Organic Compost as Catalyst or Mediator for Speedy and Cost Effective Bioremediation

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Abstract:

Bioremediation (the use of living organism, part or their products) has been reported to be an environmental friendly and cheap remediation method which is applicable in large and small scale but, the major problem facing this mechanism is the establishment of a particular biological entity in a heavily polluted soil. The soil supplementation/amendment during bioremediation was suggested to alleviate such difficulty, compost supplements role in bioremediation is majorly 'biostimulatory' a term used to explain the addition of nutrients for effective and active biological activities. Compost supplements have been a commonly used practice in agricultural practices for ages for enhancement of soil fertility and productivity but it is now known that this practice also enriches the microbial population in soil which promotes soil remediation as they act upon the organic waste to release its nutrients. This practice as well have been reported to enhance biological degradation, mineralization or extraction of a pollutant for clean-up/remediation of a polluted soil. Today, bioremediation mechanism which combines action of two or more organisms have been gaining more interests, application of soil amendments in such setting may serve as fuel to run the system feeding both entities the nutrients, creates environment conducive for their survival and enhances tolerance as well as responses. In this chapter, we gave accounts of biostimulatory and bioaugmentation mechanisms brought about by soil amendment using composts, we considered different examples and their impacts on soil bioremediation mechanisms.

Keywords: Polluted soil; bioremediation; soil amendment; fertility; biostimulatory.

1.0 Introduction

Compost supplements have been found to act by supplying nutrient and adjusting the soil conditions to favor the growth of biodegraders present or applied to remediate a polluted soil. The action of compost supplements are classified as '*biostimulation*' or '*bioaugmentation*' and these enables them play good roles in bioremediation of polluted soils. Most polluted soils have low intrinsic metabolic potential and need some biostimulation (nutrient supplementation) and/or bioaugmentation (increase in soil's microbial populations) for faster remediation. In addition, compost supplements have been found particularly beneficial to plant growth and microbial productivity when applied to acidic and nutrient-poor soils (Asemoloye et al., 2017a&b) this also promotes the rhizospheric co-action of plant and soil microorganism for better growth establishment and hence soil remediation. Compost amendments have also been shown to enhance the soil health by adjusting the soil's pH, saline and calcareous solutions. Composts supply micronutrients particularly bio solids. In the last few years the most common organic soil supplements used for the remediation of pollutants is compost or activated sludge, manure and so on.

Concerns over a large number of hazardous chemicals entering into the natural ecosystem every day necessitate development of achievable and effective remediation technology either in large or small scale medium, there is serious need for a mechanism that is environment friendly and cost effective. Bioremediation which the use of living organism, part or product(s) for remediation of polluted environment have been reported to fulfil this need and currently gaining interests among the soil scientists (Asemoloye et al., 2017a). This bioremediation technology involves different mechanisms depending on the type of organism(s) involved examples are the Phytoremediation (the use of plant), Zooremediation (the use of animals), Microremediation (The use of bacteria), Mycoremediation (The use of fungi), Phycoremediation (the use of algae), etc. However, the use of these organisms for soil remediation relies on the fact that they are to be exposed to different pollutants to be remediated. Recently, it has been revealed that several practices can enhance bioremediation technology.

The effectiveness of bioremediation technology relies on the capacity of the particular bioremediating organism to positively respond, survive, and degrade/mineralize the pollutants, by this the organism must be able to survive to toxic properties of the polluted environment. This results in major limitation as many potential bioremediating organisms might not be able to survive a heavily polluted sites especially when the organism or group of organisms are to be newly introduced into the polluted environment. Although, it might have been proven in the laboratory experiment that a particular organism can biodegrade or mineralize a pollutant, it might not function as such in field trials because the environmental condition on site cannot be controlled like that of the laboratory. One of the major practice is the use of supplements/additive to enhance the sustainability of bioremediation (Lisa et al., 1997). Soil amendments/supplements are substances that can be added to enhance soil profile, fertility, and its biological activities. They can be categorized into three different classes viz; Organic and inorganic supplements, Surfactants or solubilizer and Carbon sources (Lisa et al., 1997). There is therefore need to support bioremediation with some practices that would help the biological entities to survive the polluted environment and hence fulfils the requirement of remediating the environment. This review therefore advocates the concept of soil amendment for enhanced bioremediation using compost supplements, some mechanistic actions of soil amendments such as Bioaugmentation, Biostimulation, Biosufactants and Enzymes are discussed with potential innovative and developmental impacts of soil supplements to bioremediation mechanisms.

2.0 Concept of compost technology

2.1 Production and importance of composts

Composting is a process by which an organic materials such as plant or wood materials are oxidized to decompose and transform into carbon dioxide (CO_2), Amonia (NH_3), water (H_2O) and stabilized final product with reduced toxicity. Composting can be employed as a dependable option for waste treatment, and it has added advantage as it subsequently provides stabilized products (compost) which can be used to boost/enhance the soil fertility (Qian et al., 2014). Production of compost is itemized in Fig 1, composts are usually made from organic waste materials such as wood straw, decaying wood, some agricultural wastes, garden clippings, plant or animal materials etc., these are commonly disposed as waste which may create environmental pollution if not properly managed. Composting therefore can be seen as a waste to wealth approach as it involves the decomposition of organic matters useful product (compost) through microbial activities. Composts are formed naturally through the degradative actions of macro or microorganisms which are available in contaminant matrix, but today composting has been modernized through the use of technology usually developed for recycling mineral nutrients that could be utilized for agricultural purposes and this is gaining public acceptance today as the application of compost on soils is environment friendly with no residual effects (Wang et al., 2015; Proietti et al., 2016). According to Das et al. (2011), a good compost is expected to be free of therefor in many cases thermal heating has been introduced to composting process to destroy any possible pathogen (Kulikowska et al., 2015; Kulikowska, 2016). So today composting is done mainly through decomposition and humification of organic matter which we can call the formation of humic acid and humic substances (Pandey et al., 2016).

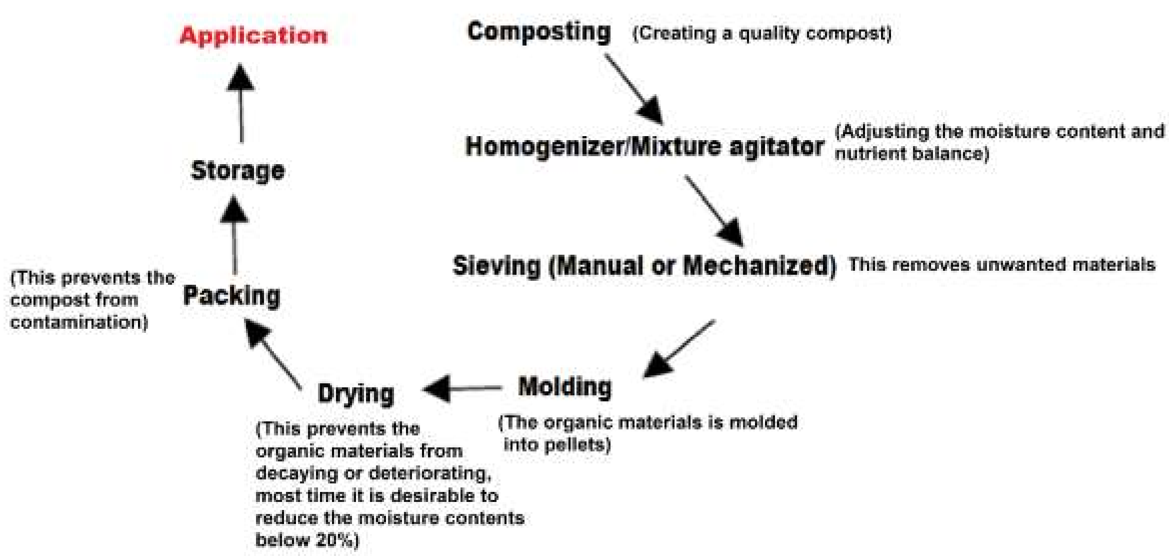

Fig. 1: Compost production

Composts usually enhance the soil's physicochemical parameters such as moisture content, temperature, particle size, aeration, pH, and electrical conductivity when applied to soils (Giglotti et al., 2005; Li et al., 2013; Juarez et al., 2015; Wang et el., 2015). It has also been well established that compost used as soil supplements usually improves the soil nutrients scientifically called 'Biostimulation', this also enhances the soil's microbial population termed as 'Bioaugmentation'. These two mechanisms usually redesign the soil characteristics for sufficient aeration and optimal environmental conditions which favors 'Bioremediation', by this compost plays significant roles in bioremediation process as a stabilizer (Kulikowska et al., 2015).

3.0. Organic compost as soil amendments for enhanced bioremediation

Composting can be done on a large or small scale, with the management requirements and intensity increasing dramatically as system size increases. Bioremediation on the other hand can be described as the use of living organisms (mostly plants and microorganisms) to destroy or immobilize waste materials (Jonathan et al., 2012). This is a process of detoxifying targets the harmful chemicals by mineralization, transformation, or alteration (Shannon and Unterman, 1993). Bioremediation is a process which uses microorganisms and their products to remove contaminants from the soil (USEPA, 2000&2012; Jonathan et al., 2016a). In particular, native soil microorganisms play a key role in soil bioremediation as biogeochemical agents to transform complex organic compounds into simple inorganic compounds or into their constituent elements. This process is termed mineralization. The microorganisms are adsorbed to soil particles by the mechanism of ionic exchange (Leahy and Cowell, 1990).

The use of composts in bioremediation of has been reported far back in the 1980s when it was used in the remediation of chlorophenol, mineral oil and PAH within tar oil or creosote contaminations (Valo and Salkinoja-Salonen, 1986; Häggblom and Valo, 1998; Antizar-Ladislao et al., 2004). Addition of bio-solids to metal contaminated sites increased the leaching process, compost amendments as also been found to ease the transport of colloidal particles around the soils (Kästner and Miltner, 2016). Higher degradation rate was observed after adding some composts to polluted soil with PAH by Loick et al. (2012) and Semple et al. (2001). This is very important in bioremediation of PAH polluted soil due to low oxygen demand and low bio-availability of PAHs making it not easily degradable. Successful application of compost in bioremediation has been reported by many scientists and this should be advocated. However, there is widespread confusion regarding the terms 'composting' and 'compost application', sometimes the term composting is considered to describe the incubation of contaminated soil with any (waste-) biomaterials including bacteria (otherwise known as bioaugmentation. The term is also used for the simple addition of biogenic bulking agents (such as bark chips, straw or garden clippings) or smart mixtures of them in order to provide sufficient aeration and to adjust matrix conditions such as water content, nutrients and pH (Brian et al., 2002; Bento et al., 2004; Abdulsalam and Omale, 2009; Chen et al., 2015). Whether a bioremediation measure, e.g. composting or compost addition, is regarded successful or not, it often depends on the defined target values; due to very low targets in several European countries, it is often difficult to meet the threshold values for unrestricted reuse of the soil (Antizar-Ladislao et al., 2006).

The residual contamination levels are mostly acceptable for reuse of the soil material in landscape building and management but not for settling, gardening, and farming purposes. There is also a severe disadvantage associated with the addition of organic materials to contaminated soils: due to the high load of organic materials, they can no longer be used as building ground. In addition, mixing large amounts of organic additives to contaminated soil requires excavation of the soil and ex situ treatment resulting in higher effort and costs in comparison to in situ treatments. This is certainly justified for contaminated soils in urban areas, where the economic pressure for reuse of the sites is high enough to make even cost-intensive remediation measures economically feasible. It is thus sometimes more reasonable to treat the contaminated soil by soil-washing methods (Kumpiene et al., 2008; Trellu et al., 2016) in order to separate the less contaminated mineral fraction from the more contaminated organic materials and to treat the latter fraction separately, e.g. by compost treatments thereby substantially reducing the volume of material to be treated. Examples of composts are given below:

i. Plant waste composts

Modern remediation approaches increasingly focus on in situ environmentally friendly techniques, such as assisted natural attenuation and Phytostabilization (Plant waste composts) often primed by the addition of soil amendments (Mench et al., 2010). Of the numerous amendments used for in situ stabilization of contaminants, organic materials such as biosolids, manures and composts, rich in organic matter, have proved successful at reducing the mobility of contaminants in multi-metal polluted soils (Clemente et al., 2006; Hartley et al., 2008). Plant waste composts has increased dramatically resulting in nationwide establishment of composting facilities making quality PWC widely available. Many frequently encountered inorganic contaminants such as Cu, Pb, Zn and Cd show varying degrees of affinity for organic matter (Brown et al., 2003; Dickinson et al., 2009), encouraging the study of experimental application of PWC to contaminated soils. Furthermore, increasing interest in integrating remediation and the provision of ecosystem services, such as carbon sequestration in soils, has provided an attractive land management option for contaminated sites (Vidali, 2001) using materials rich in carbon.

ii. Animal droppings

Bioremediation is an option that offers the possibilities to destroy or renders harmless various contaminants using natural biological activity (Lee et al., 2015). Bioremediation involves three principal approaches namely, natural attenuation (reliance on natural biodegradation activities and rates), which is sometimes called intrinsic bioremediation; biostimulation (stimulation of natural activities by environmental modifications such as fertilizer addition to increase rates of biodegradation); and bioaugumentation (addition of exogenous microorganisms to the hydrocarbon-impacted ecosystem to supplement the existing microbial population). Biostimulation is a method of biodegradation that is geared towards enhancing and speeding the process (Lee et al., 2010). Most laboratory studies have shown that the addition of limiting nutrients like nitrogen and phosphorous has enhanced the rate of oil biodegradation (Ijah and Antai, 2000; Chikere, 2012). Therefore, poultry droppings , cow dung and goat manure due to their high nitrogen content can be used to enhance biodegradation in soil (Agarry et al., 2010; Orji et al., 2012), increase soil fertility and at the same time solve the problem of waste management with regards to the animal waste.

iii. Agricultural wastes

Disposal and environmental friendly management of these wastes has become a global priority. Therefore, much attention has been paid in recent years to develop low-input and efficient technologies to convert such nutrient rich organic wastes into value-added products for sustainable land practices. However these can be managed through vermicomposting. A vermicomposting is nothing but a joint action between the earth warms and microorganism. Microorganism helps in degradation of organic matter and earth warm drives the process and conditioning to the substrate and altering the biological activity Vidali, M. (2001) and Lee (2015). This huge quantity of waste can be converted to boifertilizer by vermicomposting. Vermicomposting often results in mass reduction, shorter time for processing, and high levels of humus with reduced phytotoxicity in ready material (Kwang and Lee, 2004). A variety of combinations of crop residues are used in vermicomposting trials to obtain a value-added product, i.e., vermicomposting, at the end, the higher concentrations of plant nutrients in end products indicate a potential for using agriculture wastes in sustainable crop production (Korkama-Rajala et al., 2008; Orji et al., 2012).

iv. Spent mushroom compost (SMC)

There are several reports on types of composts, examples are spent mushroom compost and food waste compost (Fig. 2 and 3). However, their overall positive impacts on the physical properties of soil, growth and yield of plants. Annabi et al. (2007) showed an improvement in the aggregate stability of a silt loam after application of composted urban organic wastes. This improvement is a result of enhanced soil microbial activity and the inward diffusion of binding organic substances within the aggregates as stated by Forge et al. (2003). Leroy et al. (2008) also observed that although the separate application of vegetable, fruit and garden compost at an optimal rate of 22.5 t ⁄ ha ⁄ yr and cattle slurry on a sandy loam results in significant increase in aggregate stability, compost combinations give the highest stability. Aggelides and Londra (2000) report that when composted town waste and sewage sludge were added to loamy and clay soils at rates ranging from 75m3 ⁄ ha to 300 m3 ⁄ ha, such improvements were proportional to the rate of applied compost. Courtney and Mullen (2008) investigated the influence of 0, 25, 50 and 100 t/ha spent mushroom compost (SMC), forced aeration compost (FAC) and inorganic fertilizer on soil properties and yield of barley (Hordeum vulgare). The SMC was found to produce the strongest correlations between soil nutrient levels and plant yield. Also, the report of Hassanein and Abul-Soud (2010) reported the effect of rice straw, cucumber canopy and maize stalk compost on growth and yield of three maize hybrids and the result indicated that cucumber canopy compost had the highest values of N, P and K % content and lowest maturity period and C/N ratio while maize stalk compost the lowest N, P and K % content, highest maturity period and C/N ratio.

Fig. 2: Mushroom compost

Fig. 3: Food waste compost

4.0 Innovation and Developmental Impacts of compost supplements in bioremediation mechanisms

There has been reports about the increase of innovative applications of composting and manure compost to the bioremediation of contaminated soils with PAHs, pesticides, petroleum and other pollutants by provision of nutrients, large numbers of active microorganisms and degrading matrix (Scelza et al., 2008; Chen et al., 2015). To enhance the bioremediation process different organic supplements such as poultry manure, bio solids and fertilizer products are used. All these supplements used to increase the soil fertility, provide nutrients such as nitrogen and phosphorous and also increase efficiency of microorganism to remediate the pollutants (Lindahl et al., 2007). Several studies has been conducted to evaluate the process of bioremediation by adding organic supplements. Abioye et al. (2012) studied the organic supplements increased the degradation of diesel and motor oil in soil. Different bio wastes such as potato skin, leaf and soy cake has applied to soil. According to them rate significantly rate of degradation increased as compared to control (85-10%). Another organic supplement cow dung used to remediate the crude oil (mangrove swamps) in Nigeria (Orji et al., 2012) and there was significantly decrease the oil 62% as in control (without cow dung) the rate of degradation recorded was 20%. Other reported organic supplements are presented in Table 1

Table 1: Organic matter supplements and role in bioremediation of pollutants

Pollutants	Organic matter	Percentage degradation	References
Marine sediments contaminated with petroleum oil	Poultry waste	95-98% in 56days	Chikere, 2012
Mangrove swamps contaminated with hydrocarbons	Cow dung/ cow excreted waste	63% in 70 days	Orji et al., 2012
Lubricating and petroleum oil	Brewery products, banana skin, and mushrooms	79%, 92% and 5% in approximately 3 months	Abioye et al., 2012
Crude and petrolieum oil, hydrocarbons	Woody chips and activated sludge	100% in 3 months	Atagana, 2008
Diesel oil	Woody materials including tea leaves, and potato skin	25-82% in 3 months approx.	Dadrasnia, 2013
Crude oil / petroleum hydrocarbons	Fruits including oil palm and sugarcane waste	97-100% in 20days	Hamzah et al., 2014
Cr (VI)	Poultry, fish, pig, mushroom manure	50% reduction	Bolan et al., 2003
Cd	Poultry manure	49-67% adsorption Increases	Chen et al., 2010

One of the potential approaches to bioremediation is bioaugmentation by addition of compound-degrading microbes or organic amendments containing active microorganisms such as compost. In recent time, there have been investigations on the roles of compost or farmyard manure addition as well as composting with various organic supplements in soil bioremediation. Steffen et al. (2007) investigated the bioremediation of PAH polluted soil using the compost (cow dung, water hyacinth and sawdust) and plant technology. However, Bastida et al. (2016) also showed an original insight into the impacts of petroleum contamination and the bioremediation potential of compost amendment, as an enhancer of the microbial activity in semiarid soils. Chen et al.(2016) investigated the effect of a simulated compost-amended landfilled reactor under hypoxic conditions on polychlorinated-p-dioxins/dibenzofurans contaminated soil using. Baldantoni et al. (2017) also established the role of compost amendment on Anthracene and benzo(a)pyrene degradation in soil. The impact of spent mushroom compost (SMC) on phytoremediation of black-oil hydrocarbon polluted soil was also assessed by Asemoloye at al. (2017b). The compost technology mechanism has been shown to include the following mechanisms:

i. Bio augmentation

Bio augmentation involves the addition of microorganism or GMO (genetically modified microorganism) to clean the contaminated sites. This technique mostly used to activate the process of remediation. The process of bio augmentation is not mostly successful in situ bioremediation. Because the environmental condition are difficult to control to maintain the growth or activeness of auxiliary microorganisms. This process is mostly used to treat the municipal waste by activating the sludge bioreactor (Adams et al., 2015).

ii. Bio stimulation

Bioremediation is complex process depends on environmental factors, concentration of microorganisms and nature of contaminants. So bio stimulation is defined as "introduction of nutrients and oxygen in contaminated sites to enhance the activity and growth of microorganism (Fan et al., 2014). This process enhanced the biological activity to degrade the pollutants from natural system. Microbial strains needs carbon nitrogen, phosphorous, sulphur oxygen for the building macromolecules to reproduce and growth. These nutrients can be provided by adding different fertilizer. In addition to this manure, straw and wood materials also used a source of these nutrients.

iii. Bio surfactants

It is defined as the biological isolated and non-isolated compounds has capability to reduce the interfacial tension. Many microorganism such as bacteria and fungi having ability to produce the surfactants extracellularly by the cell membrane. It can be classified into two group's i.e biosurfactants (low molecular weight) and biomulsans (higher molecular weight). Biosurfactnats includes lipopeptide, glycolipids, phospholipids and proteins (Ann et al., 2008).

5.0. Application of compost in bioremediation of selected pollutants

5.1 Petroleum hydrocarbons

One of the most prominent anthropogenic pollution problems in the petroleum hydrocarbon pollution. Composting of petroleum polluted soils is however a special bioremediation technique characterized by the addition of organic matter to the soil. Composting is a favorable technology for soil remediation due to its relatively simple operation and design and low capital and operating costs. Composts as soil amendments stimulate biodegradation as it acts as substrate and nutrient source and at the same time improving the soil structure and its water holding (Van Gestel et al., 2003). Adequate population of microbial population is required for degrading petroleum pollutants rather than single organism capacity (Adebusoye et al., 2007), compost enhances bacteria and fungi growth as they first decompose organic matter and absorb its nutrients to enhance their metabolic process of hydrocarbon mineralization. This have been reported wood shavings and pig slurry composts (Marin et al., 2006) feedstock which includes plant leaves, wood shavings, and municipal biosolids, (Salimen et al., 2004; Wang et al., 2008) reported the use of vegetable, fruit, and garden bio-waste compose to degrade crude oil hydrocarbon, while (Hwang et al., 2006) reported the use of compost to remediate sewage sludge.

5.2. Petroleum and related products

Lee et al. (2008) amended heavy mineral oil contaminated soils with mineral nutrient, sawdust, hay and compost, this resulted in decontamination percentages of 18–40%. However, only 9% of the initial hydrocarbon disappeared in un-amended soils. A mathematical modelling depending on the reaction kinetics, mass and energy balances, was introduced to predict the effect of composting on remediation of petroleum hydrocarbon-contaminated soil (Khamforoush et al., 2013). The predicted results were compared with experimental data, validating the reliability of this model. The study was further investigated to show the effect of wood chips (a kind of bulking agent), amendment types (food waste, yard waste, biowaste and sludge), the ratio of amendment/ bulking agent to soil and experimental conditions on the soil bioremediation

5.3 Polyaromatic hydrocarbons (PAHs)

PAHs are one of the prominent persistent organic pollutants, they are not easily degraded in soils and functions differently in soils. Many PAHs forms complex with soil nutrients making them unavailable for plant or microbial use, at times they may percolate in soils blocking air spaces and creating anaerobic condition unfavorable for soil biotic components. However, many scientists have suggested the use of bioremediation for biodegradation or biotransformation of these pollutants using some specific organisms that can respond, tolerate and survive their toxicity and/or mineralize them. Compost also have been demonstrated by some other researchers as an effect mechanism for remediation of PAHs Kästner et al. (1995; 1999) and Kästner and Mahro, (1996) as well reported the degradation of pyrene, naphthalene, phenanthrene, Fluoranthene, anthracene and some other polycyclic aromatic hydrocarbons in soil using soil-compost mixtures. Haderlein et al. (1999; 2001) investigated the roles played by compost made with humic matter on the mineralization of PAH-contaminated wastes while Carlstrom and Tuovinen (2003) used compost from domestic waste to degrade phenanthrene in biometers.

Spent Mushroom Compost (SMC) which is made from growing a mushroom called *Pleurotus pulmonarius* reported to degrade phenanthrene, naphthalene, benzo[a]pyrene and benzo[g,h,i]perylene by Lau et al. (2003), this compost includes wheat straw, horse manure, dried blood, and ground chalk and similar result was reported by Asemoloye et al. (2017a, b & c) on crude oil, black oil, polyaromatic hydrocarbons and a pesticide called lindane. Atagana (2004) successfully demonstrated removal of PAHs through soil composting with > 30,000 $mg \cdot kg^{-1}$ of creosote and poultry manure in 19 months periods. Atagana and Asemoloye et al. both reported that SMC adjust the pH of the experimented soil to 6.7-7.5 and enhances soil bioaugmentation with mixed population of *Aspergillus, Rhizopus, Penicillium,Fusarium,* and *Pleurotus* species of fungal strains as well as *Bacillus, Pseudomonas, Rhodococcus* and *Mycobacterium* species of bacterial dominant strains. Liu et al. (2008) showed a novel insight into the interaction between phenanthrene and tricyclazole in medium, soil and the mixture of soil and compost was investigated, showing a negative effect on their degradation, which is attributed to their molecular similarity. The bioremediation effect on anthracene-contaminated soil by composting was evaluated by Ma et al. (2003). The finding revealed the removal percentages of anthracene for composting materials with old compost and without old compost were 55.3% and 50.5%, respectively. Cheng et al. (2008) established the use of pig manure which was able to increase the number of microbial population, organic matter and dissolved organic carbon content as well as Tween 80 that increased the pyrene bioavailability by acting as a surfactant, had a beneficial effect on pyrene removal. Many other reports such as those of Conte et al. (2005), Bogan and Sullivan (2003) and Moretto et al. (2005) to mention a few have proven that composts are good activator of PAH bioremediation.

5.4. Pesticides and chlorophenols

Studies had proven the use of compost to improve the herbicide removal of atrazine, trifluralin and metolachlor in contaminated soils. Moorman et al. (2001) incorporated 0.5% manure, 5% cornstalk and 5% peat in contaminated soils which enhanced the atrazine removal, and the addition of sawdust, corn fermentation byproduct, manure and cornstalk at a rate of 5% increased the metolachlor degradation. However, all amendments proved to be ineffective in enhancing the trifluralin degradation. Another study done by Delgado-Moreno and Peña (2009) discovered that the overall removal of simazine, cyanazine, terbuthylazine and prometryn did not increase despite the addition of compost, vermicompost and olive cake in soils. In addition, Gan et al. (1998) enhanced the degradation of methyl isothiocyanate (MITC) and methyl bromide (MeBr) from soils, and thus reduced the emission or volatilization of MITC and MeBr by almost 100% and 12%, respectively, by employing composted manure and biosolid manure. Noteworthy, comparison of degradation kinetics between nonsterile and sterile amended soils indicated that the degradation mechanism of these two compounds differed. Kadian et al. (2008) also investigated the impact mushroom spent compost, biogas slurry, farmyard manure and sodium citrate on the removal of atrazine in contaminated soils.

5.5. Heavy metals

Heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc etc are known to be micronutrients that are naturally available in the environments but indiscriminate human activities has altered their natural geochemical cycles and balances in biochemical status and their accumulation in soil and water can pose harmful effect to both human health, animals and aquatic biota. Many heavy metals occur naturally as a result of pedogenetic weathering processes from parent materials and also through anthropogenic sources, weathering of minerals, flooding, erosion and volcanic eruption. Anthropogenic sources (human activities) include smelting, mining, electroplating, increase use of pesticides, fertilizer, and municipal sewage disposal from the manufacturing industries (Wuana and Pyatt, 2007). Many heavy metals have been reported to toxic carcinogenic and mutagenic at low concentrations [95].

The addition of a composts to heavy metal contaminated soil can reduce the interfacial tension thus increasing the mass transfer of the contaminants (Oleszczuk, 2008). In this context, several researchers have shown that various compost can enhance bioavailability, desorption, solubilization of heavy metals (Dahrazma and Mulligan, 2007; Rufino et al., 2011). Asemoloye et al. (2017b & c) discovered a sharp decrease in the level of heavy metals in SMC mixed soil, because the isolated biomass of SMC works as an ion exchanger. The microflora thriving on SMC has been found to be responsible for faster heavy metals bioremediation in SMC mixed soils. It has also been shown that composts bind heavy metals and prevent them from migrating to water resources or being absorbed by plants. Chen, (2015) also reported that composts contains an abundance of biomass such as bacteria, fungi, high levels of enzymes and other oxidants that make them act as a biosorbent for removing cadmium, chromium and lead in laboratory batch systems and they discovered that SMS had vast applicable potential to remove heavy metals from solutions.

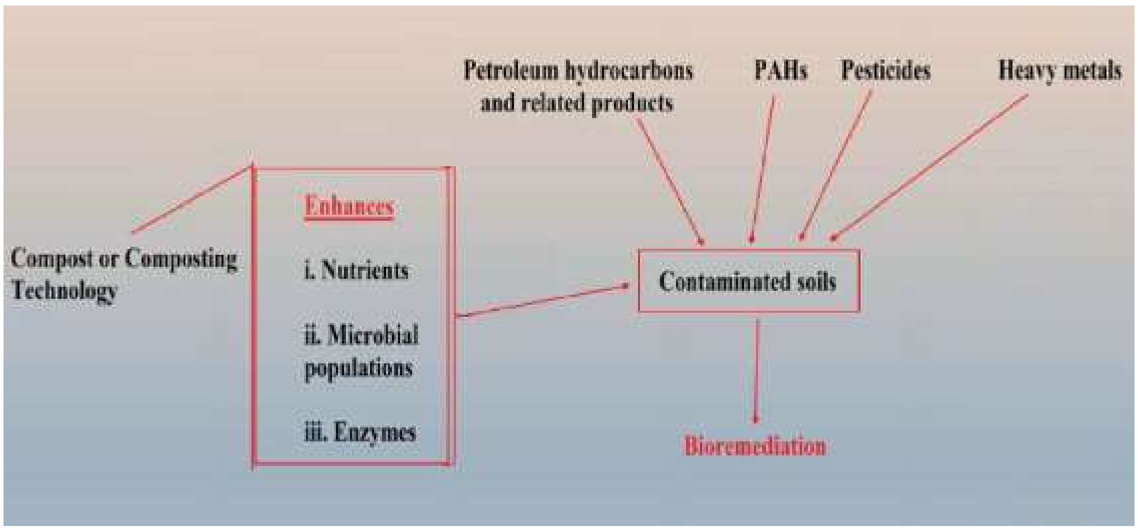

Fig. 4: Bioremediation of soils contaminated with organic pollutants and heavy metals by composting or compost.

6.0 Microbial Enzymes can be enhanced by compost amendments

Enzymes are biological catalyst plays important role in the biochemical and metabolic reactions, free enzymatic remediation can be used to detoxify many pollutants in short time and it is highly specific in nature (Pandey et al., 1999; Chandrakant et al., 2011). It catalysis degradation of xenobiotics such as pesticide residues they are mostly of different classes based on their detoxification mode of action i.e. The oxidoreductases, transferases, hydrolases, lyases, isomerases, ligases (synthetases) and so on (Brown et al., 2003; Husain, 2006). The industrial application of enzymes and theirs sources are given Table 2 below

Table 2: Enzymes and their industrial application

EC	Enzymes	Industrial enzymes	Sources	Applications
1	Oxidoreductases	Catalases oxidases and Laccases	Fungi, bacteria	Bioremediation, chemicals and pharmaceuticals industries
2	Transferases,	Glucosyltransferases and Fructosyltransferases	Fungi, bacteria	
3	Hydrolases,	Amylases, Lipases Cellulases, Proteases Mannanases Phytases Xylanases Pullulanases Pectinases	Fungi, bacteria	Paper, leather, textile, baking and bioremediation
4	Lyases,	Pectate lyases, decarboxylases Alpha-acetolactate	Fungi, bacteria	Pulp and paper industry, baking industry
5	Isomerases,	Glucose isomerases Topoisomerases and Epimerases Mutases	Fungi, bacteria	Chemical and syrup industry
6	Ligases	Glutathione synthase Argininosuccinate	Fungi, bacteria	Pharmaceutical industry

Having established the compost enhances the nutrients and microbial activities in soil, it means that enzyme secretions by these microorganisms can be also enhance in soils amended with composts. Many composts are made from plant and wood materials which are rich in lignin and cellulose, for microorganism to reach nutrients enclosed, they have to secret enzyme systems to decompose it. The impact of compost or composting that are free from pathogens on microbial enzyme production is effective as it serves as substrate which promotes microbial growth.
Fungi especially the Basidiomycota group which contains fungi genera have been well reported as effective degraders of lignin through their enzymes such as lignin or manganese peroxidases, catalases, laccases or Cytochrome P450 clans and these enzymes are usually secreted extra-cellularly on their substrates, using those substrate as composts for soil amendment promote bioremediation (Eggen, 1999; Canet et al., 2001; Lau et al., 2003; Asemoloye et al., 2017c. More specifically, these lignin degrading enzymes often times contains necessary complex arrays and mechanisms for degradation of some soil pollutants such as PAHs. In addition, composting usually results in elevated soil temperature, solubility and mass transfer rate of soil pollutants, these are factors needed for enhanced enzyme actions needed for active biodegradation processes. Composting also enhances co-oxidation due to its range of alternative substrates and it also modifies the physical and chemical microenvironments which also increases the diversity of the microflora present (Jonathan et al., 2016 b, c & d; Asemoloye et al., 2017d).

7.0. Conclusion

Higher increased industrials processes, crude oil exploration, inadequate waste disposal and so on are factors increasing the environmental pollution and concurrent health hazard. There is therefore need to develop adequate treatment to improve soil health and remediation. High amount of organic matter in soils there is therefore need to be encouraged through the use of compost technology, this process requires no large cost, applicable in small scale and can be also used to promote agriculture. Today, bioremediation mechanisms is gaining interests and acceptance due to its environmental friendly approach and cost effectiveness. However, it may be difficult to establish bioremediation mechanism for remediation of heavily polluted site as it may be very difficult for the biological component to survive in such environment. This and some other problems which bioremediation mechanisms might be facing can be averted through the use of combined actions of two or more organisms. However, we advocate compost or composting technology with appreciable research reports as a very a useful and imminent technology to be considered in establishing a bioremediation or synergistic bioremediation processes. Composts serve as fuels which run the bioremediation systems, feeding different biological entities by supplying nutrients and creating conducive environment for positive response, adaptation, survival and co-habitation of difference biological entities.

Competing interests

The authors declare they have no actual or potential competing financial interests.

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