporophore yield during cultivation on saw dust of different woody plants. *International Journal of mushroom Sciences* 2 (2):41 – 46.

Oso, B.A.(1977). *Pleurotus tuber regium* for Nigerian. *Mycologia* 69:271-279.

Oudot, J.(1999). Selective migration of low and medium molecular weight hydrocarbon in petroleum contaminated terrestrial environment. *Oil and chemical pollution* 6:251-261.

Rowell, M.J.(1977). The effects of crude oil on soil: a review of literature. In : Trogod, J.A. (Ed.) . The remediation of agricultural soils after spill. Part one. Edmonton publishers, Canada. Pp 1-3.

Sasek, V. (2003).Why Myco-remediation has not come into practice. In: Problems and solution. V. Sasek,; J.A. Glaser and P. Baveye (Ed.).Dordrecht. The Netherlands. Kluwer Academic publishers. 247- 266.

Schliephake, K.; Baker, W.I. and longergan, G.T.(2003). Decolorization of industrial wastes and degradation of dye water. In: *Fungal biotechnology in Agricultural, food and Environmental applications*.

Arora, D. P.; Bridge, P.D. and D. Bhatnagar (Eds.). New York. Marcel Dekker publisher.

Schollenberger, C.J.(1930). Reclamation of soil contaminated with crude oil. *Soil Science*29:260-266.

Schwendinger, R.B.(1968). Reclamation of soil contaminated with oil. *Journal of Petroleum Institute* 58:182-197.

Stamets, P. (2005).Mycelium Running. How mushroom can help save the world Ten speed Press, Berkeley/Toronto. 1st Edition. 339pp.

Stebbing, R.E. (1970). Recovery of salt marsh in Brittany, sixteen months after heavy pollution of oil. *Environmental pollution* 1:163-167.

Thomas, S.A.; Becker, P.; Pinza, M.R.; Word, J.Q. and Stamets, P.O. (1999) Mycoremediation. A method of test to pilot scale. In: *Phytoremediation and innovative strategies for specialized remedial applications*. A. lesson and Allenman, B.C. (eds.). Columbus, OHIO, Bettelle press.

Udo, E.J. and Fayemi, A.A.A.(1975). The effects of oil pollution on soil, germination, growth and nutrient uptake of Corn. *Journal of Environmental Quality* 4 (4): 537-540.

Udo, E.J. and Oputa, C.O. (1984). Some studies on the effect of crude oil pollution on soil and plant growth. *Journal of Biology and Applied Chemistry* 29:3-14.

Wang, C.W.(1984). Cellolytic enzymes of *Volvarialla volvaceae*.In: *Tropical mushroom: Biological nature and cultivation methods.*

Chang, S.T.; Quimi, T.H.(Eds.). Hong Kong: The Chinese University press. 493pp.

Wasser, S,; Berreck, M. and Haselwandler, K. (2003). Radiocesium contaminants of wild growing mushroom in Ukraine. *International Journal of Medical Mushrooms* 5:61-86.