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Review

The effect of cassava effluent and empty oil palm fruit bunch on remediation of petroleum polluted soil and crop production in the tropics: A Review

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Abstract

Purpose There is an increased demand for proper utilization of wastes to benefit humans especially as it relates to generation of economic gains. Although the agro-based industry and the petroleum industry contribute to high levels of waste generation, it is possible that the wastes from the agro industry could be used for management of petroleum hazards and pollution. This review focuses on the identification of potential benefits of two highly ignored agro wastes: cassava effluent and empty oil palm bunch, which contribute to the emission of greenhouse gases and increasing the disease causing potentials of these wastes for people living where they are disposed.

Methods In this review, we utilized available literature to reveal the importance of agro wastes as well as their different beneficial applications especially as they concern the remediation of crude oil pollution.

Results Evidence from previous research indicates that cassava effluent contains some beneficial nutrient components that negatively affect soil chemistry and plant growth. The use of empty oil palm bunch, on the other hand, has been reported to contribute to the improvement of soil nutrient properties and crop production.

Conclusion We postulate that the chemical constituent of these two agricultural wastes may significantly complement their ability to improve crop production when combined, as well as mediate cleanup of soils exposed to crude oil pollution over time.

Keywords Cassava effluent, Empty oil palm bunch, Agro-wastes, Pollution, Remediation

Introduction

Any waste generated from cultivation, processing or packaging of agricultural products is regarded as agricultural wastes. They include residues emanating from fruit and vegetable crops, poultry and dairy products (Obi et al. 2016). These wastes comprise the non-product output of the agricultural industry, and in some cases they include substances that have potential value if recycled (Agamuthu 2009). In some other cases, agricultural wastes could be detrimental to human existence, as their continual discharge threatens the safety of the environment and those living therein. Agricultural wastes occur as liquids, slurries or solids, and they include animal waste (manure, dung, and carcasses), crop waste (husk, maize stalks and cobs, sugar cane bagasse and fruits and vegetables), food processing waste (cassava effluents, palm oil effluents), toxic substances emanating from pesticides and herbicides (Obi et al. 2016).

Agricultural wastes are thought to contribute significantly to waste matter generated all over the world as the expansions of agro-based production has led to an increase in quantity of livestock wastes, crop wastes, and agro-industrial byproducts. As in 2016, it is estimated that about 998 million tons of agricultural wastes are generated annually, and this amount is likely to double in a decade considering the increasing demand for agricultural production (Gontard et al. 2018). Relative to solid wastes, organic wastes amount to about 80% of the total waste generated in any farm.

For this review, agricultural wastes are classified under four broad headings according to their sources of generation: wastes generated from plant cultivation activities, wastes generated from plant processing and packaging, wastes generated from animal husbandry, and wastes generated from aquaculture activities. The focus of this review, therefore, is on tropical wastes and their applications on tropical soil amendment with them.

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Agricultural wastes generated from plant processing and packaging

Plant processing and packaging remain the highest source of agro-waste generation and production in the tropical areas of the world. This processing line includes harvest practice, post-harvest processing, and storage. Most of the solid wastes coming from agriculture include cellulosic materials and biomass usually generated from plant stalks, as in maize, banana, and plantain, as well as rice. The production of tubers contributes greatly to generation of high content of biomass in the form of peels, which often are improperly managed. On the other hand, liquid wastes, which are produced mainly from crop processing, constitute the greatest threat to the environment, as they often include contaminants that impinge life (Hai and Tuyet 2010). Sources of effluent from crop processing are usually from cassava, sugar cane processing, palm oil processing, etc. Other forms of solid wastes generated in the course of plant processing and packaging include biomass arising from the oil palm and rice industry which include palm bunch and fronds, rice husk, and barley. Although most organic wastes are recycled into organic fertilizers and other useful products, more than 80% of generated wastes are underutilized and end up constituting a nuisance in most environments in which they are produced and deposited.

Agricultural wastes generated from animal husbandry

Such waste products generated include animal dung, urine, food remnants and carcasses from the slaughter house, effluents emanating from bathing animals and maintenance of slaughter houses and many others (Than 2005; Prasertsan and Sajjakulnukit 2006; Abdeshahian et al. 2010; Pampuro et al. 2016; Daryabeigi et al. 2018; Khalil et al. 2019). In some other cases, they could be directed into post pollution soil remediation (Agarry et al. 2010; Urhibo and Ejechi 2017).

Wastes generated from aquaculture activities

Aquaculture, like livestock production, has contributed significantly to improved food production as well as waste generation by consistently encouraging the use of feed formulas for enhanced production. The implication of this is that the amount of feed used in an aquaculture system is a determining factor in the quantity of waste generated (Miller and Semmens 2002). Suspendable and dissolvable metabolic waste is a major source of wastes generated in aquaculture, and even in a properly managed farm, approximately 30% of feeds utilized end up as solid wastes. If properly managed, these wastes could be used as manures or, in the case of effluents, for the remediation of different forms of pollution, including crude oil (Achuba and Oshiokpu 2019). One way of reducing aquaculture agro-based wastes is giving special attention to the water-flow patterns in the different units so as to reduce fragmentation of fish faeces in favor of rapid settling and concentration of the sedimentary solids in the waste.

Beneficial application and uses of agricultural wastes: An overview

Ample research and industrial evidence exist on the beneficial applications and utilization of agricultural wastes. These are outlined in the Table 1.

Application of agricultural wastes for remediation of crude-oil pollution

Efforts to utilize cost-effective and readily available techniques for the remediation of crude oil pollution are ongoing, and there are significant positive outcomes from various research efforts. The use of animal and plant waste from different points in the agricultural value chain, including farming, processing and storage, has been explored within the last decade. Plant wastes that have been tested include rice husk, oil palm branches and bunches, wheat and barley straw, yam peels, and orange and mango peels. The animal wastes that have been explored include cow and poultry dung, pig dung, animal fur and bird feathers, waste water from abattoirs and fish ponds.

Husseien et al. (2009) tested the use of barley straw for oil spill cleanup, examining the adsorption capacity of raw barley straw because of its richness in fibre. They reported that the efficacy of barley straw to remove oil spill from water was dependent on oil concentration, fiber size, and oil temperature, as well as the individual surface properties of the straw. They noted that cyclic sorption and desorption studies suggested that squeezing was effective to remove most sorbed oil, and that barley straw had feasibility for recycling. Hamoud et al. (2018) also investigated the efficacy of wheat straw to enhance the carbon mineralization of crude-oil contaminated soils as well as its effects on other biochemical indices. In this study, treatment of crude-oil contaminated soil at different concentrations of 50, 100 and 150 ml/kg with 5 g/kg of wheat straw was investigated. The treatment of contaminated soil with wheat straw significantly contributed to biodegradation of the crude oil, with highest percentage of degradation recorded at 100 ml/kg and 150 ml/kg crude-oil contaminated soil, respectively. The study concluded that the use of wheat straw could bio-stimulate the gradual breakdown of crude oil in cases of crude-oil pollution.

In another study utilizing cereal agricultural waste in the remediation of soil and sediment contaminated by automobile gas and oil, Amechi et al. (2017) com-

Table 1 Applications of agricultural wastes for remediation of pollution and other benefits

Sources of waste generation	Type of waste	Application	References
Crop production, processing and packaging	Cassava peels	Bioethanol production	Tonukari (2004) Osumah and Tonukari (2010)
		Amendment of poultry feeds	Chibuzor et al. (2016) Isitua et al. (2018)
	Rice Husk, barley straw, wheat Straw	Manure, adsorbent for crude oil	Amechi et al. (2017) Yeneneh et al. (2011) Husseien et al. (2009) Hamoud et al. (2018) Alotaibi et al. (2018)
	Maize cobs	Carbon adsorbent Adsorbent and remediation of polluted water	Tsai et al. (2001) Opeolu et al. (2009) Mwangangi (2015)
	Sugar cane bargase	Adsorption of heavy metals	Yeneneh et al. (2011)
	Coconut shell	Crude oil remediation	Ibrahim et al. (2016)
	Banana peels, orange peels	Adsorbent for crude oil	Roldán-Martin et al. (2006) Kumar et al. (2016) Thani et al. (2017) El-Din et al. (2018)
		Adsorbent for heavy metals and manure Cyanide removal from water	Doshi et al. (2019) Salim et al. (2016) Abbas et al. (2014)
	Olive mill waste	Compost manure	Altieri and Esposito (2010)
	Oil palm fronds	Remediation of crude oil pollution	Achuba (2019)
	Extracts of oil palm fronds Powdered leaf of oil palm fronds	Treatment of crude oil mediated toxicity in rats	Achuba (2018 a,b)
Livestock production	Abattoir effluent	Manure	Umanu and Owoseni (2013) Achuba and Ekute (2017)
		Crude oil and other petroleum product pollution remediation	Achuba and Ja-anni (2018) Achuba and Iserhienrhien (2018) Achuba and Erhijivwo (2017)
	Poultry dung, feathers	Manure, crude oil remediation	Urhibo and Ejechi (2017)
		Heavy metal removal from water	Al-Asheh et al. (2003)
	Cow, pig, goat dungs	Manure, crude oil remediation	Urhibo and Ejechi (2017) Amechi et al. (2018) Nwaogwu et al. (2015)
	Animal skin and fur	Adsorbent for heavy metals	Agarry et al. (2010)
	Carcasses	Manure, biogas production	Tápparo et al. (2019)
Aquaculture	Artificial fish pond waste water, Algae residues, fish faeces	Manure, crude oil remediation	Achuba and Oshiokpu (2019) Achuba and Ohwofasa (2019)

pared rice husk soil amendments to the renewal by enhanced natural attenuation (RENA). They reported significant increase in the percentage degradation in the total petroleum hydrocarbon TPH and the activities of soil dehydrogenases in soil amended with rice husk is compared with the RENA method. Likewise, soil amendments using rice husk were observed to have a 97.85% removal efficiency compared to the 53.15% reported for RENA over a two- month period. The use of rice husk was also reported to significantly influence microbial biota due to the high presence of *Micrococcus luteus* and *Rhizopus arrhizus*. It was thus concluded that rice husk was a good candidate for use as an alternative for field bioremediation of crude oil contaminated soil. In a similar study also, Shamsollahi and Partovinia (2019) carried out a review of the successful use of rice husk in the removal of different pollutants. They reported that rice husk was more efficient in the remediation of waste water commonly introduced into fields. However, the study opined that rice husk need pretreatment before being used as a remediating agent. This pretreatment is a major challenge in the use of rice husk as an adsorbent in a contaminated soil. The study also suggests that chemical treatment of rice husk was an effective way compared to heat treatment for improving its adsorption efficiency when applied to clean up of pollutants, although applications of biocatalyst immobilization holds an excellent prospect and potential for rice husk use in bioremediation of polluted bodies.

The utilization of fruit peels has been well explored, especially the use of banana peels in remediation of crude-oil polluted soil, water and other forms of contaminants. Particularly, El-Din et al. (2018) investigated the use of banana peels for removal of oil spill in water and reported that the ability of banana peels was dependent on oil type, film thickness, temperature, and sorption time. They further noted, based on Fourier transform infrared spectroscopy (FTIR) analysis, that the best conditions for successful adsorption of crude oil by banana peels were achieved at 0.3625 mm particle size and a temperature of 25^{o}C for 15 minutes. Another study by Thani et al. (2017) assessed the efficiency of banana peels for crude oil removal based on oil concentration, adsorbent dosage and contact time and reported that the best achievement was attained at a dosage of 4.94 g, for 10.29 hours contact time and the initial oil concentration as high as 8.74%. It further reported a significant relationship between dose and contact hours. Also, Aliyu et al. (2015) explored the potentials of banana peels in the removal of crude oil from contaminated water. The study was carried out by using banana peels as an adsorbent in a column through which water polluted with an initial oil concentration of 200 mg/l circulated for 6h and revealed that increased bed height significantly influenced the removal of the oil from 87.82-97.45% at a contact time of 20 minutes and flow rate of 21.6ml/min. This led to a high positive significant correlation between service time and bed height.

The use of orange peels for crude oil remediation has also been greatly explored. Roldán-Martín et al. (2006) reported in a solid culture experimental model that the peels of orange enhance degradation of total petroleum hydrocarbon (TPH) by 69% over 15 days in a 92:2 soil: orange-peel ratio and increase bacterial and fungal isolates in the polluted soil. In another study, Kumar et al. (2016) explored the use of orange peel as a bio-surfactant to enhance degradation of crude oil in a polluted soil sample. In comparison with several other substrates, orange peels were reported to have the best potential, yielding 1.796 g/L and emulsification of activity of 75.17% against diesel. Yelebe et al. (2015) revealed that ash from oil palm empty fruit bunch (OPEFB) was a good substance for remediating the impacts of crude-oil pollution on several soil physicochemical properties, increasing the microbial population and reducing total petroleum hydrocarbon. Their study for the purpose of establishing a kinetic model for bioremediation of petroleum contamination using OPEFB ash and oil palm wood ash, by adding the ashes in ratios of 50:100:50 grams to 1000 g of petroleum-contaminated soils, respectively and monitored over a period of 20 weeks. Outcomes from the study revealed that palm bunch ash and wood ash treatment had the highest level of reduction of total petroleum hydrocarbon, while the attainment of 99.5% THC reduction was accomplished by 150 g of OPEFB ash and palm wood ash in a soil mixed with 50 g of petroleum before treatment. This study thus submitted that this was efficacious for bioremediation and remains a sustainable replacement for NPK fertilizer utilization in remediating soil crude oil pollution.

The animal based agricultural wastes that have been explored include abattoir water for the biodegradation of diesel in an agricultural soil by Umanu and Owoseni (2013). They reported that sterile and non-sterile abattoir water had a degradation efficiency of 92.31, 80.47, 97.63 and 91.12%, compared to the control efficiency of 35.5%. Likewise soil amendments with abattoir effluent contributed to increases in soil pH and biota relative to the control over a study period of 10 weeks. Several studies done by Achuba and Okunbor (2016), Achuba and Erhijivwo (2017), Achuba and Iserhienrhien (2018) and Achuba and Ja-anni (2018) explored the efficacy of abattoir waste water to mitigate metabolic malignancies in cow pea seedlings planted in soil contaminated by kerosene, diesel, gasoline and crude oil. Plant morphological parameters such as height, leaf weight and area, as well as fresh and dry weight of plant were restored to normal following treatment with abattoir waste water. Also, metabolic malignancies which resulted in loss of plant antioxidants, such as the beta carotenes and superoxide dismutase, as well as oxidative stress indices, were all reversed to near control values. In a similar study, Achuba and Ohwofasa (2019) used spent water from an artificial fish pond to ameliorate the negative effects of diesel pollution on cowpea seedlings. They successfully reversed loss of key metabolic enzyme activities, such as the starch phosphorylase, alpha amylase, superoxide dismutase and catalase. It also reduced rising trend in lipid peroxidation due to crude oil contamination in soil and reversed the effects on total chlorophyll, total protein, total amino acid and beta carotenes, all of which are metabolic markers of interest.

In another study, the use of poultry and pig waste has been reported by Urhibo and Ejechi (2017). Their study, which was based on selective isolation of hydrocarbon utilizing bacteria from poultry and pig wastes, as well as soil amendment with poultry and pig waste, revealed that total petroleum hydrocarbon degradation and removal was maximized via soil amendments with the poultry waste achieving significant TPH removal.

Cassava effluent and its physicochemical properties

Cassava effluent comprises the milky colloid emanating from the fresh tuber paste, the latex and the water used to wash the cassava during the processing of cassava. Its discharge into the environment is known to cause serious levels of pollution, and this is more prominent at mills where the cassava tuber is grated to produce garri. The fermentation of the effluent that emanates from the dewatering process that yields garri leads to the production of several pungent gases and encourages growth of several microorganism of negative economic importance. Also, the eventual discharge of the effluent to plant fields has been established as detrimental to soil and plant biochemistry. Specifically, there are studies that reveal that cassava effluent or cassava waste water contains high levels of cyanogenic glycosides and heavy metals, and results in a poor water quality index.

The study of Sam et al. (2017) reported that an analysis of the physicochemical properties of four different varieties of cassava indicates that they have very low pH (4.0-4.2), while the electrical conductivity ranged from 11.28 to 22.28 dS/m. Likewise, there were high levels of suspended solids (44-241 mg/L) and phosphate (8.80-11.65 mg/L), as well as other mineral elements, such as cadmium, calcium, and potassium (24-30 mg/l, 1200-1800 mg/L and 6000-6600 mg/L respectively). The cyanide concentration was reported as 12.96- 16.86 mg/L and BOD reported at 1.63-2.45 mg/L. The same study also reported mild to high concentrations of trace metals in all four varieties of cassava compared with control values in standard borehole water. The concentration of lead was highest in all the effluents emanating from different varieties of cassava (171-229 mg/L), followed by nickel (3.72-8.441 mg/L), then vanadium (1.114-1.632 mg/L), cadmium (0.218-0.451 mg/L) and chromium (0.101-0.180 mg/L).

In another related study, Uguru and Obah (2019) reported that an untreated cassava effluent discharged into the surrounding had pH lower than the Nigerian industrial standard (NIS) permissible limit of 6.5-8.5 allowed in drinking water, as well as average trace-element concentration of cyanide, chromium, nickel, and zinc higher than the control, treated sample and the NIS standard (3.33, 2.33, 2.12, 10.95 mg/L respectively). Relative to the indices for survival of life, it was reported that the total coliform count of bacteria in the cassava effluent was higher than the treated effluent, while the phosphorus and nitrogen concentrations were lower than the treated effluent and the control. The implication of these reports according to the researchers was that the physicochemical properties of the cassava effluent may be injurious to the environment and has the tendency of not supporting biological life. Another report on the physicochemical properties of cassava effluent indicated high concentrations of heavy metals, low phosphate concentration, poor biological oxygen demand, high turbidity and high electrical conductivity. According to Obueh and Odesiri-Eruteyan (2016), these physicochemical parameters are determinant factors in the measurement of the pollutant potential of an effluent. Also, these parameters are a measure of the oxygen required for the stabilization of organic matter by microbial life and enzymes in soil.

Effect of Cassava effluent on soil texture, chemistry and microbiology

There exists a plethora of reports on the effects of indiscriminate cassava effluent discharge on fields, with emphasis on the dynamics of soil biochemistry. All of these reports have basically reported negative impacts ranging from alteration in soil porosity, soil biota, soil enzyme activities, increased index of pollution and reduced soil nutrient status. For example, a study of Orji and Ayogu (2018) was carried out to assess the effects of cassava effluents on physiochemical characteristics and bacteria flora of soils in Ezamgbo community. After sampling of different soils from varying locations in the study area, these soil samples were analyzed following standard methods. Findings from the study revealed that the physical presentation of soil color was dark brown, slight brown and brown both at the sampling site and control sites. Soil texture was reported to be fine and coarse while mean value of the highest mean value of controls was put at 6.40±0.54, while that of the polluted sites was 4.84±0. Cassava effluent exposure was reported to significantly increase mean conductivity, nitrate, phosphate, sulphate, sodium, potassium, calcium and magnesium of soil samples relative to control. On Bacteria population, significant reductions were reported in cassava effluent polluted sites compared to control with the highest mean count put at 1.33±0.19CFU/g^{-1} (10^5) for the control and 1.17±0.17 CFU/g^{-1}(10^5) among the contaminated samples and a bacteria prevalence of 41.53% for contaminated soil samples while 58.47% was obtained for the control. The bacteria species characteristic of the soils were *Staphylococcus aureus, Bacillus* species, *Proteus* species, *Pseudomonas* species, *Escherichia coli, Klebsiella* species, *Micrococcus* species, *Enterobacter* species and *Chromobacterium* species from the analyzed soil samples with *Pseudomonas* species and *Micrococcus* species attaining the highest (9.28%) and least (2.19%) prevalence respectively in the polluted site and *Bacillus* specie (9.84%) and *Enterobacter* species (4.92%) recorded as highest and lowest in the control soils. The study concluded that cassava effluent can have an increasing or limiting effect on the bacteria diversity of the contaminated soil because of changing physicochemical properties of the soil.

Also in line with the above submissions by Orji and Ayogu (2018) were earlier reports by Obueh and Odesiri-Eruteyan (2016) who noted a drastic reduction in bacterial and fungi life in soils around a cassava mill and a cassava effluent discharge pit. On assessment of the effect of cassava effluent on the soil microbial and physicochemical dynamics structure, Igbinosa and Igiehon (2015) reported the prevalence of different bacteria species such as *Bacillus subtilis, Bacillus macerans, Pseudomonas aeruginosa*, *Klebsiella aoxytoca* and *Escherichia coli* and eleven species of fungi belonging to the genera *Aspergillus*, *Penicillium a*nd *Rhizopus* were reportedly isolated. The study further noted that relative to control, the polluted soil had higher coliform counts which were attributed to low and acidic pH of cassava effluent exposed soils. Comparative to bacteria, it reported that cassava effluents supported growth of bacteria better than the fungi counts. It further noted that the deposition of heavy metal in the cassava effluent exposed soils was increased relative to control sites. Relative to other soil physicochemical parameters, Igbinosa and Igiehon (2015) reported that the soil particulate was mainly made up of sandy, silt and clay particles with sandy particles in polluted soils ranging from 86-89% compared to control indicative of the ability of cassava effluent to affect soil particle components. They further reported increase in organic carbon content of polluted soils relative to control as well as increased total nitrogen that was attributed to nitrogen mineralization due to organic matter degradation by microorganisms. Relative to heavy metals, the authors further noted that the deposition of heavy metals such as zinc, iron, copper and manganese in the cassava effluent exposed soils was increased relative to control sites implying a soil enrichment of heavy metals by cassava effluent as attributed by Osakwe (2012) to emanate from possible wear-off of the cassava grating chamber in a cassava processing mill.

In Aba, a Nigeria based study by Ezeigbo et al. (2014) reported the effect of cassava effluent on soil microbial populations and noted that *Bacillus* species*, Pseudomonas* species, *Klebsiella* species, *Escherichia coli, Micrococcus* species and *Chromobacterium* species were the most dominant isolates in a cassava effluent impacted soil while the fungal isolates include *Aspergillus* species, *Penicillum* species, *Mucor* species, *Rhizopus* species and yeast and may be indicative of an adverse effect of cassava mill effluent on soil microorganisms. Also, Izonfuo et al. (2013) based on data emanating from a study in the Niger Delta area of Nigeria reportedly noted that introduction of cassava effluent to soils in most rural communities contributed to a changing dynamic in soil physicochemical parameters such as pH, organic matter, BOD and soil exchangeable cations. It further revealed a drop in soil Mg levels relative to control and a significant correlation between pH and CN- (r = 0.18); K (r = 0.17); Ca (r = 0.97); Mg (r = 0.13); Na (r = 0.03); P (r = 0.08); N (r = 0.40); Organic Carbon (r = 0.08) and organic matter (r= 0.06) thus having negative implications to the thriving of agricultural produce in such soils.

Effect of Cassava effluent on plant morphology and metabolic indices

Anything that has the capacity to alter the biochemical stability of soil, most likely will impact the growth of plants. Several studies have reported a significantly negative influence of cassava mill effluents on different plant species arising from soil acidification, heavy metal deposition, loss of soil nutrients and microbial life. The study of Nwakaudu et al. (2012) using maize as a model reported that exposing soil to cassava effluent for 14 days impeded the growth of seedlings. In addition, leaves were reportedly greenish yellow compared to the deep green for the control soil. Also, it reported a drastic drop in height of plants, which ranged from 9.0 to 9.4 cm in all contaminated samples relative to a 22 cm height in the control. Their submission indicated that cassava effluent discharge had the ability to inhibit the synthesis of chlorophyll, a major metabolite in the sustenance of plant growth and health.

In another study, Dantas et al. (2014) reported the positive potential of cassava mill effluent in promoting the cultivation of sunflower. They reported that exposure of cassava waste water of varying doses significantly impacted the soil nutritional input in a dose-dependent manner, resulting in increased aerial fresh matter (65,881 kg ha^{-1}) in soil fertilized with the highest dose of cassava waste water (136m^3 ha^{-1}), as well as producing the highest total fresh matter of plant parts. Likewise, the study further reported an improvement in the capitulum dry matter profits (8.328, 9 kg ha^{-1}) when cassava waste water was used as a substitute for mineral fertilization. This was higher than those (3,882.5 kg ha^{-1}) obtained in the study of Zobiole et al. (2010) when growing the sunflower hybrid BRS 191 in Rhodic Eutrudox (eutroferric Red Latosol) managed with mineral fertilizers. In justifying their submission, they noted that the responses of capitulum fresh and dry matter presented in their research are similar to those found in another study by Joner et al. (2011), when quantifying yield and contribution of achene, leaf, stem, and capitulum in fresh and dry matter of sunflower hybrids Helio 251 and Helio 360 for silage production. They found 1,315.54 and 2,180.89 kg ha−1 of capitulum dray matter and 6,473.65 and 11,648.04 kg ha−1 of capitulum fresh matter for the hybrids Helio 251 and Helio 360, respectively, indicative of the fact that cassava waste water attended the nutritional exigency of the crop in their study.

Most recently, Ogunyemi et al. (2017) reported the Mutagenic and genotoxic effects of Cassava Waste Water (CWW) using *Allium cepa* root meristematic cells.

Their study found out the at the end of 72-hour cultivation time to varying concentrations of cassava waste water led to strong growth retardation at the root tipis exposed to high concentrations of the effluent with effective concentration (EC) value of 5.67%. The mitotic index (MI) 50 rapidly decreased with increasing effluent concentration compared to control, indicating a significant increase in frequency of chromosome aberrations (stickiness, c-mitosis, vagrant, bridged fragment, binuclei, multipolar anaphase, attached chromosome and laggard chromosome). The authors also noted that at lower concentrations of the cassava effluent, binuclei formation, vagrant chromosome and bridged fragment were the most common aberrations observed, while at higher concentrations, (100 %), c-mitosis, vagrant and bridged fragment were the typical aberrations observed. The results indicate that the effluent samples collected were highly mutagenic. The implications of increasing food poisoning occasioned by cyanide accumulation and deposition in different root tubers grown in farm land exposed to cassava mill effluent has been earlier reported by Uhegbu et al. (2012). The authors reported that *Dioscorea rotundata* had 10.13±1.9 mgHCN/kg, while *Dioscorea alata* had 9.12±0.93 mgHCN/kg. *Xanthosoma sagittifolium* and *Colocasia esculenta* were found to have values of 15.19±1.69 mgHCN/kg and 11.81±1.19 mgHCN/kg, respectively. *Ipomea batatas* [red cultivar] had cyanide level of 8.44±1.20 mgHCN/kg, while the white cultivar had 8.44±1.20 mgHCN/kg. Also, *Dioscorea dumetorum* (domestic) showed cyanide level of 35.44±1.69 mgHCN/kg. These values are significantly [$p<0.05$] higher compared to values from the control site for the same cultivars (9.65±1.36 mgHCN/kg, 8.45±1.60 mgHCN/kg, 14.77±1.33 mgHCN/kg and 10.89±1.55 mgHCN/kg, respectively), while *I. batatas* and *D. dumetorum* had control values of 7.26±1.34 mgHCN/kg and 32.76±0.05 mgHCN/kg, respectively.

In another study using maize as a plant model, Sam et al. (2017) reported that treatment of soils with cassava effluents impacted negatively all growth parameters in four different varieties of maize seedlings when compared to the growth factors in the same varieties planted in an un-impacted cassava effluent soil. The growth parameters investigated include percentage and time of germination, plant height, root length, leaf length, root and shoot ratio, leaf width, leaf area, mean dry weight, mean fresh weight and moisture content of the different varieties. The study concluded that cassava effluent treatment impacted negatively on metabolic stability of maize seedlings. The study in question thus gives credence to an earlier study by Ehiagbonare et al. (2009) that reported the ability of different concentrations (25, 50, 75, 100%) of cassava effluent to inhibit the survival of different species of plants, namely *Sida acuta*, *Icacina trachanta*, *Euphorbia hirata*, *Tridax procumbens* and *Chromelaena odorata*. Also, Izah et al. (2018) reviewing the impact of cassava mill effluent in Nigeria submitted that cassava effluent inhibits growth parameters and the availability of soil exchangeable ions, which in turn affects nutrient availability to plants. They concluded that cassava effluent is toxic and is detrimental to crop and food-production economy.

The oil palm empty fruit bunch: Constituent and chemical characteristics

Empty Oil Palm Fruit Bunch (EOPFB) has been reported to have high content of carbon-rich substances, thus its continual exploration as an adsorbent for most pollutants. The essence of this new-found love for empty oil palm fruit bunch might not be far from its unique properties, its relative abundance and its non-utilization after the oil palm fruit has been harvested from it. There exist many studies that have successfully utilized the EOPFB for removal of dyes and heavy metals mainly from waste waters. Several other forms of modification of these abundant agricultural wastes have increasingly expanded its importance and usefulness in cleaning up of polluted waterways and lands. Basically, carbon constitutes the basic elemental composition of EOPFB, which is followed by oxygen, hydrogen and sulphur. As in other plants, it has as its structural base the lignin, hemicellulose and cellulose components. The proportions of these structural bases may vary with species, origin, and environmental factors such as soil fertility and weather, as well as specific methods used for analysis and sample preparation (Daneshfozoun et al. 2014). In its natural state, EOPFB is alkaline with a pH between 7.20 and 7.80; thus it makes it a natural neutralizer of acidic soils and favors the adsorption of several cationic pollutants (Kavitha et al. 2013; Arshadi et al. 2014). Studies have revealed that it has a Brunauer-Emmett-Teller (BET) surface area from 1.48 to 28.4 m^2/g in its natural state, which increases as it undergoes modification (Thoe et al. 2019**).** EOPFB has a multifunctional group property which varies from hydroxyls, carboxylates, carbonyls, amides, phenols and alkyl groups. These multifunctional group properties of the EOPFB have been determined mainly by using the Fourier-transform infrared (FTIR) technique at different wave numbers (Setiabudi et al. 2016) and influence their efficiency in removal of pollutants from waste waters (Fatah et al. 2014; Wirasnita et al. 2015).

Empty Oil Palm Fruit Bunch Ash (EOPFBA): Physicochemical properties and nutrient composition

Empty oil palm ash has been long used as an alternative to inorganic fertilizer owing to its ability to neutralize soil acidity to an acceptable alkaline level, as well as its effectiveness as an adsorbent for the reduction of sulphur concentrations in soils (Awodun et al. 2007; Mohamed et al. 2005). Its chemical constituents include high levels of essential soil minerals such as phosphorus, potassium, calcium and magnesium (Aya and Lucas 1976 in Amajuoyi and Wemedo 2015), and it is usually obtained as a byproduct of burning the palm bunch from which the fruits have been successfully collected for oil milling. It has a highly basic pH of 12.0 according to Lim (2000) and Hasnol et al. (2005), and has a mineral distribution of 30% potassium, 5% calcium, 4% phosphorus and 6% magnesium (6%) according to a study carried out by Hasnol et al. (2005).

A study by Udoetok (2012) reported that EOPFBA also contains metals such as 0.088 mg/kg of chromium, 0.38 mg/kg of zinc and 0.63 mg/kg of sodium, in addition to potassium and magnesium, which had been earlier reported by Aya and Lucas (1976) in Amajuoyi and Wemedo (2015). Anions reported also to be constituents of the oil palm bunch ash were chloride, nitrates and sulphates. The physiochemical properties, as reported by Udoetok (2012), indicated high total organic carbon (TOC) of 100 mg/kg, total organic matter (TOM) of 172.4 mg/kg, and salinity of 2500 mg/kg and a relative electrical conductivity of 4735 µs/cm. Unlike the pH of 12.0 which was reported previously, Udoetok (2012) reported a pH of 10.9, which was still highly basic and alkaline.

Effect of Empty Oil Palm Bunch Ash (EOPFBA) on Soil Nutrient, Plant Morphology and Metabolic Indices

Several studies have been carried out assessing the effects of empty oil palm bunch ash either singly or combined with other agricultural wastes or manure substances on morphological and metabolic indices of different plants. The earliest attempt at such a study, by Awodun et al. (2007), was aimed at improving maize yield through the use of oil palm bunch ash soil amendments for improved soil and plant nutrient composition. This study was conducted in two fields using 0, 2, 4, 6 and 8 t/ha of oil palm bunch refuse ash and 250 kg/ha NPK fertilizer and found that the relative deficiency in soil organic matter, Mg, Ca, K, as well as high acidity were significantly reversed by NPK fertilizer and oil palm bunch refuse ash (OBRA). OBRA at 8 t/ha had better improvement efficiency on soil organic matter, N, P, Ca and Mg than the control. Although NPK and 6t/ha OBRA had similar improvement efficiency for cob and grain yield, relative to control. Moreover, NPK, and OBRA (2, 4, 6 and 8 t/ha) increased grain yield in the following order of 44, 29, 31, 43 and 9%, respectively. In a similar study by Ojeniyi et al. (2010), the combined effects of NPK fertilizer and palm bunch ash were investigated on soil plant nutrients and maize performance, and it was reported that relative to control, all treatment forms which included palm bunch ash alone, NPK alone and different percentage combinations of NPK and oil palm bunch ash had increased soil organic matter, N, P, K, Ca, Mg, pH, plant nutrients content, growth and cob yield. The 75% NPK + 25% OPBA and 50% NPK + 50% OPBA were reported to significantly have better outcomes relative to NPK alone or OPBA. However, oil palm bunch had the most increased soil pH and potassium ion concentration.

In another study by Ebeniro et al. (2012), oil palm bunch ash (OPBA) was compared with poultry manure at 0, 3, 6 and 9 t/ha in their effects on growth and yield parameters of ginger (*Zingiber officinale*). The study revealed that palm bunch ash had no significant effect on mean number of tillers/plants relative to control and the poultry manure. However, there was improved plant height relative to control. In the same vein, applications of the poultry manure and palm bunch ash at 3 t/ha respectively improved ginger yield significantly relative to control. It was concluded that optimal effects and improvements of ginger yield was best at 3 t/ha for the poultry manure and palm bunch ash. An entirely field-based study carried out in the forest Agro-ecological Zone of Ghana by Adjei-Nsiah (2012) on the effect of palm bunch ash and mineral fertilizer application on grain yield and nutrient uptake in maize as well as soil chemical properties during the major and minor raining seasons revealed that application of palm bunch ash significantly increased soil pH, soil phosphorus, and exchangeable cations. Although the maize grain yield varied significantly among the different treatments in both the major and minor rainy seasons, the best maize grain yield was achieved by treatment with 6120 kg/ha of palm bunch ash at both major and minor raining seasons compared to control and the NPK fertilizer respectively.

A comparative evaluation of oil palm bunch ash efficacy for improvement of garden eggplant, pepper and okra (*Abelmoschus esculentus* L) growth and yield was done by Adjei-Nsiah and Obong (2013) in a randomized complete block design at the field and the pot experiments. Findings from the studies noted that PBA application significantly increased soil pH, soil phosphorus and exchangeable cations. Field experimental studies revealed mineral fertilizer had 93% better efficacy for improving fruit yield in garden eggs and pepper compared to both controls and PBA, which had 55-91% yield improvement. In a similar trend, mineral fertilizer increased Okra yield by 83% relative to controls, which was more than the increase with PBA (8 to 69%). Interactions between vegetables and palm bunch ash application ratio indicates that the highest yield was 9.52 t ha^{-1} while pepper and the okra highest fruit yields of 6 and 4.96t ha^{-1} were obtained at a PBA application rate of 2 t ha^{-1}. This, therefore, is suggestive that PBA is a significant candidate for soil liming and fertilizer supplementation. Similarly, Agbede (2013) reported that oil palm bunch ash and poultry manure reversed the detrimental effects of tillage on soil chemical properties and ginger.

In another development, a randomized complete block controlled design by Ogbuehi (2016) was experimented on the efficacy of soil amendments with 100 g, 200 g and 300 g palm bunch ash to improve Okra yield. Soil amendments were carried out two weeks prior to planting and at the end of the study, soil pH was reportedly increased, while germination rate was best at the 100 g PBA treatment yielding 74.79% emergence compared to the control which had 45.63%. Monitoring of plant growth and development indices revealed significant improvements in plant height, stem girth, number of leaves and leaf area and relative growth rate. It further revealed a significant difference in growth parameters across PBA treated plots, with the application of 100g rate having optimal improvement for vegetative growth and soil nutrient status, while a 300g rate was optimal for improving fruit yield of Okra. Adikuru et al. (2016) compared lime and palm bunch ash effects on maize performance and soil pH and reported that palm bunch ash contributed to alkalinization of the soil via increment of the soil pH, and this was dependent on the amount applied per hectare of land relative to the unamended soil. This alkalinization of the soil due to palm bunch ash contributed to increased plant height, leaf number and area, leaf and stem dry matter. In addition, there was a reduction by 50% in the days required for tasseling and silking, as well as a decrease in the interval between anthesis-silking and physiological maturity. Compared with lime, the palm bunch ash was reported to have a better prospect for improving maize production.

In another field-based study in Ghana by Adjei-Nsiah et al. (2018), improvement of pigeon pea productivity by palm bunch ash and NPK fertilizer was targeted, as well as their residual effects on maize production. It was reported that genotype and fertilization did not significantly influence grain yield of the pigeon pea. Also, the palm bunch ash treatment alone was reported to have influenced total dry-matter yield significantly by both genotype and fertilization, with the genotype ICPL 88034 producing the highest dry matter (7.29 t ha^{-1}) and ICPL 88039 producing the lowest dry matter (4.95 t ha^{-1}). The PBA-treated plots produced significantly increased dry matter yield compared with the control. The application of PBA alone after 40 weeks increased available P and exchangeable cations (K, Ca and Mg). Yield of maize planted on pigeon pea plots previously fertilized with PBA without NPK was increased by 25% relative to yield of maize planted to pigeon pea on control plots. The study suggests that in the oil palm growing areas in Ghana where soils are acidic, PBA which is found in abundance could be used as a liming material and as organic fertilizer supplement to improve the yield of staple food crops.

Fahrunsyah et al. (2019) investigated the utility of coal fly ash and oil palm fruit empty bunch compost on soil phosphorus uptake and maize yield on an ultisol. The study compared treatment of four coal fly ash doses (0, 20, 40 and 80 t/ha) against three treatments of the oil palm fruit bunch compost (0, 10 and 20 t/ha) within 2, 4, 6 and 8 weeks' intervals post planting. Findings from the study indicated that the 80 t/ha and 20 t/ha of coal ash and oil palm fruit bunch improved phosphorus uptake, growth and yield of maize. Compared to the control, phosphorus uptake, fresh cob weight, dry cob weight, biomass dry weight, and dry seed weight more than doubled and were all above 250% improvement. Aniefiok et al. (2019) compared organic manure efficacy for improved performance of Waterleaf (*Talinum triangulare*) in the Calabar ecological zone of Nigeria. Soil amendments were carried out using poultry manure, cow dung, palm bunch ash and their combinations before planting. The study reported that the treatment with 10 t ha^{-1} poultry manure and a combination of 5 t ha^{-1} poultry manure plus 4 t ha^{-1} oil palm bunch ash had the best performance in all parameters including plant height, number of leaves and branches and leaf area per plant, and fresh and dry weights of water leaf. Another attempt to improve plant yield with the oil palm bunch ash and poultry manure was done on the Mung beans (*Vigna radaita* (L) Willczek) by Effiong et al. (2019) at the University of Nigeria during the 2014 and 2015 planting season. This study employed three levels of oil palm bunch ash (OPBA) (0, 5 and 10 t ha^{-1}) and three levels of poultry manure (PM) (0, 5 and 10 t ha^{-1} and assessed plant growth at 2, 4 and 6 weeks post planting and yield data, including days to fifty-percent flowering. The best agronomic index and yield attributing characters were obtained at the application of 10 t ha^{-1} OPBA. All of the application variants significantly reduced the number of days for 50% flowering relative to control, with the highest seed yields of 0.77 t ha^{-1} with 5 t ha^{-1} OPBA + 10 t ha^{-1} PM in 2014, and 0.82 t ha^{-1} 10 t ha^{-1} OPBA + 10 t ha^{-1} PM in 2015. The study concluded that the yield of mung beans could be improved by singly applying OPBA or PM or combined under the best possible mix ratio.

Conclusion

This review indicates that there exists great opportunity for scientists to explore a plethora of economic gains in the proper use of agricultural wastes. Although agricultural wastes are often a nuisance when not properly managed, this review shows that they may not be entirely useless. The potentials inherent in the use of several agricultural wastes for management of soil pollution from different sources constitute an ideal area that remains to be fully explored. Also, the solution to the increased loss of farm lands to crude oil pollution in oil producing areas of the world may be said to be closely on sight as several agro wastes like the abattoir effluent, fish pond waste water, rice husk, barley husk, empty oil palm bunch, goat and cow dungs as well as poultry droppings have been reported to contribute significantly to crop production and the effective management of metabolic malignancies in plants exposed to different levels of crude oil contaminations and cross contaminations.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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