SpringerLink

Published: 21 July 2018

Effect of biochar on the nutrient contents and metal recovery efficiency in sorghum planted on landfill soils

O. Oziegbe, O. T. Aladesanmi & O. O. Awotoye

International Journal of Environmental Science and Technology volume 16, pages2259–2270(2019)Cite this article

Abstract

The study investigated the quality and bioaccumulation of selected heavy metals in sorghum grown in biochar-treated landfill soils. Composite soil samples were collected from the three main landfill sites in Lagos State, Nigeria. All soil samples were obtained at 0–15 cm soil depth, and a control site was established at 3 m downstream of each of the site. The soil samples were air-dried and analysed for physico-chemical properties and metals concentrations using standard methods in the laboratory. Sorghum seeds were planted in five landfill soil pots, treated with wood biochar at 5 t ha^{-1} interval, from 0 to 20 t ha^{-1}, and replicated thrice for each soil in a completely randomized design approach for a screenhouse experiment. The plants were harvested at 12 weeks after planting and later oven-dried at 70 °C for 48 h before they were digested and analysed. The results showed that Cu and Pb concentrations in the landfill soils exceeded standard guidelines for agricultural soils, but these reduced with biochar application rate in the soils. Biochar applications at 10–15 t ha^{-1} also produced the best growth performance and tissue nutrient in the sorghum. Assessment of the biomass efficiency indicated greater performance in the capacity to immobilize more metals concentrations at 20 t ha^{-1} and was worse at 5–10 t ha^{-1} biochar applications. The study concluded that the use of biochar as organic amendment on contaminated soils can be vital for soil remediation in polluted environments.

References

Agency for Toxic Substances and Disease Registry (ATSDR) (2005) Cadmium toxicity where is cadmium. http://www.atsdr.cdc.gov/. Accessed 15 July 2016

Anikwe MAN, Nwobodo KCA (2001) Long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. Bioresour Technol 83:241–250

Article

Google Scholar

Antonious GF, Snyder JC (2007) Accumulation of heavy metals in plants and potential phytoremediation of lead by potato, Solanum tuberosum L. J Environ Sci Health 42:811–816

Article

CAS

Google Scholar

APHA, Awwa, WEF (1992) Standard methods for the examination of water and wastewater. American Public Health Association, Washington

Google Scholar

Asai H, Samson BK, Stephan HM, Songyikhangsuthor K, Homma K, Kiyono Y, Inoue Y, Shiraiwa T, Horie T (2009) Biochar amendment technique for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. Field Crops Res 111:81–84

Article

Google Scholar

Beesley L, Moreno-Jimenez E, Gomez-Eyles JL, Harris E, Robinsin B, Sizmur T (2011) A review of biochars' potential role in remediation, revegetation and restoration of contaminated soils. Environ Pollut 159:2369–3282

Google Scholar

Borchard N, Prost K, Kautz T, Moeller A, Siemens J (2011) Sorption of copper(II) and sulphate to different biochar before and after composting with farm yard manure. Eur J Soil Sci 63(3):399–409

Article

Google Scholar

Bouyoucos GF (1962) Hydrometer method improved for making particle size analysis of soils. Agron J 54:464–465

Article

Google Scholar

Bray RH, Kurtz LT (1945) Determination of total organic and available forms of phosphorus in soils. Soil Sci 59:39–45

Article

CAS

Google Scholar

Bremner JM, Mulvaney CS (1982) Nitrogen-Total. In: Page AL, Miller RH, Keeney DR (eds) Methods of soil analysis. Part 2. Chemical and microbiological properties. American Society of Agronomy, Soil Science Society of America, Madison, pp 595–624

Google Scholar

Cameron KC, Di HJ, McLaren RG (1997) Is soil an appropriate dumping ground for our wastes? Aust J Soil Res 35:995–1035

Article

Google Scholar

Cao X, Harris W (2010) Properties of dairy manure derived biochar pertinent to its potential use in remediation. Bioresour Technol 101(14):5222–5228

Article

CAS

Google Scholar

Carter S, Shackley S, Sohi S, Suy TB, Haefele S (2013) The impact of biochar application on soil properties and plant growth of pot grown lettuce (Lactuca sativa) and cabbage (Brassica chinensis). Agronomy 3(2):404–418

Article

CAS

Google Scholar

Chaab A, Savaghebi GH (2010) Effect of zinc application on the Cadmium uptake of maize growth. Agr Segment 1515

Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S (2008) Using poultry litter biochars as soil amendments. Aust J Soil Res 46:437–444

Article

Google Scholar

Cui L, Li L, Zhang A, Pan G, Bao D, Chang A (2011) Biochar amendments greatly reduces rice Cd uptake in contaminated paddy soil: a two year field experiment. Bioresources 6(3):2605–2618

CAS

Google Scholar

Dahlbert J, Wilson JP, Synder T (2004) Sorghum and pearl millet: health foods and industrial products in developed countries. In: Alternative uses of sorghum and pearl millet in Asia. Proceedings of an expert meeting, ICRISAT, Patancheru, Andhra-Pradesh, India, pp 42–59

Deenik JL, McClellan T, Uehara G, Antal MJ, Campbell S (2010) Charcoal volatile matter content influences plant growth and soil nitrogen transformations. Soil Sci Soc Am J 74:1259–1270

Article

CAS

Google Scholar

Doran JW, Zeiss MR (2000) Soil health and sustainability: managing the biotic component of soil quality. Appl Soil Ecol 15:3–11

Article

Google Scholar

Ducic T, Polle A (2005) Transport and detoxification of manganese and copper in plants. Braz J Plant Physiol 17:1

Article

Google Scholar

Fellet G, Marchiol L, Delle Vedove G, Peressotti A (2011) Application of biochar on mine tailings: effects and perspectives for land reclamation. Chemosphere 83:1262–1267

Article

CAS

Google Scholar

Fessler TA (2005) Trace element monitoring and therapy for adult patients receiving long-term total parenteral nutrition. Practical gastroenterology, Nutrition issues in gastroenterology, Series 25

Food and Agricultural Organization (FAO) (1984) Plant production and protection series-agrochmatological data for Africa countries north of the equator. FAO, Rome, vol 1(22), p 8

Gaskin JW, Speir RA, Harris K, Das KC, Lee RD, Morris LA, Fisher DS (2010) Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. Agron J 102:623–633

Article

CAS

Google Scholar

Gwenzi W, Gora D, Chaukura N, Tauro T (2016) Potential for leaching of heavy metals in open-burning bottom ash and soil from a non-engineered solid waste landfill. Chemosphere 147:144–154

Article

CAS

Google Scholar

Henry RJ (2000) An overview of phytoremediation of lead and mercury. United States Environmental Protection Agency, Office of solid waste and emergency response technology innovation office, Washington, DC

Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN (2014) Toxicity, mechanism and health effects of some heavy metals. Interdiscipl Toxicol 7(2):60–72

Article

CAS

Google Scholar

Jiang J, Xu R, Jiang T, Li Z (2012) Immobilization of Cu(II), Pb(II) and Cd(II) by the addition of rice straw derived biochar to stimulate polluted utisol. J Hazard Mater 229–230:145–150

Article

CAS

Google Scholar

Jones DL, Healey JR (2010) Organic amendments for remediation: putting waste to good use. Elements 6:369–374

Article

CAS

Google Scholar

Juo ASR (1982) Automated and semi-automated methods for soil and plant analysis. IITA, Ibadan, p 33

Google Scholar

Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG (2008) Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environ Pollut 152(3):686–692

Article

CAS

Google Scholar

Lehmann J, Kern DC, Glaser B, Woods WI (2003) Amazonian dark earths: origin, properties and management. Kluwer Academic, Netherlands

Google Scholar

Lia MS, Luo YP, Su ZY (2007) Heavy metal concentrations in soils and plant accumulation in a restored manganese mineland in Guangxi, South China. Environ Pollut 147(1):168–175

Article

CAS

Google Scholar

Lima IM, Boykin DL, Klasson KT, Uchimiya M (2014) Influence of post-treatment strategies on the properties of activated chars from broiler manure. Chemosphere 95:96–104

Article

CAS

Google Scholar

Lu H, Zhang YY, Huang X, Wang S, Qiu R (2012) Relative distribution of Pb2+ sorption mechanisms by sludge-derived biochar. Water Res 46:854–862

Article

CAS

Google Scholar

Martin S, Griswold W (2009) Human health effects of heavy metals. Environ Sci Technol 15:1–6

Google Scholar

Nagajyoti PC, Lee KD, Sreekanth TVM (2010) Heavy metals, occurrence and toxicity for plants: a review. Environ Chem Lett 8(3):199–216

Article

CAS

Google Scholar

Ndor E, Dauda SN, Azagaku ED (2015) Response of maize varieties (Zea mays) to biochar amended soil in Lafia, Nigeria. Am J Exp Agric 5(6):525

CAS

Google Scholar

O'Day PA, Vlassopoulous D (2010) Mineral-based amendments for remediation. Elements (Que) 6:375–381

Article

CAS

Google Scholar

Oancea S, Foca N, Airinei A (2005) Effects of heavy metals on plant growth and photosynthetic activity. Analele Univ. Al. I. Cuza, 1, pp 107–110

Odesola IF, Owoseni TA (2010a) Development of local technology for a small-scale biochar production processes from agricultural wastes. J Emerg Trends Eng Appl Sci 1(2):205–208

Google Scholar

Odesola IF, Owoseni TA (2010b) Small scale biochar production technologies: a review. J Emerg Trends Eng Appl Sci 1(2):151–156

Google Scholar

Odu CTI, Esurosu OF, Nwaboshi IC, Ogunwale JA (1985) Environmental study (soil and vegetation) of Nigeria Agip oil company operation area. A report submitted to Nigeria. Agip Oil Company Limited, Lagos, pp 102–107

Google Scholar

Ogbemudia FO, Mbong EO (2013) Soil reaction (pH) and heavy metal index of dumpsites within Uyo municipality. Merit Res J Environ Sci Toxicol 1(4):82–85

CAS

Google Scholar

Oladipo OG (2013) Effect of microbial heavy metal remediation in soils from selected mine site in Osun and Ekiti States, Nigeria on maize performance. A Ph.D. Thesis of the Institute of Ecology and Environmental Studies. Obafemi Awolowo University Nigeria, p 228

Olarinoye IO, Sharifat I, Kolo MT (2010) Heavy metal content of soil samples from two major dumpsites in Minna. Nat Appl 11(1):90–102

Google Scholar

Oriola E, Omofoyewa O (2013) Impact of charcoal production on nutrients of soils under woodland Savanna Part of Oyo State, Nigeria. J Environ Earth Sci 3(3):46–53

Google Scholar

Park JH, Choppala GK, Bolan NS, Chung JW, Chuasavathi T (2011) Biochar reduces the bioavailability and phytotoxicity of heavy metals. Plant Soil 348(1–2):439–451

Article

CAS

Google Scholar

Paz-Ferreiro J, Lu H, Fu S, Mendez A, Gasco G (2014) Use of phytoremediation and biochar to remediate heavy metal polluted soils: a review. Solid Earth 5:65–75

Article

Google Scholar

Quraishi SM, Adams SV, Shafer M, Meliker JR, Li W, Luo J, Neuhouser ML, Newcomb PA (2016) Urinary cadmium and estimated dietary cadmium in the women's health initiative. J Expos Sci Environ Epidemiol 26(3):303–308

Article

CAS

Google Scholar

Radwan MA, Salma AK (2006) Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food Chem Toxicol 44:1273–1278

Article

CAS

Google Scholar

Reeves DW (1997) The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil Tillage Res 43:131–167

Article

Google Scholar

Riederer AM, Belova A, George BJ, Anastas PT (2013) Urinary Cadmium in the 1999–2008 U.S. National Health and Nutrition Examination Survey (NHANES). Environ Sci Technol 47(2):1137–1147

Article

CAS

Google Scholar

Sathawara NG, Parikh DJ, Garwal YK (2004) Essential heavy metals in environmental samples from western India. Bull Environ Contam Toxicol 73:264–269

Article

CAS

Google Scholar

Shareef TME, Zhao BW (2017) Review paper: the fundamentals of biochar as a soil amendment tool and management in agriculture scope: an overview for farmers and gardeners. J Agric Chem Environ 6:38–61

CAS

Google Scholar

Sharma P, Dubey RS (2005) Lead toxicity in plants. Braz J Plant Physiol 17:35–52

Article

CAS

Google Scholar

Smith CJ, Hopmans P, Cook FJ (1996) Accumulation of Cr, Pb, Cu, Ni, Zn and Cd in soil following irrigation with untreated effluents in Australia. Environ Pollut 94:317–323

Article

CAS

Google Scholar

Snowball K, Robson AD (1991) Nutrient deficiencies and toxicities in wheat: a guide for field identification. International Maize and Wheat Improvement Center, Mexico

Google Scholar

Steinbeiss S, Gleixner G, Antonietti M (2009) Effect of biochar amendment on soil carbon balance and soil microbial activity. Soil Biol Biochem 41:1301–1310

Article

CAS

Google Scholar

Steiner C, Glaser B, Teixeira WG, Lehmann J, Blum WEH, Zech W (2008) Nitrogen retention and plant uptake on a highly central amazonian ferralsol amended with compost and charcoal. J Plant Nutr Soil Sci 171(6):893–899

Article

CAS

Google Scholar

Tellez-Plaza M, Jones MR, Dominguez-Lucas A, Guallar E, Navas-Acien A (2013) Cadmium exposure and clinical cardiovascular disease: a systematic review. Curr Atheroscler Rep 15:356

Article

CAS

Google Scholar

Thomas GW (1982) Exchangeable cations. In: Page AL, Miller RH, Keeney DR (eds) Methods of soil analysis. Part 2. Agronomy monographs no 9, 2nd ed. American Society of Agronomy, Madison, pp 403-430

Trakal L, Komarek M, Szakova J, Zemanova V, Tlustos P (2011) Biochar application to metal-contaminated soil: evaluating of Cd, Cu, Pb and Zn sorption behavior using single multi element sorption experiment. Plant Soil Environ 57(8):372–380

Article

CAS

Google Scholar

Uchimiya M, Bannon DI, Wartelle LH (2012) Retention of heavy metals by carboxyl functional groups of biochars in small arms range soil. J Agric Food Chem 60:1798–1809

Article

CAS

Google Scholar

United Nations Environment Programme and United Nations University (UNEP and UNU) (2009) Recycling from e-waste to resources. Sustainable innovation and technology transfer industrial sector studies. www.ewasteguide.info/UNEP_2009_Ew2R. Accessed 15 June 2015

United Nations Food and Agriculture Organisation (FAO) (2012) Trade data base, production data base. http://faostat.fao.org. Accessed 15 June 2015

United States Environmental Protection Agency (USEPA) (2007a) The use of soil amendments for remediation, revitalization and reuse. https://clu-in.org/download/remed/epa-542-r-07-013.pdf. Accessed 18 Sept 2016

United States Environmental Protection Agency (USEPA) (2007b) Municipal solid waste generation, recycling and disposal in the United States: facts and figures for 2006. http://www.epa.gov/.../advancing-sustainable-materials-management-facts-and-figure. Accessed 18 Sept 2016

Van Zwieten L, Kimber S, Downie A, Morris S, Petty S, Rust J, Chan KY (2010) A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. Aust J Soil Res 48:569–576

Article

CAS

Google Scholar

Varvel GE, Peterson TA (1990) Nitrogen fertilizer recovery by corn in monoculture and rotation systems. Agronomy 82:935–938

Article

CAS

Google Scholar

Verheijen FGA, Jeffery S, Bastos AC, Van der Velde M, Diafas I (2009) Biochar application to soils—a critical scientific review of effect on soil properties, processes and functions. EUR 24099EN, Office for Official Publications of the European Communities, Luxembourg, p 149

Walkley A, Black IA (1934) An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci 37:29–37

Article

CAS

Google Scholar

Wang X, Sato T, Xing B, Tao S (2005) Health risk of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Sci Total Environ 350(1–3):28–37

Article

CAS

Google Scholar

Woolf D (2008) Biochar as a soil amendment: a review of the environmental implications. http://orgprints.org/13268/1/Biochar_as_a_soil_amendment_-_a_review.pdf. Accessed 15 June 2016

Yilangai RM, Manu AS, Pineau W, Mailumo SS, Okeke-Agulu KI (2014) The effect of biochar and crop veil on growth and yield of Tomato (Lycopersicum esculentus Mill) in Jos, North central Nigeria. Curr Agric Res J 2(1):37–42

Article

Google Scholar

Download references

Acknowledgements

The authors appreciate the contributions of Dr. A.O. Eludoyin of the Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria for statistical analysis and providing guidance to the first author in the course of this publication; the Central Science Research Laboratory at the Obafemi Awolowo University, for providing space for laboratory analysis; and the reviewers for their corrections and clarification.

Author information

Affiliations

Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria

O. Oziegbe, O. T. Aladesanmi & O. O. Awotoye

Corresponding author

Correspondence to O. Oziegbe.

Ethics declarations

Conflict of interest

The authors declare that there is no conflict of interest in either the research that form the basis of this paper or the content of the paper itself. We also want to clear that the research did not receive any sponsorship or funding from any individual, organisation, group or country, and as such does not have any conflict of interest with them.

Appendix 1: Growth performance of sorghum as affected by biochar concentration

Appendix 1: Growth performance of sorghum as affected by biochar concentration

Landfill	Biochar concentration	Plant height	No. of leaves	Dry weight
Olusosun	0	27.75	4	0.15
	5	150.00	10	5.51
	10	90.00	6	13.91
	15	26.00	4	0.34
	20	28.00	6	0.67
Control	0	220.00	12	29.16
	5	200.00	12	16.25
	10	124.99	7	19.06
	15	152.00	10	10.64
	20	150.00	10	12.22
Solous II	0	50.00	5	0.62
	5	46.00	15	1.19
	10	23.00	4	0.32
	15	23.75	4	0.23
	20	140.00	8	23.45
Control	0	130.00	8	19.50
	5	121.17	7	1.49
	10	126.25	8	7.95
	15	20.00	12	13.58
	20	280.00	18	23.20
Solous III	0	150.00	10	10.32
	5	200.00	8	14.43

10	180.00	8	39.80	
15	180.00	12	21.24	
20	240.00	25	72.54	
Control	0	190.00	8	19.57
5	84.98	7	1.65	
10	106.31	8	6.70	
15	224.04	12	6.97	
20	251.12	18	24.00	

About this article

Verify currency and authenticity via CrossMark

Cite this article

Oziegbe, O., Aladesanmi, O.T. & Awotoye, O.O. Effect of biochar on the nutrient contents and metal recovery efficiency in sorghum planted on landfill soils. Int. J. Environ. Sci. Technol. 16, 2259–2270 (2019) doi:10.1007/s13762-018-1843-3

Download citation

Received

27 May 2017

Revised

13 November 2017

Accepted

12 June 2018

Published

21 July 2018

Issue Date

01 May 2019

DOI

https://doi.org/10.1007/s13762-018-1843-3

Keywords

Bioaccumulation of heavy metals

Contaminated soils

Landfill sites

Organic amendments

Sorghum performance