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Impact of Burning E-waste on Soil Physicochemical Properties and Soil Microorganisms

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Short Research Article

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ABSTRACT

Aims: To investigate the impact of burning e-waste on soil physical, chemical and microbiological properties at sub-surface.
Study Design: Soil samples from six different spots were collected at a depth of 0–6 cm from e-waste dumpsite where e-waste are burnt to disposed them. The samples were then mixed together to give a general view of the impact of burning the e-waste on the dumpsite soil. The soil sample was then subjected to physicochemical and microbiological analyses. This was repeated for soil without e-waste.
Place and Duration of Study: Soil samples were collected from e-waste dumpsite Alaba International Market, Lagos State, Nigeria.
Methodology: The organic carbon and organic matter were determined using gravimetric techniques, nitrogen was determined using kjeldhal methods, exchangeable bases were determined using flame emission spectrometry and EDTA classical methods titration, heavy metals determination in soil samples were estimated using atomic absorption spectrometer (ASS) and the microbiological analyses were carried out using standard methods.
Results: Burning of e-waste increased the moisture content, organic matter, organic carbon, organic nitrogen, exchangeable bases (with the exception of calcium and sodium) and all the heavy metals assessed as compared to soil without e-waste. The concentration of the heavy metals in e-waste soil is Pb>Zn>Mn>Ni>Co>Cr>Cd while the concentration in soil without e-waste is

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Zn>Pb>Mn>Cr>Ni>Co>Cd. However, decreased were observed in the pH and organic phosphorus of the e-waste soil. Furthermore, eight microorganisms were isolated from soil of e-waste dumpsite where e-waste is burnt while five microorganisms were isolated from soil without e-waste. The bacterial population ranged from 1.68×10^7–1.92×10^7 cfu/ml while the fungi population ranged from 1.0×10^5–2.0×10^5 sfu/ml. The genera of microorganisms isolated were; *Bacillus, Proteus, Enterobacter, Staphylococcus, Candida, Zoopage, Articulospora* and *Varicosporium*.

Conclusion: The formation of substances such as ash and charred matter due to burning might improve soil properties. On the other hand the burning leads to increase in the soil's heavy metals, which might become toxic to organisms in the soil if their permissible level is surpassed. This causes environmental pollution and therefore it is useful to study the impact of e-waste burning on soil properties. Moreover, it is important to consider a recycling strategy in order to protect the soil and its living organisms from harsh process of burning e-waste.

Keywords: Burning; e-waste; impact; soil; microorganism; physicochemical.

1. INTRODUCTION

Electronic waste is any household or office appliance consuming electricity and reaching the end of its life cycle [1]. Electronic waste (e-waste) includes a wide and developing range of electronic appliances ranging from large household appliances, such as refrigerators, air-conditioners, cell phones, stereo systems and consumable electronic items to computers discarded by their users [2]. E-waste contains valuable metals (copper, platinum group) as well as potential environmental contaminants, especially lead, mercury, nickel, selenium, cadmium, polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs). Most e-waste is disposed in landfills. Effective reprocessing technology, which recovers the valuable materials with minimal environmental impact, is expensive. Consequently, although illegal under the Basel Convention, rich countries export an unknown quantity of e-waste to poor countries, where recycling techniques include burning and dissolution in strong acids with few measures to protect human health and the environment [1]. Such reprocessing initially results in extreme localized contamination followed by migration of the contaminants into receiving waters and food chains [3].

Methane, carbon oxides (CO and CO_2), nitrogen oxides (NO and NO_2), volatile organic carbon and aerosols emitted as a result of the deliberate or accidental burning which constitute a large component of the greenhouse gas emissions of many African countries. In sub-Saharan Africa, biomass burning is the primary source of carbon IV oxide emissions in this region [4]. Loss of plant nutrients, up to 80% of nitrogen, 25% of phosphorous, 21% of potassium [5] and 4-60% of sulphur [6] had been reported due to burning. Burning had been also identified as a contributor to soil structural degradation [7]. While some studies have suggested that burning activities might increase availability of plant nutrients [8].

Soil quality and resilience have a profound impact on productivity and environmental quality. Soil quality refers to the soil capacity to produce economic goods and services and to regulate the environment. Its capacity sustain plant and animal productivity, maintain or enhance water quality and promote plant and animal health. Soil quality is thus an ideal indicator of sustainable land management [9]. Soil resilience is the ability of the soil to restore its life support processes and environmental regulatory function after major anthropogenic disturbance, that is, its ability to absorb agriculture practices are among the largest source of stress and disturbance of the environment [10].

Soil biological processes contribute to soil fertility enhancement by increasing the amount and efficiency of nutrient acquisition and recycling, the regulation of the retention and flow of water and nutrients and the maintenance of good soil physical structure. Soil biological processes influence ecosystem functioning through nutrient cycling, organic matter transformation, microbial decomposition and nutrient retention [10]. Through their feeding and nesting activities, soil organism generates and maintains soil chemical, physical and biological characteristic within the ecosystem. Bacteria can directly or indirectly modify soil properties through their feeding activities, burrowing and casting [11]. Burning may release nutrient to fertilize the soil. Ash from burning also increases the pH of the soil, a process that makes certain nutrients, (especially phosphorous) more available in the short term. Burning also drives off temporarily, soil microorganism, pests and established plants long enough for crops to be planted in the ashes [10]. Therefore the present study is undertaken, to investigate the impact of e-waste burning on soil properties as compared to adjacent soil. And results are geared towards raising public awareness on the danger of burning e-waste to dispose them and its impact on soil microbes.

2. MATERIALS AND METHODS

2.1 Collection of Soil Samples

Soil samples were collected from e-waste dumpsite Alaba International Market, Lagos State, Nigeria. Samples were obtained using soil auger at depths of 6cm. The samples were collected in sterile containers and taken for physiochemical and microbiological analysis [12], [13].

2.1.1 Cultural characteristics of fungi

Visible observation and microscope at low power magnification (x40), the parameters such as colony colour, characteristics of the submerged hyphae rhizoid, spiral or regular and characteristic shape of mature fruiting bodies were observed.

2.1.2 Microscopic examination of fungi

This involved transferring a small piece of mycelium free of medium using a sterile inoculating loop unto a clean glass slide containing a drop of cotton blue-in-lactophenol and the mycelium was spread properly. The preparation was covered with a clean grease free cover slip and observed under medium power (x100). The observations made were used in identifying the fungi [14].

2.2 Biochemical and Morphological Identification of Bacteria Isolates

Individual colonies were identified by morphological and biochemical techniques using methods described by [15].

2.3 Total Plate Count

Plates in triplicates from e-waste soil and soil without e-waste were observed for their microbial loads.

2.4 Enumeration of Fungi and Bacteria Counts

Spore/colony counting was carried out by counting the number of visible spores/colonies that appeared on the plates. Calculation of spore/colony forming unit (sfu/cfu) per ml for fungi and bacteria were based on the volume of the sample used.

2.5 Physiochemical Parameters

The physiochemical parameters measured were; pH [16], Organic carbon determination and Organic matter, total phosphate determination, exchangeable bases and nitrogen determination [17] and heavy metals determination in soil samples were estimated using atomic absorption spectrometer [18].

3. RESULTS

Table 1 shows the physiochemical characteristics of the soil samples with differences in all the determined parameters, while Tables 3 and 4 show the microbiological profile of the soil samples with similarities in some bacterial and fungal isolates present.

4. DISCUSSION

The differences in colour of the soil samples (Table 1) could be due to variation in the quantity of organic matter and elemental composition of the soil samples [21].

The pH value of soil sample from e-waste dumpsite could be linked with accumulation of basic metabolites as well a high mineral content of the soil [22]. The high content of organic matter and organic carbon in soil samples from e-waste dumpsite compared with that from the control (soil without e-waste) could be attributed to burning e-waste which probably as many organic components [23].

The lower phosphorous value of sample A could be due to the effect of e-waste burning on this limiting element of the soil. Some amounts of phosphorous might have been lost to the atmosphere by volatilization during burning of the e-waste [24].

All the heavy metals analyzed for in the soil samples falls below the standard permissible limit (Table 2), continuous burning of e-waste on this dumpsite can bring the value beyond the permissible limit. Since the values of heavy metals from e-waste dumpsite soil was higher than soil without e-waste. This would have come from the release of heavy metals from e-waste components during burning. The heavy metal values which were below the permissible level could have resulted from the fact that the rate of heavy metals release through the burning of e-waste is not the same rate at which it is been leached or it formed compounds.

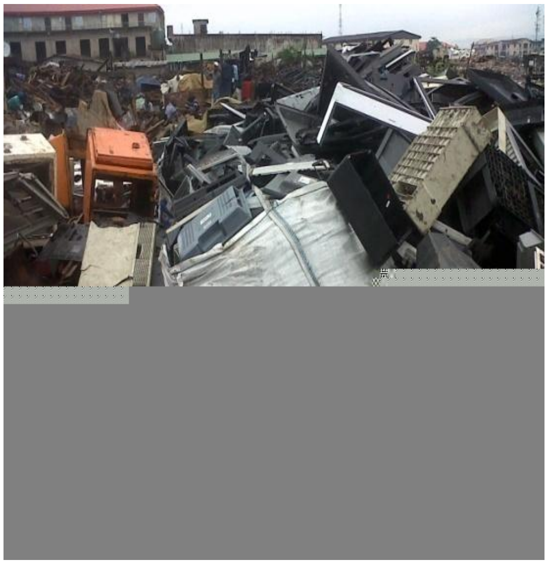
The heavy metals analyses of the soil samples also revealed that soil from e-waste dumpsite where e-waste is burnt had higher quantity of heavy metals in part per million than soil without e-waste (Table 1). This could have resulted from e-waste burning on open land which lead to increase in the released of heavy metals to the soil. Of the heavy metal assessed, lead had the highest quantity (64.90 mg/kg). This gave a probable insight to the extent of lead usage in the manufacturing of electrical electronic equipments or gadgets. This was in line with the reports of other researchers that lead is the fifth most widely used metal after iron, aluminium, copper and zinc. It is commonly used in the electrical and electronics industry in solder, lead-acid batteries, electronic components, cable sheathing, in the glass of cathode ray tubes. Lead and the other heavy metals in this research are known to be environmental contaminates and are toxic to living cells [25]. High quantity of these heavy metals in the soil could affect the micro and macro organisms in such soil if their maximum limit is exceeded. Herna´ndez et al. [26] documented that application of biosolid containing heavy metals to soil has reserve effects in quality and quantity of microbial biomass while Frostegard et al. [27] documented the effect of heavy metals in biosolid on microbial community structures. It can also lead to bioaccumulation in plants growing on this soil and this can invariably affect higher animals such as human feeding on those plants. Non control burning of e-waste at the dumpsite (the site (Fig. 1) can be seen as an open place without facility for control burning) increases heavy metals mobility contained in circuits covered with plastic grid while not being bioavailable following wash-out. They are released to the atmosphere during burning. This could leads to dissolution or settling of airborne contaminants, which could also result in the contamination of aquatic systems [1].

The exchangeable bases Na^+, K^+, Ca^{2+} and Mg^{2+} in the soil samples (Table 1) were high compared with those from tar sand and crude oil contaminated soil. This could be due to the accumulation of charred biomass [28]. Reports had also shown that low pH (acidic) favours the abundance of exchangeable anions, but reduced cations, while high pH (basic) favours the abundance of exchangeable cations, but reduced anions in soils [29]. Hence, the latter reason could also be responsible for the results of cations in this study.

Table 1. Soil physiochemical parameters

S/N	Parameter	A	B
1.	Colour	Black	Brown
2.	Texture	Sandy-loamy	Sandy
3.	pH	7.90	8.70
4.	Moisture content (%)	3.86	2.24
5.	Organic matter (%)	17.60	5.00
6.	Organic carbon (%)	10.17	2.89
7.	Organic nitrogen (%)	0.35	0.21
8.	Organic phosphorus (mg/kg)	146.65	160.00
9.	Lead (mg/kg)	64.90	3.06
10.	Cadmium (mg/kg)	0.32	0.02
11.	Zinc (mg/kg)	35.50	3.34
12.	Cobalt (mg/kg)	0.83	0.05
13.	Chromium (mg/kg)	0.54	0.26
14.	Manganese (mg/kg)	18.60	2.99
15.	Nickel (mg/kg)	2.82	0.08
16.	Sodium (mg/kg)	24.40	31.40
17.	Potassium (mg/kg)	33.30	32.90
18.	Calcium (mg/kg)	182.00	245.00
19.	Magnesium (mg/kg)	34.00	29.70

Key: A- soil from e-waste burning site, B- soil without e-waste



1a). Newly dumped e-waste at the dumpsite

1b). Dismantled e-waste at the dumpsite

1c). E-waste recycling process at the dumpsite 1

1d). Recycled e-waste parts at the dumpsite

Burning e-waste on soil might kill some of the soil microorganisms. The products of the burning might become new substrates that encourage/discourage the colonization of the substrate and the area by new organisms. This might have been responsible for the disparity in the microbial population of soil samples in this study (Table 3). A total of four (4) fungi and (4) bacteria were isolated from the e-waste soil sample while two (2) fungi and three (3) bacteria were isolated from soil without e-waste sample (Table 4). The low number and variety must have been influence by the burning. Different effects of burning on soil microorganisms had been studied. Kara and Bolat [30] found no significant differences in microbial biomass carbon between the burned and unburned soils. In other studies, however, it was reported that soil microbial biomass carbon was reduced after burning [31]. Similarly, Choromanska and DeLuca [32] observed that repeated burning can diminish microbial biomass carbon relative to soils that have been only burnt once. Theodorou and Bowen [33] found, after 4 weeks of a bushfire of moderate intensity, an increase in microbial numbers in the burned soil in comparison with the control. Bauhus et al. [34] found that fire could promote autotrophic bacteria over chemotropic bacteria because of the soil enrichment in mineral salts. The different responses in the microbial biomass carbon variations between the studies were likely caused by several interlaced factors, including fire frequency and severity, soil surface conditions (wetland or forest), soil organic carbon change and prevailing weather conditions [35]. These authors also found a higher bacteria/fungi ratio in burned soil caused by the rise in pH after fire. In soil rich in organic matter, fire can increase the pH by lowering the organic acid contents and producing hydroxides and carbonates added to the soil with ashes [36]. The liming effect of ashes in increasing soil pH seems to be of less importance until the rainfall leaches ash mineral constituents into the soil profile. It is well known that the organic carbon content is dramatically reduced and its quality is strongly modified by fire [37].

The use of fire as manangement practice is therefore questionable. Theodorou and Bowen [33] pointed out that one of the more serious fire threats is the burning of the unincorporated organic layer, with subsequent exposition of the soil to erosion and leaching of nutrients for several years. Although microorganisms account for 1 to 5% of soil organic matter [38], they act both as a sink of mineral nutrients and a catalyst during the decomposition of organic material. These microbial features are greatly influenced by environmental stresses, fire included.

Articulospora inflata, Zoopage nitospora, Varicosporium elodeae, *Candida* sp, *Proteus vulgaris*, *Bacillus cereus* and *Bacillus subtilis* had been isolated from many environments (such as crude oil polluted environment, gastrointestinal tract, agricultural soil) their presence also in these samples could have been as a result of their ability to adapt to different environmental conditions and use wide range of food substances as nutrient and energy source [39-42]. It was observed from this study that, the dominant bacteria were gram positive, catalase positive, coagualase negative, rod bacteria. *Bacillus* spp. has also been known to be related to carbon mineralization and known as one of the commonly found rod bacteria in the soil [43]. This might be responsible for their presence in these soil samples. The isolation of human pathogenic bacteria genera *Proteus* and *Staphylococcus* from the soil samples suggests recent human activities (possibly discharge of fecal matters and urine).

Table 2. Heavy metal maximum recommended limits in soil

Heavy metals	Maximum limits in soil (ppm)
Lead (Pb)	250 – 500
Cadmium (Cd)	3 – 6
Zinc (Zn)	300 – 600
Nickel (Ni)	Not available
Chromium (Cr)	Not fixed
Manganese (Mn)	200 – 9000

Sources: [19,20]

Table 3. Average microbial population

Sample	A	B
Bacteria loads (cfu/ml)	1.68×10^7	1.92×10^7
Fungi counts (sfu/ml)	2.00×10^5	1.00×10^5

Key: A- soil from e-waste burning site, B- soil without e-waste, cfu/ml – colony forming unit/millilitre, sfu/ml– spore forming unit/milliliter

Table 4. Microbial isolates from burnt e-waste soil and the soil without e-waste

Isolates	A	B
Bacterial isolates		
Bacillus subtilis	+	+
Bacillus cereus	+	-
Proteus vulgaris	+	+
Enterobacter sp	-	+
Staphylococcus aureus	+	-
Fungal isolates		
Candida sp	+	+
Zoopage nitospora	+	-
Articulospora inflata	+	+
Varicosporium elodeae	+	-

Key: + = present, - = absent, A- soil from e-waste burning site, B- soil without e-waste

5. CONCLUSION

Burning e-waste on soil might kill some of the soil microorganisms. The products of the burning might become new substrates that encourage the colonization of the substrate and area by new organisms. Though burning of biomass improved some soil properties, this practice causes significant environmental pollution and might kill beneficial soil microorganisms. Therefore it is useful to consider strategy to manage soil health and reduce impact of e-waste burning on the environment. Moreover more research is required to evaluate the effect of fire on other soil properties. Use of fire in the management of e-waste should be based on a sound knowledge of its potential impact on soil physicochemical and biological properties. Both short and long term studies of the soil microorganism's species composition of communities and their response to fire, are required. Since electrical electronic equipments and gadgets (source of e-waste) are also necessary and their production should not be stopped, therefore there should be laid down guidelines for the proper disposal of e-waste, if they are not recycled.

CONSENT

It is not applicable

ETHICAL APPROVAL

It is not applicable

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Gaidajis G, Angelakoglou K, Aktsoglou D. E-waste: Environmental Problems and Current Management. Journal of Engineering science and Technology. 2010;3(1):193-199.
2. Hicks C, Dietmara R, Eugsterb M. The recycling and disposal of electrical and electronic waste in China—legislative and market responses. Environmental Impact Assessment Review. 2005;25(5):459–471. ISSN 01959255.
3. Yuan C, Zhang HC, McKenna G, Korzeniewski C, Li J. Experimental Studies on Cryogenic Recycling of Printed Circuit Board. International Journal of Advanced Manufacturing Technology. 2007;34:657–666.
4. Vagen TG, Lal R, Singh BR. Soil carbon sequestration in Sub Saharan Africa: *A Review*. Land Degradation Development. 2005;16:53–71.
5. Ponnamperuma FN. Straw as a source of nutrients for wet-land rice. In: Banta S, Mendoza CV, (Eds.). Organic matter and rice. IRRI, Los Banos, Philippines; 1984.
6. Lefroy RD, Chaitep W, Blair GJ. Release of sulphur from rice residue under flooded and non-flooded soil conditions. Australia Journal of Agricultural Resources. 1994;45:657-667.
7. Hubbard RT, Clinton BD, Vose JM, Knoepp JD, Elliott KJ. Nutrient and carbon pools and fluxes following stand restoration burning in oak/pine forest types in the Conasauga river watershed; 2004.
8. Niemeyer T, Niemeyer M, Mohamed A, Fottner S, Ha¨rdtle W. Impact of prescribed burning on the nutrient balanc e of Heath Lands with particular reference to nitrogen and phosphorus. Appl. Veg. Sci. 2005;8:183–192.
9. Lai R. Soil degradation effects on slope length and tillage methods on alfisols in Western Nigeria, soil physical properties. Land Degradation Development. 1997;8: 325-342.
10. Adeduntan SA. Effects of slash and burning on soil microbial diversity and abundance in the tropical rainforest ecosystem, Ondo State, Nigeria, African Journal of Plant Science. 2010;4(9):322-329.
11. Ahn PM. The optimum Length of Planted Fallow. In. Mongi HO, Huxley PA, (Eds). Soil Research in Agroforestry. Proceedings of an expert Consultation held at the international council for Research in Agroforestry (ICRAF). Nairobi, Kenya; 1979.
12. Voroney RP. The Soil Habitat in Soil Microbiology. Ecology and Biochemistry. 2006;38:720–728.
13. Ibitoye AA. Laboratory Manual on Basic Soil Analysis. 2nd edition. Foladave Publishing Company, Akure, Ondo State, Nigeria; 2006.
14. Onions AHS, Allsopp D, Eggins HOW. Smiths Introduction to Industrial Mycology. Edward Arnold, London. 1981;398(34):1109-1113.
15. Fawole MO, Oso BA. Laboratory manual of Microbiology. 5th edition. Spectrum Books Limited, Ibadan, Nigeria; 2007.
16. Hendershot WH, Lalande H, Duquette M. Soil reaction and exchangeable acidity. In: Soil Sampling and Methods of Analysis (Carter MR, ed.). Boca Raton, FL, USA: Lewis Publisher; 1993.
17. AOAC. Official Method of Analysis: Association of Analytical Chemists. 19th Edition. Washington DC; 2012.

18. Lacatusu R. Appraising levels of soil contamination and pollution with heavy metals. In: Heineke HJW, Eckelmann AJ, Thomasson RJ, Jones A, Montanarella L, Buckley B, (Eds.). European Soil Bureau-Research Report No. 4. Section. 2000;5(7):393-403.
19. WHO. Environmental health criteria 108: Nickel. International programme on chemical safety. World Health Organization; 1989. Available:http:\\www.inchem.org/documents/ehc
20. FEPA (Federal Environmental Protection Agency). Guidelines and Standards for Environmental Pollution Control in Nigeria; 2003.
21. Wagai KH, Mayer LN, Kitayama, Knicker H. Climate and Parent matter Storage in Surface Soils. A three–pool, density approach. Geoderma. 2008;147:23–33.
22. Ijah UJJ, Abioye OP. Assessment of physicochemical and microbiological properties of soil 30 months after kerosene spill. Journal of Research in Science and Management. 2003;1(1):24–30.
23. Akinmosin A, Osinowo OO, Oladundoye MA. Radiogenic components of the Nigerian Tar Sand Deposits, Earth Science Research Journal. 2009;13(1):64-73.
24. DeBano LF, Klopatek JM. Phosphorus dynamics of pinyon-juniper soils following simulated burning. Soil Science Society of America Journal. 1988;52:271-277.
25. Grant K, Goldizen FC, Sly PD, Brune MN, Neira M, van den Berg M, Norman RE. Health consequences of exposure to e-waste: A systematic review, The Lancet Global Health. 2013;2214-{109X}.
26. Herna´ndez T, Moral R, Perez-Espinosa A, Moreno-Caselles J, Perez Murcia MD, Garcı´a C. Nitrogen minerlisation potential in calcareous soils amended with biosolids. Bioresources Technology. 2002;83:213–219.
27. Frostegard A, Tunlid A, Baath E. Phospholipid fatty acid composition biomass and activity of microbial communities from two soil types experimentally exposed to different heavy metals. Applied Environmental Microbiology. 1993;59:3605–3617.
28. Abebe N, Endalkachew K. Impact of Biomass Burning on Selected Physicochemical Properties of Nitisol in Jimma Zone, Southwestern Ethiopia. International Research Journal of Agricultural Science and Soil Science. 2011;1(9):394-40. ISSN: 2251-0044.
29. Oyedele DJ, Gasu MB, Awotoye OO. Changes in soil properties and plant uptake of heavy metals on selected municipal solid waste dump site in Ile-Ife, Nigeria. African Journal of Environmental Science and Technology. 2008;3(5):107-115.
30. Kara O, Bolat I. Short-term effects of wildfire on microbial biomass and abundance in black pine plantation soils in Turkey. Ecological Indicators. 2009;9: 1151–1155.
31. Harris WN, Boutton TW, Ansley RJ. Plant community and soil microbial carbon and nitrogen responses to fire and clipping in a southern mixed grassland. Rangeland Ecology and Management. 2008;61(6): 580–587.
32. Choromanska U, DeLuca TH. Microbial activity and nitrogen mineralization in forest mineral soils following heating: evaluation of post-fire effects. Soil Biology and Biochemistry. 2002;34:263–271.
33. Theodorou C, Bowen GD. Effcets of a bush fire on the microbiology of south Australian low open dry sclerophyll forest soil, Australia Forest Resources. 1982;12:317–327.
34. Bauhus J, Khan PK, Raison RJ. The effect of fire on carbon and nitrogen mineralization and nitrification in an Australian forest soil, Australia Journal of Soil Resources. 1993;31:621–639.
35. Zhao H, Tong DQ, Lin Q, Lu X, Wang G. Effect of fires on soil organic carbon pool and mineralization in a Northeastern China wetland. Publications, Agencies and Staff of the U. S. Department of Commerce. 2012;424.
36. Ulery AL, Graham RC, Amrhein C. Wood-ash composition and soil pH following intense burning, Soil Science. 1993;156:358–364.
37. Gillon D, Gemendy V, Houssard C, Maréchal J, Valette JC. Combustion and nutrient losses during laboratoriy burns, International Journal of Wildland Fire. 1995;51:1–12.
38. Raison RJ, McGarity JW. Changes in carbon and nitrogen fractions of graminaceous straws after burning, Plant and Soil. 1979;51:311–318.
39. Aimee KZ, Molly B, Wiley S, Barbara AL, Jackie LM, John RP. Risk of Fungemia Due to *Rhodotorula* and Antifungal

Susceptibility Testing of *Rhodotorula* Isolates. Journal of Clinical Microbiology. 2003;41(11):5233–5235.

40. Ashlee ME, Richard L, Roberto K. Ecology and genomics of *Bacillus subtilis*. Trends in Microbiology. 2008;16(6). DOI: 10.1016/j.tim.03.004.
41. Alfreda ON, Ekene GO. Bioremediation of crude oil polluted soil using bacteria and poultry manure monitored through soybean productivity. Polish Journal of Environmental Studies. 2012;21(1):171–176.
42. Krijgsheld P, Bleichrodt R, Van Veluw GJ, Wang F, Muller WH, Dijksterhuis J, Wosten HAB. Development in *Aspergillus*. Studies in Mycology. 2013;74:1–29.
43. Perfumo A, Banat IM, Marchant R, Vezzulli L. Thermally Enchanced Approaches for Bioremediation of Hydrocarbon-Contaminated soil. Chemosphere. 2007; 66(1):179-84.

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