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African Journal of Environmental Science and Technology

Table of Contents: Volume 10 Number 3 March 2016

ARTICLES

Effects of vegetation's degradation on carbon stock, morphological, physical and chemical characteristics of soils within the mangrove forest of the Rio del Rey Estuary: Case study – Bamusso (South-West Cameroon) 58
NDEMA NSOMBO Eugene, AKO'O BENGONO Frédéric, ETAME Jacques, NDONGO DIN, AJONINA Gordon, and Paul BILONG

Physico-chemical and microbiological profile of bacterial and fungal isolates of Ikpoba River in Benin City: Public health implications 67
OLOGBOSERE, O.A., ALUYI, H.S.A., OGOFURE, A.G., BESHIRU, A. and OMEJE, F.I.

Effect of biochar on soil properties and lead (Pb) availability in a military camp in South West Ethiopia 77
Bayu Dume, Tadesse Mosissa and Amsalu Nebiyu

Assessment of sharps waste management practices in a referral hospital 86
Veilla E. Matee and Samwel V. Manyele

Using geographic information system (GIS) to determine waste transfer stations in relation to location of landfill sites in Accra Metropolis 96
Lyndon Nii Adjiri Sackey

academicJournals

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Full Length Research Paper

Effects of vegetation's degradation on carbon stock, morphological, physical and chemical characteristics of soils within the mangrove forest of the Rio del Rey Estuary: Case study – Bamusso (South-West Cameroon)

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This study was conducted to assess the capacity of mangroves soils to stock carbon and how degradation can influence its various properties. Transect method was performed. So, two transects of 100 m length and 10 m wide were established according to the degradation level. Total of 18 Soil samples were taken to be described and analysed. The degraded transect (T_1) shows a mean carbon stock value of 2102.06 ± 405 $Mg.ha^{-1}$ while natural (T_2) accumulate 2476.6 ± 409 $Mg.ha^{-1}$. Colour are more light inside the degraded transect (Brown to grayish) than the natural transect (brown to blackish) while spots are more colored in natural transect (gray and yellow) than degraded one (yellow). pH mean value showed that soils of degraded transect was more acidic than those of natural one. Organic matter amount was very high and proves that these soils can be valorized to agricultural activities without previous enrichment. Total Nitrogen was low in the two transects while the available phosphorus values showed that natural transect has more available phosphorus that can be used by the plants than degraded transect. So, degradation would take along reduction of available phosphorus rate in the soils. According to this result showing important different values of carbon stock and soils properties between natural and degraded transect, it is necessary to implement conservation methods in order to stop degradation and enhance capacity of mangroves soils properties.

Key words: Bamusso, degraded transect, natural transect, soils, values.

INTRODUCTION

Along Cameroon's coast, mangrove swamps are estimated to cover a surface area of roughly 1961.84 km^2 (Spalding et al., 2010). They are mainly distributed between two estuaries (Rio del Rey Estuary and

Cameroon Estuary) but are equally present in small zones with variable surface areas in the South Region of Cameroon (Rio Ntem Estuary).

Mangrove swamps for some decades now have been recognized as having public interest. Undeniably, their benefits are both economical (Kovacs, 1999) and ecological. Ecotone between land and marine environment, the ecosystem of mangrove swamps is a very unique structural and functional zone (Betoulle, 1998), playing a role in coastal food chains (Dittmar et al., 2001; Laedgaard and Johnson, 2001) and constituting an important source of carbon (Twilley et al., 1992; Gattuso et al., 1998). Most recent studies on mangrove swamps have proven the ability of this ecosystem to avert the phenomenon of climate change by sequestrating the carbon of these various components (Trevor et al., 2014; Adame et al, 2013; Donato et al, 2012; Lovelock et al, 2011). Moreover, mangrove swamps play a barrier role against natural disasters. This is the way they safeguard the surrounding populations against damage which can be caused by cyclones, tsunamis and hurricanes (Dahdouh-Guebas, 2006; Alongi, 2008). They also produce goods and services as well as income to the community (Krauss et al., 2008).

Mangrove swamps also constitute an important source of revenue and several other survival and commercial activities such as fishing and wood exploitation are carried out there (Din et al., 2006).

However, several studies show that approximately 5 to 85% of the original area of mangrove swamps was predominantly lost during the second half of the 20th century due to degradation and deforestation.

Degradation of ecosystems is qualified as reduction of the quality of factors like forest crown, fauna, soils or carbon stock loss. Associate to the deforestation, degradation constitute about 18% of anthropogenic emission of CO_2 through the forest sector (IPCC, 2007). The recent estimation suggest that 9.4% of Amazonian forest at Brazil have been loss and about 16% within Congo Basin forest (Bernou et al., 1999).

The mangrove swamps of Africa endure enormous pressures during the last decades, to the point that in west and central Africa, 20 to 30% of mangrove swamps have vanished in 25 years (UNEP, 2007). This is due to several factors and in particular is urbanization through the development of infrastructures and residences, the exploitation of salt mines and sand, pollution caused by industries, the industrial agrochemical products and the exploitation of oil and gas, the absence of an appropriate legislation, the cutting down of trees for fish smoking (Ajonina and Usongo, 2001; Ajonina et al., 2005), the increase of insidious species and the effects of climate change, amplified by population growth.

Nowadays, Cameroon hydrology and mangrove soils properties are highly disturbed due to vegetation degradation. Deforestation release not only carbon in atmosphere but has also negative effects on biodiversity, soils protection and local climate regulation. More also, use land for urbanization and agriculture activities contribute gradually to release soils and plants carbon stock (Michalak et al., 2011).

In view of the above observations the major objective of the present study is to assess how degradation of vegetation influences carbon stock and soils parameters within Bamusso mangrove's forest.

MATERIALS AND METHODS

Study site

The study was carried out in the mangrove forest of the locality of Bamusso (Rio del Rey Estuary). Being the sub-divisional capital, Bamusso is a peninsula located in the Ndian Division of the South West Region. Bordered to the South and the West by the Atlantic Ocean, to the North by Ekondo Titi and to the East by Meme and Fako Divisions (Figure 1), this locality of geographical coordinates latitude 4° 45 ' - 4° 50 ' North and longitude 8° 30 ' - 9° 00 ' East has a vegetation of evergreen forest subjugated by the mangrove swamp and intermittent by a shrubby meadow (Ajonina, 2011). This mangrove forest conquered by the family of Rhizophoraceae is cut apart by a large number of waterways for fishermen, poachers and tourists. The climate of the region is influenced by the propinquity of the Atlantic Ocean and Mount Cameroon on one hand, and on the other hand, by the Intertropical Convergence Zone where the anticyclone of the Azores of the Northern hemisphere and that of Saint Helena coming from the South converge (Din, 2001).

This climate fits into the equatorial domain of littoral type or "Cameroonian" which is characterized by two seasons with a long rainy season (from March to November) that can totally expunge the dry season always interspersed with rains. Bamusso shows annual average precipitation of the order of 3800 mm. The sociological component is made up of non-native and natives. While the natives consider mangrove swamps as sacred sites dedicated to diverse rites, the non-natives use them for construction, fish smoking and to a lesser extent for farming.

Methods

The sampling method is that of transects (Imbert, 1985). Two transects of 100 m length and 10 m wide giving a surface area of 1000 m^2 each were established one named transect 1 or T_1 inside degraded mangrove forest and another (transect 2 or T_2) in natural or non disturbed mangrove forest. They were 5 km apart with base lines directed WSW-ENE and perpendicular to the main channel. Each transect was split into three plots of 20 m x 10 m and each division was further subdivided into four meshes of 10 m x 5 m using systematic approach (Ndema et al., 2008). One manual drill was established in the middle of each mesh and one well (30 cm diameter and one meter depth) in the middle of each plot. Totally, three wells and twelve manual drills (four per plot) were established within each transect (Figure 2). Morphological characteristics of

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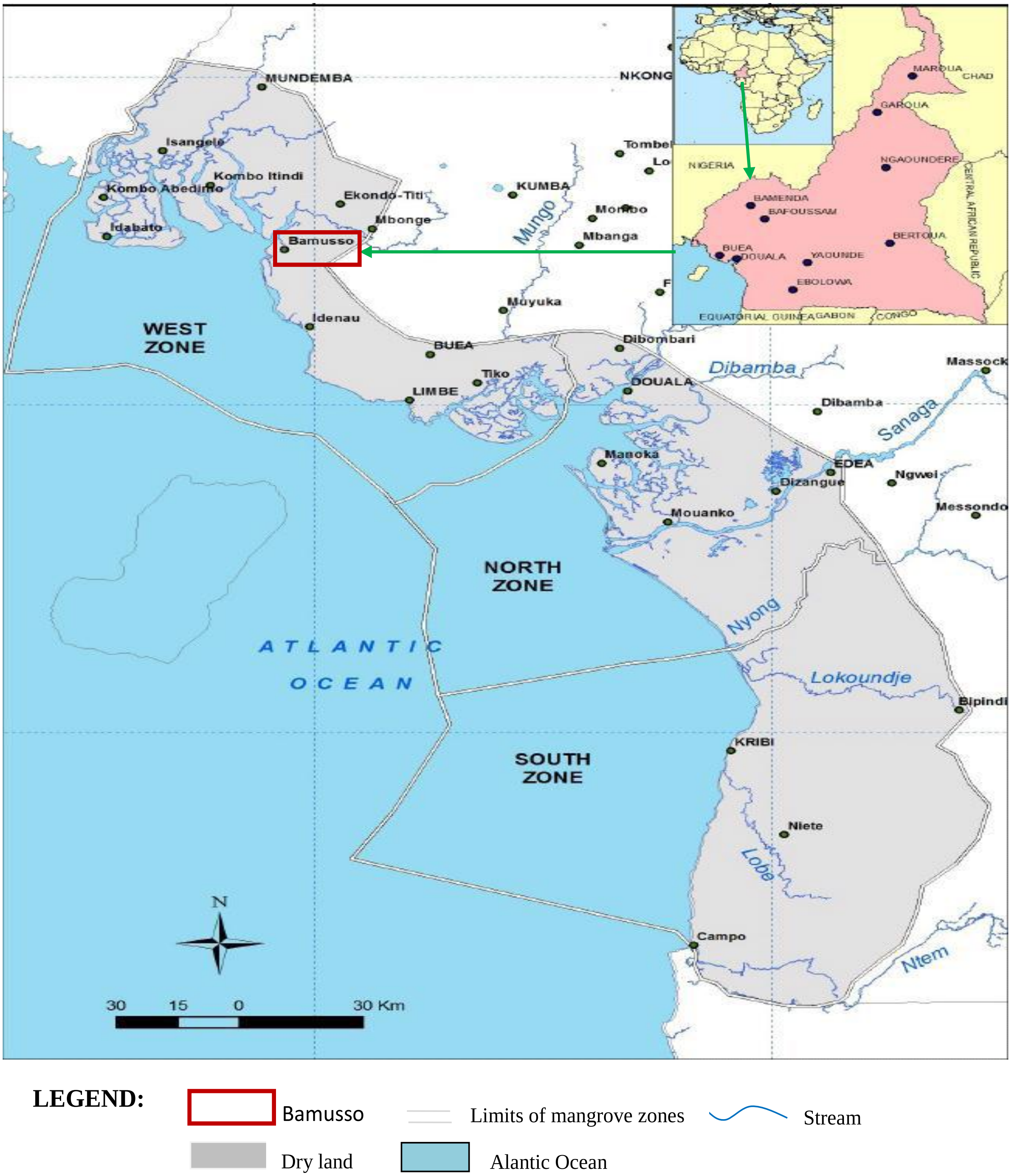

Figure 1. Localization of the study site (modified from Ajonina, 2011)

soils were determinate during digging process of drills and wells by observation of soils cuttings and monoliths (Figure 3A and B). So, colour of horizon was determined by using Munsell soils colour chart, structure by soil's aggregate observation, texture by hand wetted soils touching and organic elements as dead leaf, roots and spots by direct observation.

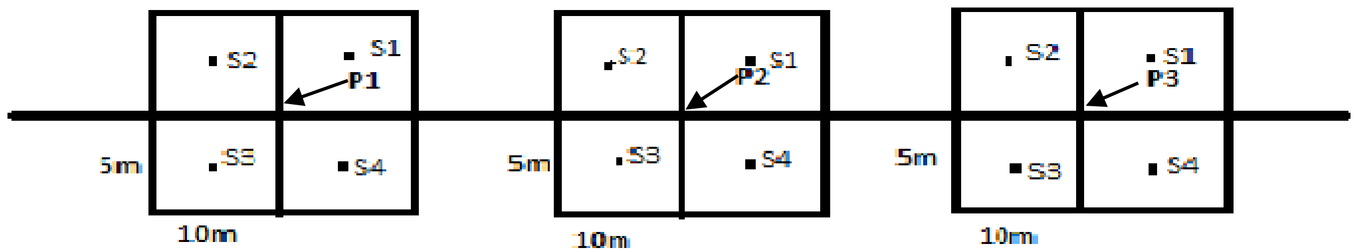

Figure 2. Meshing of plot and position of wells (P) and drills (S).

Figure 3. Field soils works: Well digging (A); Monolith extraction (B)

Analysis of soils samples

Soil samples were taken from six different wells (three per transect) at three depths intervals (0 - 30, 30 - 50 and 50-100 cm). Eighteen composite samples prepared from 0 – 30 cm (six samples), 30 - 50cm (six samples) and 50-100 cm (six samples) depths were analyzed in the laboratory. The parameters analysed included (i) particle size distribution by the pipetting method of Robinson (Schalk, 1988), (ii) bulk density by using a peat auger consisting of a semi-cylindrical chamber as described by Yoro and Godo (1990), (iii) soil pH was measured by reading method through field multi parameters conductive meter (Anderson, 1999), (iv) organic carbon was measured by the procedure of Walkley and Black (1934), (v) exchangeable potassium, sodium, calcium and magnesium of the soil using the procedure of Jackson (1958), (vi) total nitrogen content by the method of Kjeldahl (Bremner, 1996), (vii) available phosphorus by the method of proportioning colorimetric starting from the nitrochlorhydric solution of ashes (Stuffins, 1967), (viii) cationic exchange capacity (CEC) by colorimetric using spectrophotometer (Jackson, 1965) while carbon stock was determinate by the formula C (kg/m^2) = C ($mg.g^{-1}$ Sol)*Da*e (Da=Bulk density, e=thickness of horizon).

Data analyzes

The collected data were statistically handled and analyzed by two approaches: the descriptive and the inferential statistics. The descriptive statistical analysis consisted in arranging the data in EXCEL spreadsheet, and in obtaining the results in the form of tables and graphs. The inferential statistical analysis was made by means of the SPSS software package; and the latter served to determine if there is a significant difference between the soils characteristics of the different transects using one ANOVA test.

RESULTS AND DISCUSSION

Effects of degradation on soil carbon stock

The degraded transect (T_1) shows a mean carbon stock value of 2102.06 ± 405 $Mg.ha^{-1}$ while natural or non disturbed transect (T_2) accumulate 2476.6 ± 409 $Mg.ha^{-1}$ (Table 1). Following depth, in surface (0-30 cm), the carbon stock is 2006.8 ± 199.07 $Mg.ha^{-1}$ inside degraded transect (T_1) while it is 2308.6 ± 503.9 $Mg.ha^{-1}$ in natural transect (T_2). In middle depth, (30-50 cm), the degraded transect shows value of 1375.4 ± 105.71 $Mg.ha^{-1}$ against 1346.6 ± 139.74 $Mg.ha^{-1}$ for the natural transect. The stock of carbon in depth horizons is 2954 ± 944.77 $Mg.ha^{-1}$ in T_1 and 3774.6 ± 528.59 $Mg.ha^{-1}$ in T_2.

Carbon stock present high value within natural transect than degraded one. So, degradation contribute to reduce carbon stock in the mangroves soils. This carbon is released on atmosphere and enhances climate change phenomena. At Bamusso, degradation would be responsible of release of 374.54 $Mg.ha^{-1}$ of carbon.

Effects of degradation on morphological properties of soils

The degraded transect showed globally clayey to silty texture, doughy to fibrous structure, brown to grayish color and abundant thin roots, yellows spots as well as

Table 1. Carbon stock per transect and per depth at Bamusso (values are mean ± SE).

Transect	Depth (cm)	Da (g/cm^3)	CO (%)	Carbon stock (Mg/ha)
	0-30	0.73 ± 0.57	9.11±0.41	2006.8±199.07*
Degraded (T_1)	30-50	0.73 ± 0.57	9.38±0.17	1375.4±105.71*
	50-100	0.73 ± 0.57	7.93±2.39	2924±944.77*
		Mean		2102.06
	0-30	0.93 ± 0.11	8.16±0.95	2308.6±530.09*
Natural (T_2)	30-50	0.93 ± 0.11	7.33±1.55	1346.6±139.74*
	50-100	0.93 ± 0.11	8.12±1.02	3774.6±528.59*
		Mean		2476.6

***significant at p=0.05 using One Way ANOVA test

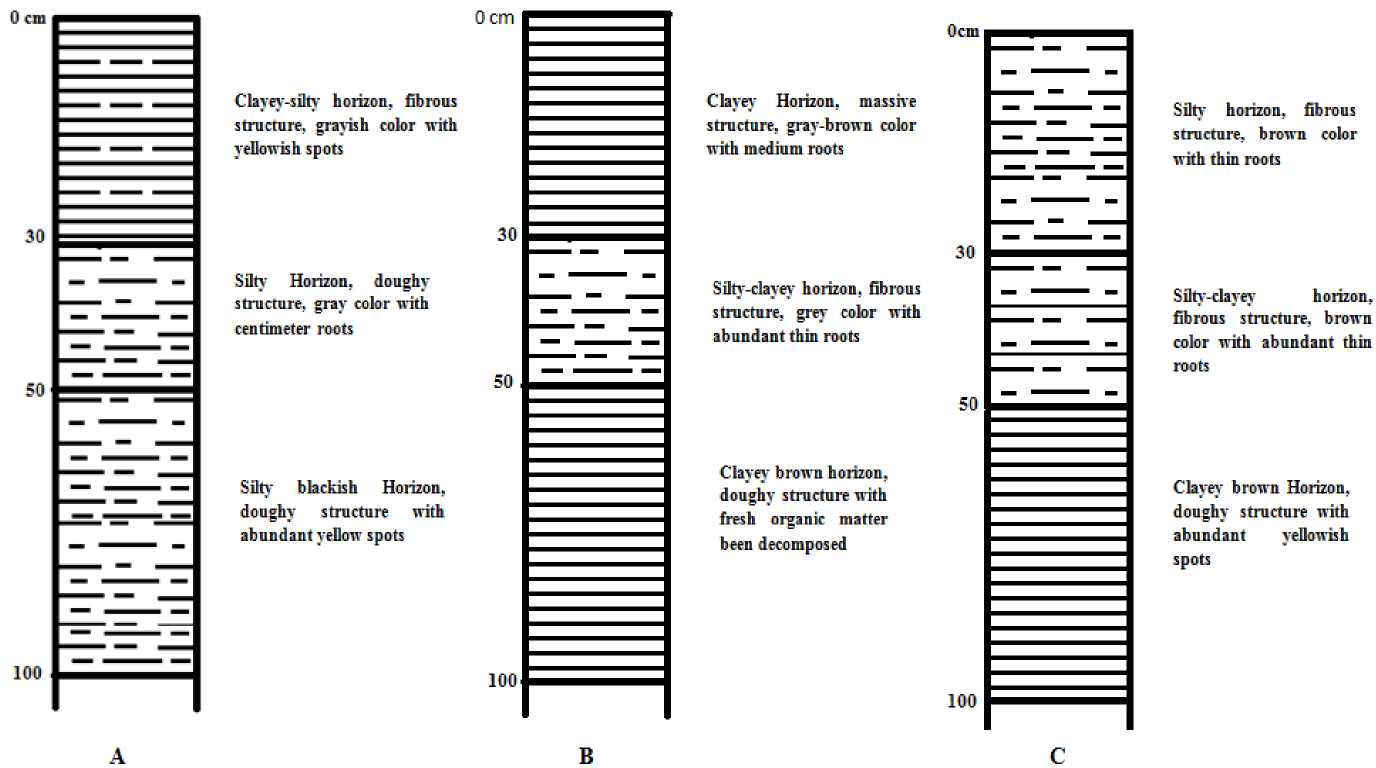

Figure 4. Profiles of soils in degraded transect (T_1): Well n^o 1 (A); Well no 2 (B); Well no 3 (C)

decomposed organic matter (Figure 4A, B and C). Within natural transect the texture was clayey to clayey-silty, with a doughy to massive structure, a brown to blackish color and medium roots, yellowish to grayish spots as well as fresh and decomposed organic matter (Figure 5A, B and C). Organic elements are similar between the two transect but the texture is more fine in the natural transect (clayey to clayey-silty) than in the degraded one (clayey to silty). That can be explain by the high microbiological activity that transform macromolecular to fine particles within the natural transect. Also the importance of leaching phenomenon in the degraded transect can explain his less fine texture (Duchaufour, 2001). Color also are more light inside the degraded transect (Brown to grayish) than the natural transect (brown to blackish) while spots are more colored in natural transect (gray and yellow) than degraded one (yellow) as in Abata (1994) study inside the Wouri mangroves. We can conclude that degradation change texture from fine to coarse and color from dark to light. Yellows and grays spot explain the temporary hydromorphy phenomenon of soils within the two

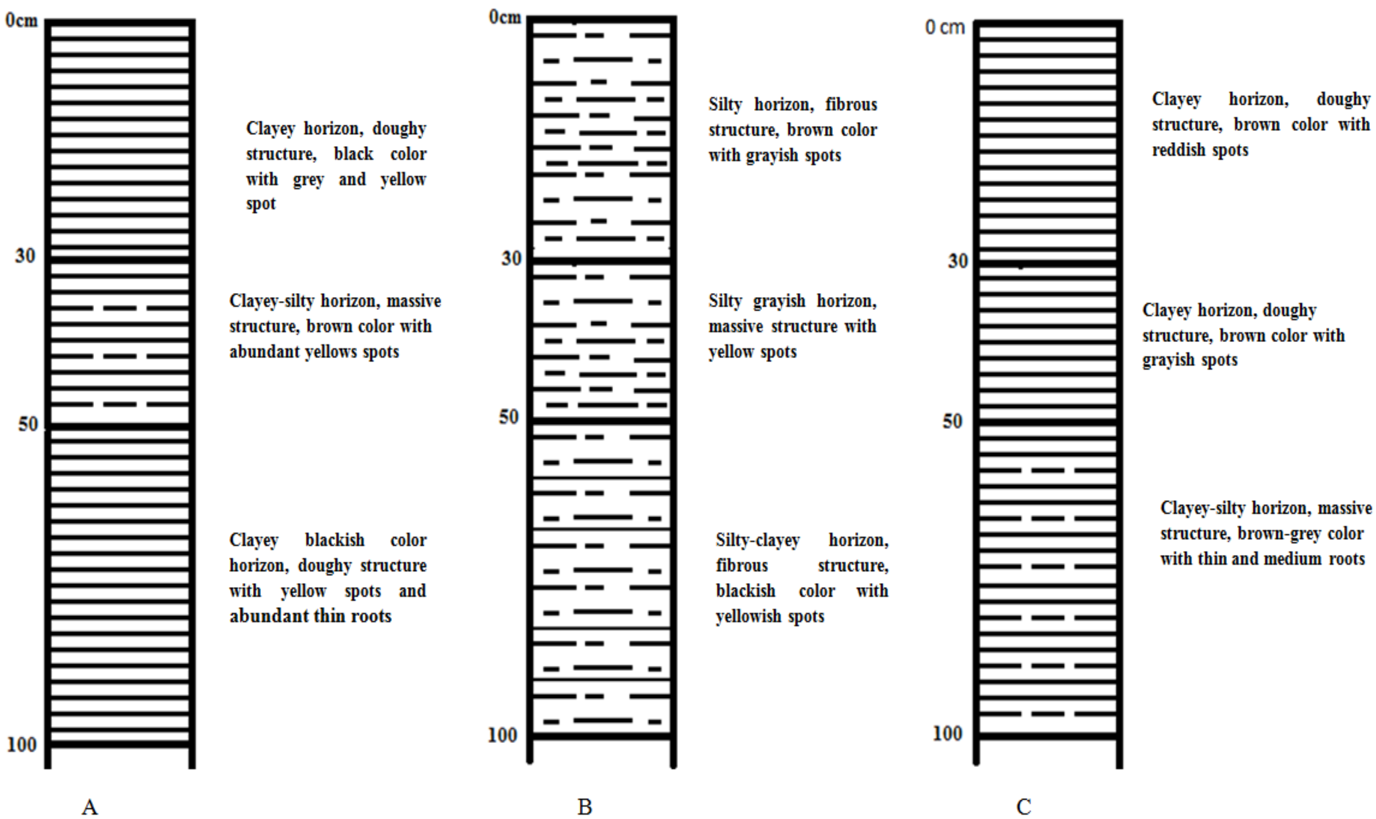

Figure 5. Profiles of soils in natural transect (T_2): Well n° 1 (A); Well n° 2 (B); Well n° 3

Table 2. Comparison of morphological characteristics of soil.

Characteristics				Study area	Reference
Structure	**Texture**	**Color**	**Organic elements**		
Lumpy, fibrous and spongy	Clayey to clayey-silty	Blackish to grayish	Brown, red or light spots	Mangroves forest of Cameroon estuary	Baltzer (1995) Abata (1994)
Doughy, tchick, particulary to fibrous	Sandy-silty	Black, gray-black	Leftovers of shell , sulfurus smell, Plants leftovers	Mangrove forest of Port-Gentil (Gabon)	
Particulary	Sandy	Light	Plants leftovers	Marshy forest of Gabon Forest	Ondo (2006)
Particulary	Sandy	Light	Plants leftovers	Rainy Savana forest	
Doughy to fibrous	Clayey to silty	Brown, blackish to grayish	Decomposed plants leftovers, yellowish and grayish spots, thin roots	Mangroves of Rio Del Rey Estuary (Bamusso)	Present study

transects (Ondo, 2006).

These morphological characteristics are more near to the one described by Baltzer (1995) and Abata (1994) than those of Ondo (2006) (Table 2).

Effects of degradation on physical and chemical characteristics of soils

Particle size shows in mean 45 ± 5.5% of sand, 30 ± 5.5%

Table 3. Physical and chemical characteristics of soils at Bamusso

Transect	Particle size (%)			pH		CO (%)	MO(%)	N_{tot}(%)	P_{ass} (mg/kg)	Exchangeable bases (cmol/kg)				CEC (cmol/kg)
	Sand	Silt	Clay	pH water	pH KCl					Ca	Mg	K	Na	
Degraded (T_1)	45±5.5ns	30±5.5*	25±0.01**	2.25±0.33ns	2.08±0.001*	8.81±1.48ns	15.15±2.26ns	0.20±0.01ns	13.7±3.57ns	5.08±2.57ns	4.43±1.8*	0.07ns	0.01ns	21.25±7.21ns
Natural (T_2)	44±3.3ns	36±0.01*	20±3.3**	2.43±0.52ns	2.3±0.52*	7.87±1.22ns	13.77±0.62ns	0.16±0.01ns	17.86±3.57ns	2.26±0.66ns	0.99±0.7*	0.07ns	0.01ns	6.66±0.97ns

Value are mean and obtained by analyzing composite samples from different soil layers ± SE; ***=Significant at p=0.05 and 0.01 respectively; ns=non-significant)

of silt and 25 ± 0.0001% of clay within degraded transect(T_1) against 44 ± 3.3% of sand, 36 ± 0.01% of silt and 20 ± 3.3% of clay in natural transect (T_2). pH water means values are 2.25 ± 0.33 in degraded transect and 2.43 ± 0.52 in natural transect. Those of pHKCl are 2.08 ±0.001 in T_1 and 2.3 ± 0.52 in T_2.

Organic carbon (CO) was 8.81 ± 1.48% inside degraded transect and 7.87 ± 1.22% in natural transect when organic matter (MO) was 15.15 ± 2.26% in T_1 and 13.53 ± 2.06% in T_2.

Total nitrogen (N_{tot}) was 0.20 ± 0.01% in degraded transect and 0.16 ± 0.01% in natural one. Available phosphorus (P_{ass}) was 13.7 ± 3.57 mg/kg in degraded transect and 17.86 ± 3.57 mg/kg in natural transect. Exchangeable bases were 5.08 ± 2.57 cmol/kg (T_1) and 2.26 ± 0.66 cmol/kg (T_2) for calcium (Ca) against 4.43 ± 1.81 cmol/kg (T_1) and 0.99 ± 0.7 cmol/kg(T_2) for magnesium. Cation exchangeable capacity (CEC) was 21.25 ± 7.21 cmol/kg in T_1 and 6.66 ± 0.97 cmol/kg in T_2 (Table 3).

We notice slight increase of sandy particle inside degraded transect (T_1). So, degradation of vegetation take along soil's destitution that promote erosion and leaching phenomenon what reduce fine particles within this transect (T_1). pH mean value showed that soils of degraded transect was more acid than those of natural one. Degradation contributes to increase acidification of mangroves soils. All the pH values of soils were less than 4 means that they would be qualified as high acid soils (Landon, 1984).

The low value of CO in natural transect (T_2) illustrate a higher biologic activity characterized by rapid mineralization of organic carbon in this transect. Degradation would slow down mineralization process of organic carbon. According to Metson (1961), the mangroves soils at Bamusso have a medium carbon rate because the percentage of their organic carbon is between 4 and 10. Organic matter progress to the same direction than organic carbon because the two characteristics are linked by the linear relationship (MO=1.72*CO). Organic matter has a very high rate (Landon, 1984). These soils can be valorized to agricultural activities without previous enrichment because their organic matter rate is widely above to organic matter critical value for agriculture what is 2%.

Total Nitrogen was low (Landon, 1984) in the two transects while the available phosphorus values showed that natural transect has more available phosphorus that can be used by the plants than degraded transect. So, degradation would take along reduction of available phosphorus rate in the soils.

Exchangeable bases showed high values of calcium and low values of sodium. Their concentration respect bases leaching order (Etame, 2004) which is: Na<K<Mg<Ca. High level of calcium and magnesium would increase cultural capacities of soils and assimilation of certain elements as phosphorus (Cantin, 2004). Low values of sodium and potassium could be explained by leaching because the two bases are highly soluble. According to Landon (1984), calcium is low to the natural transect while it is medium in degraded transect. Magnesium is medium in natural transect and high in degraded transect. Sodium and potassium have low values in the two transects.

Cationic exchangeable capacity showed low values in natural transect and medium one in degraded transects (Table 4).

Conclusion

The study of effect of degradation on carbon stock and properties of soils within mangroves forest of Rio Del Rey Estuary (Bamusso) showed that carbon stock of soils samples can be highly different between degraded and natural transect. Also, this stock of carbon are higher than those of another mangroves forest and five times higher than stock of another non mangroves forest.

Total of 18 soils samples are collected inside six wells (three per transect) trough three depth intervals (0-30, 30-50, 50-100 cm) and analyzed. We noticed that degradation of vegetation would reduce fine particles within soils and contribute to their acidification. Degradation would also slow down mineralization process of organic carbon because values of organic carbon are low in natural transect than degraded one. Available

Table 4. Valuation of cationic exchangeable capacity values within mangroves soils at Bamusso.

Valuation (Landon, 1994)	CEC (cmol/kg) (Landon, 1994)	CEC (cmol/kg) at Bamusso (Present study)
Very low	< 5	-
Low	5-15	5-15
Medium	15-25	15-25
High	25-40	-
Very high	> 40	-

phosphorus was more high in natural transect than degraded one while cationic exchangeable capacity was low in natural transect and medium in degraded transect showing that degradation would take along reduction of available phosphorus rate and increase CEC in the mangroves soils.

This study shows globally low value of carbon stock and soils properties inside degraded transect than natural one. It is important to apply conservation measures to stop vegetation's degradation what it is necessary to preserve soils characteristic potential.

Similar studies are to be encouraged in other localities of Rio del Rey as well as other mangrove swamps sites. If these studies could demonstrate the high values of soils carbon stock as it is the case with the present study, the soils of mangrove swamps of Cameroon could play a preeminent role to limit the phenomenon of climate change by sequestrating atmospheric carbon.

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REFERENCES

Abata T (1994). Mangrove of Wouri Estuary (Douala-Cameroon). Study of microtopography and morphological characterization of soils. DIPES II Thesis, University of Yaounde I, 49p + annexe.

Adame MF, Kauffman JB, Medina I, Gamboa JN, Torres O (2013). Carbon stocks of tropical coastal wetlands within the Karstic Landscape of the Mexican Caribbean. PLoS ONE 8(2):e56569.

Ajonina GN, Jin E, Mekongo F, Ayissi I, Usongo L (2005). Gender roles and economics of exploitation, processing and marketing of bivalves and impacts on forest resources in the Douala-Edaa Wildlife Reserve, Cameroon. Int. J. Sustainable Dev. World Ecol. 12(2005):161- 172.

Ajonina GN, Usongo L (2001). Preliminary Quantitative impact assessment of wood extraction on the mangroves of Douala-Edéa forest reserve, Cameroun. Trop. Biodiv. 7(2)3:137-149.

Alongi DM (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine Coastal Shelf Sci. 76:1-13.

Anderson JM (1999). Tropical soil, biology and fertility hand book methods. 221 p.

Baltzer F, Rudant JP, Tonye E (1995). Applications of microwaves and C tape teledetection to mangroves cartography of Douala region (Cameroon). Proceedings of the second ERS applications workshop, London, UK.

Bernou M, Arrouays D, Cerri C, de AlencastroGraça PM, Volkoff B, Trichet J (1999). Assessment of mangroves soils carbon stock in Rondônia (Amazonie Brazilia). Study and Soils Manage. 5:31-42.

Betoulle JL (1998). Spatio-temporal variation of liter productivity on mangroves of Guyane. Doctorat Thesis. University of Paul Sabatier, Toulouse. 171 p.

Bremner JM (1996). Nitrogen-total. In: Methods of soil analysis. Part 3. Chemical methods. No.5. (ed. D.L. Sparks), pp. 1085-1121. ASA and SSSA, Madison, WI.

Cantin J (2004). Effects of mineral fertilizer in the maize farming. Guide manual. 19 p.

Dahdouh-Guebas F (2006). Mangrove forests and tsunami protection. In : McGraw-Hill (éd). Yearbook of Science & Technology, New York, USA. pp. 187-191.

Din N, Puig H, Blasco F (2006). Exploitation of woods within Douala mangrove (Cameroon). Ann. Fac. Sci. Univ. Yde I, série Sc. Nat. Vie 36(3):89-103.

Dittmar T, Lra RJ, Kattner G (2001). River or mangrove? Tracing major organic matter sources in tropical Brazilian coastal waters. Marine Chemistry 73:253-271.

Donato DC, Kauffman JB (2012). Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor, Indonesia.

Duchaufour P (2001). Introduction to the soils sciences : Soils, vegetations, environment, Dunod, Paris. 331 p.

Etame J (2004). Nephelinit rock weathering in the Etinde mount (Cameroon). Thesis, Univ Yde I, 221 p.

Gattuso JP, Frankignoulle M, Wollast R (1998). Carbon and carbonate metabolism in coastal aquatic ecosystems. Annu. Rev 12:405-433.

Imbert D (1985). Spatio-temporal organisation of vegetal communities within the Great Cul-de- sac marin mangroves (Guadeloupe). University of Montpellier II, Thesis, 132 p + annexes.

IPCC (2007). Climate Change 2007 R Mitigation of Climate Change - Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In. Cambridge University Press, Cambridge, Schlensinger 851 p.

Jackson MI (1965). Chemicals soils Analysis methods applied to exchangeable bases and cationic exchange capacity. Prentice Hall Inc. 112 p.

Jackson MI (1958). Soils chemical analysis. Prentice Hall Inc. 121 p.

Kovacs JM (1999). Assessing mangrove use at the local scale. Landscape and Urban Planning 43:207-208.

Krauss KW, Lovelock CE, McKee KL, Lopez-Hoffman L, Ewe SM, Sousa WP (2008). Environmental drivers in mangrove establishment and early development. Aquat. Bot. 89(2): 105-127.

Laegdsgaard P, Johnson C (2001). Why do juvenile fish utilise mangrove habitats? J. Exp. Marine Biol. Ecol. 257:229-253.

Landon JR (1984). Rangement of soils parameters values. Oxon, UK: Booker Tate Limited; Harlow, Essex, UK: Longman, 131 p.

Lovelock CE, Ruess RW, Feller IC (2011). CO2 Efflux from Cleared Mangrove Peat. PLoS ONE 6(6):e21279.
Metson AJ (1961). Estimation du taux du carbone organique dans le sol. NZ Soil Bur Bull. 96p.
Michalak RB, Jackson G, Marland CL (2011). A U.S. Carbon Cycle Science Plan. A report of the University Corporation for Atmospheric Research supported by NASA, DOE, USDA, USGS, NOAA, NSF, and NIST.
Ndema NE, Etame J, Taffouo VD, Bilong P (2010). Effects of some physical and chemical characteristics of soil on productivity and yield of Cowpea Vigna unguiculata L. Walp.) in coastal region (Cameroon). Afr. J. Environ. Sci. Technol. 4 (3):108-114, March.
Ondo AE (2006). Dynamic of vegetal landscape of littoral center-ouest of Gabon (Port-Gentil): Spatial aproach and field data analysis. Thesis. Univ. Paul-Valery Montpellier 3, France. 302 p.
Schalk VH (1988). Methods of soil's texture determination, Soils Analysis Guideline, 59 p.
Spalding MD, Blasco F, Field CD (2010). World Mangrove Atlas. ISME, Okinawa, Japan. 251p.
Stuffins CB (1967). The determination of phosphorus and calcium in feeding-stuffs. Analyst 92:107-111.
Trevor GJ, Harifidy RR, Lalao R, Garth C, Adia B (2014). Ecological Variability and Carbon Stock Estimates of Mangrove Ecosystems in Northwestern Madagascar. Forests 5:177-205.
Twilley RR, Chen RH, Hargis T (1992). Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. Water, Air and Soil Pollution 64:265-288.
UNEP (2007). The Mangroves of West-Central Africa. UNEP-WCMC Report. 92 p.
Walkley LP, Black JA (1934). An examination of the Detjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

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Physico-chemical and microbiological profile of bacterial and fungal isolates of Ikpoba River in Benin City: Public health implications

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This study examined the physico-chemical and microbiological profile of bacterial and fungal isolates of Ikpoba River between February 2013 and March 2013. The mean bacterial count for upstream water sample obtained in February was 2 × 10^{2} ±1 cfu/ml while 1.09 × 10^{4} ±3.6 was the count for treated industrial effluent sample collected in March. The mean fungal counts for the downstream water sample in February was 2 ×10^{2} ±1 cfu/ml while the count collected at the point of discharge of effluent into the river in March was 2.0 ×10^{3} ±7 cfu/ml. There was a significant statistical difference observed in the mean bacterial and fungal counts ($P<0.05$). The total coliform counts recorded for samples obtained from downstream was 2 MPN/105 ml while 20 MP/ 105 ml was for sample collected at the point of effluent discharge respectively. Several bacterial and fungal genera were isolated from the River water samples. Water samples collected upstream and downstream points on the river were colorless while samples collected at the point of effluent discharge were light brown in color. The mean pH, turbidity and conductivity of the respective samples ranged from 5.63±0.05 to 6.78±0.05, 4.1±0.21 to 6.81±0.55 NTU and 3.3±0.25 to 73.3±6.56 µs/cm. The biological oxygen demand (BOD), dissolved oxygen (DO) and chemical oxygen demand (COD) varied from 2.6±0.5 to 305.19±43.2 mg/l, 5.5±0.3 to 6.1±0.6 mg/l and 15.8±0.6 to 883.8±28.5 mg/l respectively. The quality of Ikpoba River is being negatively impacted by the disposal of effluent as well as human activities around the area rendering the water unsafe for consumption.

Key words: Physico-chemical, microbiological profile, bacterial, fungal isolates.

INTRODUCTION

Water is abundant in the planet as a whole, but fresh potable water is not always available at the right time or the right place for human or ecosystem use and is, undoubtedly the most precious natural resource, vital to life (Karikari and Ansa, 2004). Rivers are open systems, which have come under increasing pressure from human

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activities, often affecting their ecological integrity over the last century throughout the world (Skoulikidis et al., 2002). The physicochemical impact on water quality of rivers have been indicated by rise in conductivity, pollution of water bodies with nitrate, nitrite and soluble reactive phosphorus, by the appearance of tannin and lignin, and by the steady accumulation of inorganic and organic suspended matter along the river (Whitehead et al., 1997). The role of the river is not primarily to carry industrial waste but their ability to do so is hugely exploited. There has been significant impairment of rivers with pollutants, rendering the water unsuitable for beneficial purposes (Filkersilasie, 2011). Rivers provide a variety of services for human populations, including water for drinking and irrigation, recreational opportunities, and habitat for economically important fisheries (Leroy et al., 2002). The growing problem of pollution of river ecosystem has necessitated the monitoring of water quality (Ravindra et al., 2003). Regions with dense human populations are the areas at risk. The earliest anthropogenic threats to water resources were often associated with human health, especially disease causing organisms and oxygen-demanding wastes (Meybeck and Helmer, 1996). Rajaram and Ashutosh (2008) opined that industrial wastes were one of the major causes of irreversible degradation occurring in surface water system. Organic pollution caused by oxygen demanding wastes is common amongst surface water (Masson, 1990). The natural processes of chemical oxidation and biological decomposition that occur within water courses, consume dissolved oxygen. Decomposition of materials is a normal process in all aquatic ecosystems and is a function of decomposers such as aerobic bacteria and fungi (Filkersilasie, 2011). Nonetheless, serious consequences to aquatic biota may result if the natural mechanisms that clean the water are overloaded by large influx of pollutants. Severe oxygen depletion can result in the loss of many desirable aquatic biota and also produce an odorous anaerobic system (Zimmerman, 1993). Majority of the inhabitants that live in riverine areas rely on water from the river for domestic and drinking purposes due to the scarcity of portable water supply by the government (Shuaib, 2004). Wu et al. (1999) reported that in China, approximately 700 million people, over half the population, consume water contaminated with different levels of animal and human excreta with total coliform bacteria exceeding maximum permissible levels by as much as 86% in rural areas and 28% in urban areas. Rapu (2003) stated that in South Africa, over 15% of urban dwellers depend on polluted river waters for their domestic needs. Khalil (2005) reported that over 70% of people in Sudan get their water supply from surface waters, which in most cases are polluted by agricultural chemicals and industrial effluents. Shuaib (2004) stated that over 40% of Nigerians depend on either polluted surface waters or wells for their domestic activities. The constant use of heavily polluted water for a long time usually results in health problems. Researchers in different parts of the world have reported health problems associated with prolong time use of polluted river water, which range from dysentery, diarrhea, abortion, premature birth, viral hepatitis and gastric and duodenal ulcers amongst others (Shuaib, 2004; Odjugo, 2004; Purnamitta, 2004). Ikpoba River also called the Oken River is a fourth order stream situated within the rainforest belt of Edo State, southern Nigeria. The river is particularly important to the people of Benin City which is the capital and largest city of Edo state, estimated to have a population of 1,086,882 people according to 2006 Census. One of the major dams in the Edo State was constructed across the river in Okhoro Community. Industrial effluents and water from drainage channels are discharged into the river at various points as well. Ikpoba River is subject to pollution from storm-water run-off in the rainy season as it flows through inhabited areas and in particular, through Benin City. Most of the activities around the river in its upper reaches are agricultural such as crop farming and fishing (Atuanya *et al*. 2012). Nonetheless, industrial effluents, and drainage system are channeled to the river. Government abattoir managed by the Local government where about 50 cows and goats are slaughtered daily is also situated by the river (Atuanya *et al*. 2012). The aim of this study was to verify if physico-chemical and microbiological parameters of analyzed water are below the regulatory limits to ensure the water quality.

MATERIALS AND METHODS

Study area

The area experiences an equatorial climate. Although there is hardly any month without some elements of rainfall, rains concentrate within the months of March and October (rainy season) while the dry season with little rainfall prevails between November and February (Odjugo and Konyeme, 2008). The mean annual rainfall total is constantly above 2000 mm, relative humidity is above 80% and the mean air temperature is 28°C (Odjugo and Iweka, 2005). Industrial effluent (brewery waste) is conveyed by means of an underground metal pipe which is discharged into the river. In spite of this, people living around this section of the river use the water from the river for drinking, washing of clothes and bathing purposes. Furthermore, fishing activities are conducted by some people living around the river bank close to point of discharge.

Sample collection

Water samples were collected twice a month from three sampling points along Ikpoba River close to the discharge pipe conveying treated effluent from the nearby brewery plant using plastic containers sterilized in 5-10% bleach water thereafter rinsed with boiled water and allowed to dry. Samples of surface water were sourced from about 3 m upstream from the discharge point. Fresh water samples were obtained at the point of discharge (but before effluent discharge) of treated brewery effluent into the river. About 3 m downstream from the point of discharge of the effluent, water samples were also obtained. Also, samples of the treated effluent were also obtained with the aid of sterile plastic containers. The sampling period was conducted from February 2013 to March 2013. The plastic containers were appropriately labeled and were immediately transported to the laboratory for analysis and those that could not be analyzed immediately were stored at 4°C for 6 h in a refrigerator for subsequent analyses.

Total heterotrophic bacterial and fungal counts

The total heterotrophic bacterial and fungal counts of the respective surface water samples were evaluated according to the methods delineated by Harley and Prescott (2002) and Pepper and Gerba, (2004). The total heterotrophic bacterial count for each sample was then determined using nutrient agar as general purpose medium. About 1 ml aliquot of the serially diluted sample was transferred onto sterile labeled plates before the addition of 15 ml of cooled molten nutrient agar under aseptic conditions. Plating were done in triplicates and incubated at 30°C for 48 h. The mean count of the resultant bacterial colonies in triplicate plates were enumerated and recorded. The same procedure was applied in respect of the total fungal count for the respective samples. However, 1 ml of an antibiotic solution (500 µg of chloramphenicol dissolved in 20 ml of distilled water) was pipetted onto each plate before the pouring of 15 ml of cool molten Potato dextrose agar (PDA) (Ogbuile et al., 1998). The PDA plates were incubated at ambient temperatures (28 ± 2°C) for 5 days, after which the mean count of the fungal colonies on replicate plates was also recorded.

Determination of the total coliform and fecal coliform counts

The total coliform and fecal coliform (*Escherichia coli*) counts of the water samples were evaluated according to methods stated by Cheesebrough (2001). Both tests were conducted in three stages namely: Presumptive stage, confirmatory stage and completed stage.

Presumptive stage

Fifty (50) ml of the sample was dispensed to a labeled, sterilized 100 ml conical flask containing 50 ml of sterile MacConkey broth and an inverted Durham tube (for detection of gas production). Also 5 test tubes containing 10 ml sterilized MacConkey broth and inverted Durham tubes were prepared and 10 ml of the respective water samples were added under aseptic conditions. Another 5 test tubes containing 9 ml of sterilized MacConkey broth and inverted Durham tubes were also arranged and 1 ml of the corresponding water samples added also under sterile conditions. These tubes and conical flasks were incubated at 30°C for 48 h. The procedure was repeated for the fecal coliform count but the inoculated test tubes and conical flasks were incubated at 44°C for 24 h. At the end of the respective incubation periods, the test tubes and conical flasks were examined for both acid production and gas production, and reference was made to statistical tables to ascertain the most probable number (MPN) of both the total coliform and fecal coliform count in 10 ml of the respective surface water samples (Cheesebrough, 2001).

Confirmatory stage

About 0.1 ml of the positive presumptive test tubes was pipetted onto test tubes containing 10 ml of sterile MacConkey broth and inverted Durham tubes to detect gas production. The tubes were incubated at 30°C for 48 h for total coliform count and 44°C for 24 h in respect of fecal coliform count.

Completed stage

The contents of the positive confirmatory test tubes (the inoculated test tubes which displayed visible color change at the end of the incubation period) were streaked on freshly prepared Eosin methylene blue agar plates with the aid of a sterile inoculating loop, under aseptic conditions. The colonial morphology of the streaked colonies were observed and further biochemical tests such as methyl red, indole production, citrate utilization, Voges Proskauer and urease production tests were done to further identify the various sub cultured colonies. For the completed stage of the fecal coliform test, indole test was carried out to differentiate between streaked colonies of *Enterobacter aerogenes* and *E. coli* (Cheesebrough, 2001).

Identification and characterization of microbial isolates

Pure cultures of the heterotrophic bacterial isolates were identified and characterized on the basis of cultural, morphological and biochemical characteristics according to the methods of Cullimore (2000), Aneja (2003) and Sharma (2009). The fungal isolates were identified through macroscopic observation of their sub-cultured colonies, microscopic examination of their respective spores and hyphal appendages using wet mount technique (Sharma, 2009). Distilled water and lactophenol cotton blue were utilized as mountants (Ogbulie et al., 1998). The results of the microscopy were compared with illustrations contained in Barnett and Hunter (1972).

Determination of physico-chemical parameters

pH and temperature

The hydrogen ion concentration (pH) of each sample and temperature were measured using a HACH digital pH/temperature meter. The electrode probe was inserted into a glass beaker containing about 20 ml of the sample and the result was read from the screen and recorded. The pH meter was calibrated before and after each readings using freshly prepared pH buffers (7.00), (4.00) and (9.00).

Alkalinity

Total alkalinity was determined by titrimeteric method using standardized sulphuric acid, phenolphthalein and methyl orange indicator. The development of a pink color indicates the presence of carbonate. Then 2 drops of 0.1% methyl orange indicator was added and titrated with standard 0.25 N sulphuric acid. A colourless reaction gave the end point (APHA, 1993).

Total solids

The total solid of each water and effluent sample was derived from the addition of both the total suspended solid (TSS) and total dissolved solid (TDS) values (Ademoroti, 1996).

Electrical conductivity

The electrical conductivity of each water and effluent sample was determined using a portable conductivity meter. 50 ml of the sample was collected with a beaker and the plastic electrode probe was inserted into the sample and the result in microsiemens (µs/cm^{-1}) read from the screen. The meter was calibrated using distilled water after each measurement (APHA, 1993).

Colour

Fifty (50) ml of the water and effluent sample was dispensed into a clean conical flask. The color of the sample was observed and recorded.

Turbidity

The turbidity of the respective water and effluent samples were determined using a spectrophotometer. Twenty five milliters of the sample was dispensed into a curvette and placed in the light chamber and the absorbance was measured at a specific wavelength using distilled water as blank. The turbidity values were recorded in nepholometer turbidity unit (NTU) (APHA, 1993).

Phosphate

Twenty (20) ml of the water and effluent sample was dispensed onto a clean curvette. About 4 ml of phosphate reagent containing ammonium molybdate, antimony potassium tartate and ascorbic acid was also added to the curvette containing the effluent sample. 1 ml of 95% ethanol and 1 ml of concentrated H_2SO_4 was then added. It was shaken, and then left for 5 min to allow for color development. The absorbance was determined at a specific wavelength using a spectrophotometer (Radojevic and Bashkin, 1999).

Nitrate

Ten (10) ml of the sample was then placed in a test tube, followed by the addition of 2 ml NaCl solution, this mixture was swirled and 10 ml of H_2SO_4 solution was also added. The resultant solution was also swirled and allowed to stand. A sample blank was also prepared. To the first test tube containing the mixture of the sample, NaCl and H_2SO_4, 0.5 ml of brucine –sulphanilic acid reagent was added and the test tube was swirled and left to stand for about 20 minutes. The test tubes were allowed to develop color and the absorbance reading of the solution was taken using a spectrophotometer at a specified wave length (Ademoroti, 1996).

Sulphate

Ten (10) ml of the water sample was decanted onto a clean curvette. 1 ml of 95% isopropyl alcohol, 0.5 ml of glycerol and 5 ml of conditioning reagent which consist of NaCl, BaCl and Citric acid were added to the curvette containing the sample. The solution was left to stand for 5 min to allow colour development, after which the absorbance was read at a specific wavelength using a spectrophotometer (APHA, 1993).

Iron (Fe), Nickel (Ni), Copper (Cu) and Lead (Pb)

The concentration of the respective heavy metals (iron, nickel, copper and lead) present in the water and effluent samples were determined with the aid of an Atomic absorption spectrophotometer (Buck Scientific model 210 VGP USA). Appropriate standards of known concentrations of the respective metals were prepared and used to calibrate and auto zero the electrode. The water samples were dispensed onto sterile plastic bottles. After calibrating and auto zeroing the electrodes, the samples were read at specific wavelengths and printed results sheets were examined. The final concentration of the respective metals was deduced (Ademoroti, 1996).

Dissolved Oxygen (DO)

The dissolved oxygen content is the amount of available oxygen present in the water (Venkatesharajuik et al., 2010). The dissolved oxygen value depends on a number of physical, chemical, biological and microbiological processes (Abida and Harikrishna, 2008). 250 ml DO bottles were filled to the brim with samples, taking care to minimize contact with air. 100 ml of the sample solution was measured to which 2 drops of starch indicator was added. The resulting dark blue solution was titrated against a colourless 0.0125 M Thiosulphate solution (Ademoroti, 1996).

Biological oxygen demand (BOD)

Biological oxygen demand is a measure of the oxygen in the water that is required by the aerobic organisms (Abida and Harikrishna, 2008). The water sample was aerated using an air pump. A measured dilution of the water sample was done and seeding of the water sample was also conducted. Determination of the Dissolved Oxygen (DO_1) using Wrinkler's method on a suitable portion of the seeded water was carried out. An incubation bottle was filled to the brim with the remainder of the diluted water sample. The bottle was screw capped and incubated in the dark for 5 days at 20°C. On the 5th day, the DO value was determined. The BOD value was the result of the difference of the respective DO values divided by the percentage dilution (Ademoroti, 1996).

Chemical oxygen demand (COD)

The chemical oxygen demand is a measure of the oxygen equivalent of organic matter in a sample that is susceptible to oxidation by a strong oxidizing agent (Radojevic and Bashkin, 1999). The COD values for the water and effluent samples were determined using the colorimetric procedure as described by Ademoroti (1996). HACH COD reagents (high range), COD reactor (HACH) and HACH DR 2010 Spectrophotometer were utilized. A measured volume of the sample was added to 5 ml of high range COD reagent (HACH). This mixture was placed in a COD reactor for about 1 h. and upon cooling, the absorbance of the mixture was read at a specified wavelength using a HACH DR 2010 Spectrophotometer.

Statistical analysis

The analysis of variance of the mean microbial counts was conducted (α=0.05). Duncan Multiple Range (DMR) tests were conducted to locate the cause of any significant differences in the analyzed mean counts (Ogbeibu, 2005).

RESULTS

The mean bacterial count ranged between 2 ×10^2 ± 1 cfu/ml for upstream water sample obtained during the second week of February, 2013 to 1.09 × 10^4 ± 3.6 cfu/ml

Map 1. Ikpoba River in Benin City. Industrial effluent (brewery waste) discharged into the river.

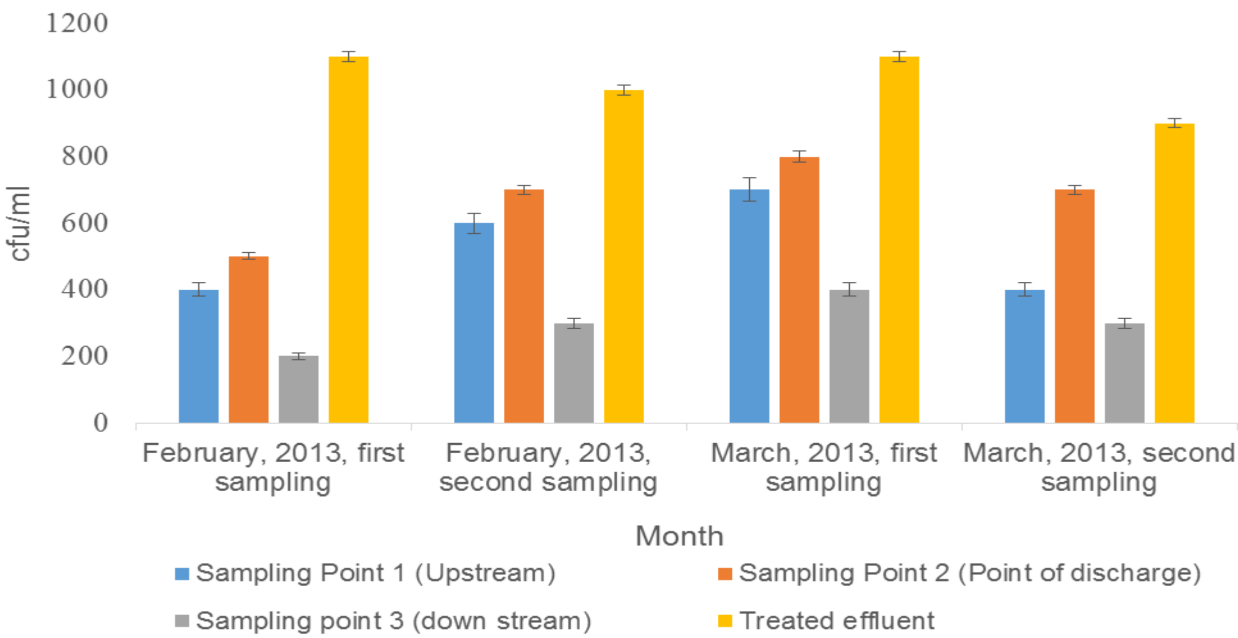

Figure 1. Mean heterotrophic bacterial counts for the water and effluent samples sourced from the respective sampling points from February, 2013 to March, 2013.

for the treated effluent sample collected during the second week of March, 2013 (Figure 1). The mean fungal counts varied from 2 $\times 10^2 \pm 1$ cfu/ml for the downstream water sample collected during the third week of February, 2013 to 2.0 $\times 10^3 \pm 7$ cfu/ml for the water sample sourced from the point of discharge of the effluent stream into Ikpoba River during the first week of March, 2013 (Figure 4). The observed differences in the mean bacterial counts was statistically significant ($P<0.05$) and counts recorded for the treated effluent were responsible for the difference. The differences in the mean fungal counts were also statistically significant ($P<0.05$) and counts recorded for both the treated effluent and point of discharge were responsible for the difference. The total coliform counts ranged from 2 MPN/105 ml recorded for samples obtained from downstream and the treated effluent during the first and second week of March, 2013 and the third week of February, 2013 to 20 MPN/ 105 ml for sample collected at the point of discharge during the second week of March 2013 (Figure 2). *Escherichia coli* counts varied from 1 MPN/105 ml recorded for upstream sample collected during the third week of February, 2013 to 5 MPN/105 ml recorded for sample collected at the point of discharge during the second week of February,

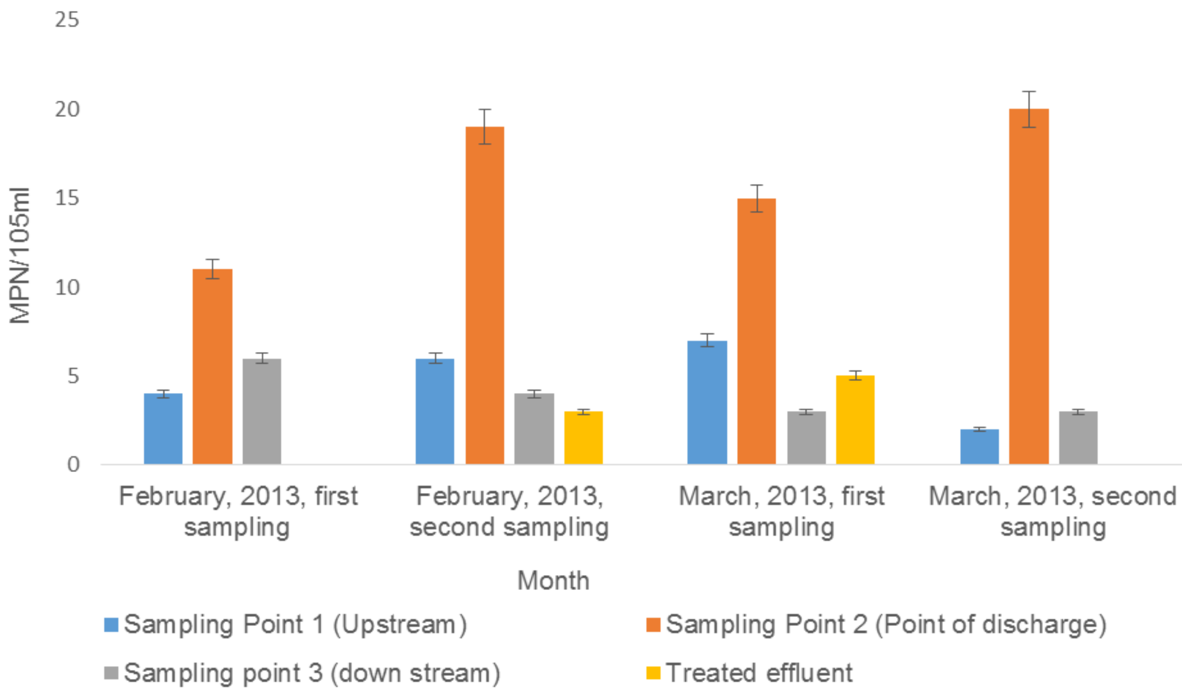

Figure 2. Total coliform counts for the water and effluent samples obtained from the respective sampling points from February, 2013 to March, 2013.

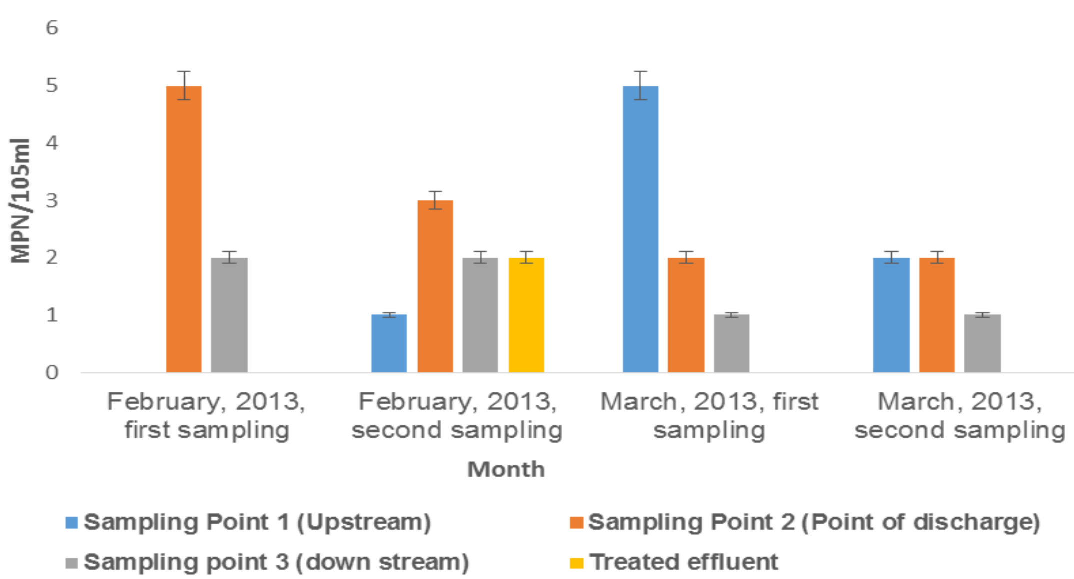

Figure 3. *Escherichia coli* (fecal coliform) counts for the water and effluent samples obtained from the respective sampling points from February, 2013 to March, 2013.

2013 and the first week of March, 2013 (Figure 3). Seven bacterial and four fungal isolates were identified; *Proteus vulgaris*, *Bacillus cereus*, *Klebsiella pneumoniae*, *Escherichia coli*, *Streptococcus* sp., *Pseudomonas* sp., *Enterobacter aerogenes*, *Saccharomyces cerevisiae*, *Candida tropicalis*, *Penicillium* sp. and *Aspergillus niger*. *E. aerogenes* and *E. coli* were the most frequently occurring bacterial isolates (100%) while *P. vulgaris* was the least occurring bacterial isolate (25%). Amongst the fungal isolates, *A. niger* was the most dominant (100%)

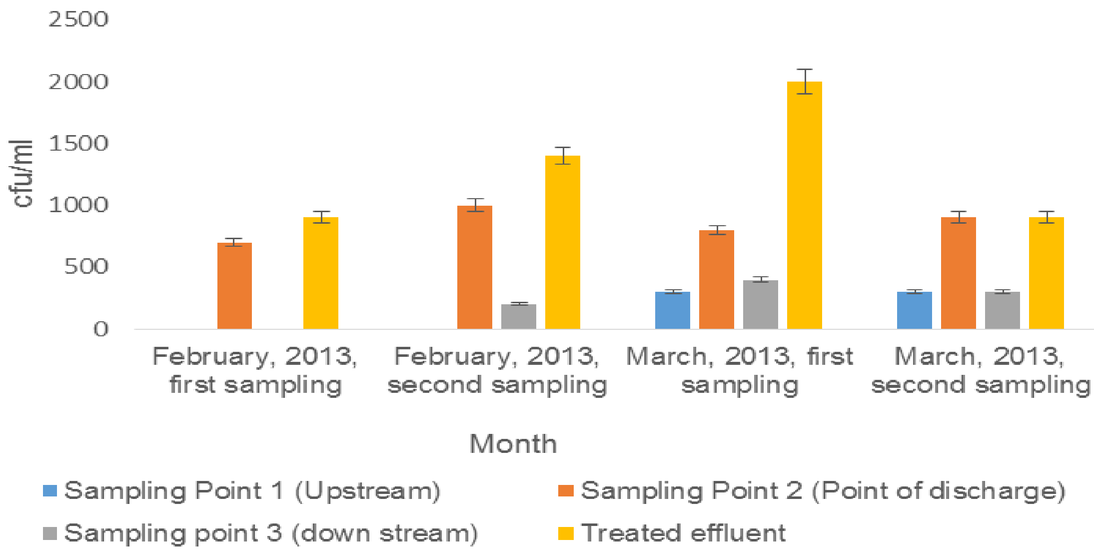

Figure 4. Mean fungal counts for the water and effluent samples abstracted from the respective sampling points from February, 2013 to March, 2013.

Table 1. Cumulative frequency of occurrence (%) of the microbial isolates.

Bacterial isolates	S.P 1 (Upstream)	S.P 2 (Point of discharge)	S.P3 (Downstream)	Treated effluent	% Cumulative freq. of occurrence
Pseudomonas sp.	+	-	-	+	50
Klebsiella pneumoniae	+	+	-	-	50
Enterobacter aerogenes	+	+	+	+	100
Escherichia coli	+	+	+	+	100
Streptococcus sp.	-	+	-	+	50
Bacillus cereus	-	+	+	+	75
Proteus vulgaris	-	-	+	-	25
Fungal isolates					
Penicillium sp.	-	+	+	+	75
Saccharomyces cerevisiae	-	+	-	+	50
Candida tropicalis	-	+	-	+	50
Aspergillus niger	+	+	+	+	100

SP, Sampling point; +, Present; -, Absent

while the yeast isolates *S. cerevisiae* and *C. tropicalis* had the least cumulative frequency of occurrence (50%) (Table 1). All water samples collected from upstream and downstream points on the river were colorless while the water samples collected at the point of effluent discharge were light brown in color. The mean pH, turbidity and conductivity of the respective samples ranged from 5.63±0.05 to 6.78±0.05, 4.1±0.21 to 6.81±0.55 NTU and 3.3±0.25 to 73.3±6.56 µs/cm respectively. The Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) varied from 2.6±0.5 to 305.19±43.2 mg/l, 5.5±0.3 mg/l to 6.1±0.6 mg/l and 15.8±0.6 mg/l to 883.8±28.5 mg/l respectively (Table 2). Heavy metals values are recorded in Table 3.

DISCUSSION

In Nigeria, especially in urban areas, surface waters have been used as the most expedient media of disposing wastes particularly effluents (Yakub, 2004). The microbiological quality of both the water samples and the treated effluent is very poor when compared with Federal Ministry of Environment limits for potable water, hence

Table 2. Mean physicochemical values for the effluent and surface water samples obtained from the respective sampling for the sampling period (February, 2013-March, 2013).

Parameters	Treated effluent	WHO standard	S.P 1 (Upstream)	S.P 2 (Point of discharge	S.P 3 (Downstream)	FME limits
pH	5.63±0.05*	6.5-8.5	6.75±0.01	6.28±0.09	6.78±0.05	6.0-9.0
Temperature (°C)	29.5±0.14	30	24.8±0.17	26.5±0.17	25.8±0.06	20-33
Colour (TCU)	Light brown	15	Colorless	Light brown	Colorless	NS
Turbidity (NTU)	6.81±0.55	5	4.1±0.21	6.71±0.2	4.75±0.42	5
Conductivity (µs/cm)	73.3±6.56	8-10,000	3.3±0.25	59.9±5.43	3.6±0.57	4000
Alkalinity (mg/l)	33.84±2.4	150	11.97±0.5	41.69±3.7	13.64±1.3	NS
Total solids (mg/l)	147.9±3.3	1000	47.69±2.4	154.7±3.4	50.13±2.1	30
Biological oxygen demand (mg/l)	233.2±16.8	30	2.6±0.5	305.19±43.2	8.9±0.8	20-25
Chemical oxygen demand (mg/l)	752.5±35.9	80	15.8±0.6	883.8±28.5	23.6±3.7	50
Dissolved oxygen (mg/l)	5.5±0.3	3.0	6.1±0.6	5.5±0.5	5.6±0.6	7.5
Nitrate (mg/l)	1.9±0.3	5	0.4±0.3	2.4±0.5	1.0±0.1	10
Sulphate (mg/l)	3.8±0.7	400	1.14±0.3	3.4±0.5	2.3±0.6	500
Phosphate (mg/l)	0.4±0.1	6.5	0.1±0.03	0.3±0.1	0.2±0.1	>5

NS, Not Specified; S.P, Sampling Point; FME, Federal Ministry of Environment; WHO, World Health Organization Standard; * Mean ±Standard deviation.

Table 3. Mean heavy metal values for the effluent and surface water samples obtained from the respective sampling for the sampling period (February, 2013-March, 2013).

Parameters	Treated effluent	WHO standard	S.P 1 (Upstream)	S.P 2 (Point of discharge)	S.P 3 (Downstream)	FME limits
Lead (mg/l)	0.001±0.0005*	0.01	ND	0.003±0.001	0.001±0	0.002
Nickel (mg/l)	0.001±0.0005	0.02	0.001±0	0.004±0.001	0.002±0.0008	0.05
Iron (mg/l)	0.37±0.1	0.3	0.18±0.02	0.62±0.1	0.25±0.1	1.0
Copper (mg/l)	ND	2	0.001±0	0.001±0.0005	0.001±0	0.1

NS, Not Specified; S.P, Sampling Point; FME, Federal Ministry of Environment; WHO, World Health Organization Standard; * Mean ±Standard deviation. ND, not detected.

discouraging the direct consumption of the water sourced from the Ikpoba River at these sampling points by individuals living along the river banks. The samples obtained at the point of discharge of the treated effluent into the river had the highest concentration of viable microbial cells in comparison to both the upstream and downstream water samples. This trend is reflective of the high organic, inorganic load of the treated brewery effluent introduced into the River which could have boosted the growth of both the resident and transient aquatic microflora. Kanu and Achi (2011) reported that brewery effluents are high in carbohydrates; nitrogen and the introduction of this wastewater, high in essential nutrients can bring about changes in the aquatic microflora present in the receiving water body. The discharged brewery wastewater might have also served as a conduit through which a plethora of viable microorganisms were introduced into the river. The identification and prevalence of fecal coliforms especially *E. coli* and *E. aerogenes* in all the examined water and treated brewery wastewater samples is alarming as the presence of these bacteria is indicative of fresh fecal contamination of the river and the potential presence of pathogens (Gerardi and Zimmerman, 2005). This trend is in tandem with an earlier observation by Bello-Osagie and Omoruyi (2012) who reported the isolation of high numbers of *E. coli* from water samples at the point of discharge of treated brewery effluent into Ikpoba River. A worrisome observation noticed during the sampling of both the treated effluent and the water sample at the point of discharge was the deliberate contamination of the treated effluent being conveyed within the pipe from the brewery plant at sections close to the river with human feces by certain individuals living around the vicinity of the river bank. This is suggestive of the abysmal level of public hygiene exhibited by people living around the river which is contributing to the fecal pollution alongside the deleterious effects of the treated brewery wastewater on the receptacle (Ikpoba River). However the total and *E. coli* counts recorded for the downstream water samples were lesser in comparison to those recorded for water samples obtained at the point of discharge. This phenomenon could be attributed to the self-cleansing activities of the river itself and the lesser anthropogenic activity occurring at this stretch of the river. More so, the effect of dilution cannot also be ruled out. This finding is in agreement with a report by Odjugo and Konyeme (2008), who investigated the impact of the urban environment and seasonality on the quality of the Ikpoba River. The isolation of *P. vulgaris* and *E. aerogenes* from the water samples is in agreement with a report by Belay and Sahile (2013) which identified these bacteria from Shinta River, which is a receptacle for Dashen brewery effluent, in Gondar town, Ethiopia.

The mean pH, temperature and electrical conductivity values recorded for the treated brewery wastewater were within the permissible limits stipulated by World Health Organization (2010) and Federal Ministry of Environment (2001). However, the chemical oxygen demand, dissolved oxygen and biochemical oxygen demand of the treated brewery effluent were above the limits prescribed by WHO (2010) and FME (2001). This trend is in agreement with an earlier study by Igboanugo and Chiejine (2012) which was a pollution survey of the Ikpoba River in Benin City, Edo State. They also stated that the Ikpoba River which is currently a receptacle for piped effluent stream from both Guinness and Bendel breweries was being subjected to effluent overloading. Apart from the dissolved oxygen mean values, the other mean values of the respective physicochemical parameters of the water samples sourced from the point of discharge were higher than those recorded for both upstream and downstream water samples. This phenomenon could be the direct result of the deliberate pumping of the treated brewery wastewater by the brewery into the river. The pH, temperature, dissolved oxygen, nitrate and phosphate mean values recorded for all the water samples were within the stipulated limits for both drinking water and aquatic life as stated by the Federal ministry of environment (2001). However, the turbidity mean values were above the permissible limits for drinking water as indicated by the Federal ministry of environment (2001). The mean BOD, COD, electrical conductivity and alkalinity values contrasted with values reported by Ekhaise and Anyasi (2005) who assessed the bacteriological and physicochemical qualities of water samples obtained from several sampling points on the Ikpoba River.

All the mean heavy metal values recorded for the respective water samples with the exception of iron were within the limits stated by Federal ministry of environment (2001). The low concentrations of trace metals in all the analyzed water samples is in agreement with an earlier report by Oguzie and Okhagbuzo (2010) which evaluated the heavy metal concentration of fresh water samples obtained from several sampling points on the Ikpoba River, Benin City.

Conclusion

The piped effluent stream emanating from the brewery close to Ikpoba River is impacting negatively the quality of the river. Although the river possess the ability to heal itself through self-purification, there is need to proffer and implement remedial measures which would reduce or eliminate the deliberate pollution of the river by activities of the brewery. The operators of the brewery should be encouraged and mandated by relevant Government agencies to explore other cost effective ways of evacuating its wastewater generated in the course of its production activities. The brewery should also investigate and develop ways of treating effluent generated sufficiently to a standard that would make it suitable for reuse. Extensive public health enlightenment schemes aimed at educating the general public and residents living close to the discharge point on the dangers of deliberate fecal pollution of the river and direct consumption of water collected from the Ikpoba River should be conducted by both relevant Governmental and Non-Governmental agencies. Further research aimed at evaluating the levels of inorganic pesticides present in the river at specific sampling points should be conducted.

REFERENCES

Abida B, Harikrishna C (2008). Study on the quality of water in some streams of Cauvery River. E-J. Chem. 5(2): 377-384.

Ademoroti CMA (1996). Standard methods for water and effluent analysis. Foludex Press. Ltd. Ibadan. 182 pp.

American Public Health Authority (APHA) (1993). Standard methods for examination of water and wastewater. 17th ed. APHA. Washington D.C. 1325 pp.

Aneja KR (2003). Experiments in Microbiology, Plant Pathology and Biotechnology. 4th Ed. New Age Pub. Ltd. New Delhi. 606 pp.

Atuanya EI, Nwogu NA, Akpor EA (2012). Effluent Qualities of Government and Private Abattoirs and Their Effects on Ikpoba River,

Benin City, Edo State, Nigeria. Adv. Biol. Res. 6(5):196-201.
Barnett HL, Hunter BB (1972). Illustrated Genera of Imperfect Fungi. 3rd ed. Burgess Publishing Co. New York. 225 pp.
Bello-Osagie I, Omoruyi MI (2012). Effect of brewery effluent on the bacteriological and physicochemical properties of Ikpoba River, Edo State, Nigeria. J. Appl. Tech. Environ. San. 2(4):197-204.
Cheesebrough M (2001). District Laboratory Practice in Tropical Countries. Part II. Cambridge Univ. Press. Cambridge. 426 pp.
Cullimore DR (2000). Practical Atlas for Bacterial Identification. CRC Press, Florida. 209 pp.
Ekhaise FO, Anyasi CC (2005). Influence of breweries effluent discharge on the microbiological and physicochemical quality of Ikpoba River, Nigeria. Afr. J. Biotechnol. 4(10):1062-1065.
Federal Ministry of Environment (FME) (2001). National Guidelines and Standards for Water quality in Nigeria. Rishab Printing Press Production, Lagos, Nigeria. 114 pp.
Filkersilasie T (2011). Impact of brewery effluent on river quality: The case of Meta abo brewery factory and Finchewa River in Sebeta, Ethiopia. MSc. Thesis. Addis Ababa University.85pp.
Gerardi MH, Zimmerman MC (2005). Wastewater pathogens. Wiley-Interscience, New Jersey. 188 pp
Harley JP, Prescott, LM (2002). Laboratory Exercises in Microbiology. 5th Ed. Mac Graw Hill, New York. 449 pp.
Igboanugo AC, Chiejine CM (2012). Pollution survey of Ikpoba River, Benin City, Nigeria. J. Emerg. Trends Eng. App. Sci. 3(3): 567-571.
Kanu I, Achi OK (2011). Industrial effluents and their impact on water quality of receiving rivers in Nigeria. J. Appl. Tech. Environ. Sanitation 1(1):75-86.
Karikari AY, Ansa-Asare OD (2004). Physico-chemical and Microbial water Quality Assessment of Densu River of Ghana. CSIR water Research Institute, Accra. 69 pp.
Khalil AA (2005). Water sanitation and human health in Southern Sudan. J. Environ. Change 8(1):64–82.
Leroy PN, Brinson M, John W, Day Jr (2002). Aquatic ecosystems and global climate change, Potential impacts on inland freshwater and coastal wetland ecosystems in the United States. USEPA, Washington DC. 76 pp.
Masson CF (1990). Biological aspect of fresh water pollution. The Royal Society of chemistry, Cambridge CB4 4WF.
Meybeck M, Helmer R (1996). An Introduction to Water Quality, In: Chapman, D. (Ed). Water Quality Assessments. A guide to the use of biota, sediments and water in environmental monitoring. Second edn. Cambridge. pp. 1-22.
Odjugo PAO (2004). The impact of petroleum oil operations on environmental degradation in Delta State, Nigeria. Know. Rev. 9(1):1-9.
Odjugo PAO, Iweka DE (2005). The impact of urbanization on microclimate: A case study of Benin City, Nigeria. J. Environ. Sci. 10(1): 68-80.
Odjugo PAO, Konyeme JO (2008). The impact of urban environment and seasonality on the quality of Ikpoba River in Benin City, Nigeria. J. Food Agr. Environ. 6(2):362-369
Ogbeibu AE (2005). Biostatistics: A practical approach to research and data handling. Mindex Publishing, Benin City. 263 pp.
Ogbuile JN, Uwaezuoke JL, Ogiehor SI (1998). Introductory Microbiology Practicals. Springfield Pub. Lagos. 309 pp.
Oguzie FA, Okhagbuzo GA (2010). Concentrations of heavy metals in effluent discharges downstream of Ikpoba River in Benin City, Nigeria. Afr. J. Biotechnol. 9(3):319-325.
Pepper IL, Gerba CP (2004). Environmental Microbiology: A laboratory manual, 2nd Ed. Elsevier Academic Press. New York. 266 pp.
Purnamitta D (2004). Valuing health damages from water pollution in urban Delhi, India: A health production function approach. Environ. Dev. Ecol. 9(1): 83-106.
Radojevic M, Bashkin VN (1999). Practical Environmental Analysis. The royal society of chemistry. Cambridge. 466 pp.
Rajaram T, Ashutosh D (2008). Water pollution by industrial effluents in India: Discharge scenarios and case for participatory ecosystem specific local regulation. Futures 40: 56–69.
Rapu OJ (2003). Urbanization, water pollution and water crisis in selected cities of South Africa. J. Energy Environ. 15(3): 128-135.
Ravindra K, Meenakshi A, Rani M, Kaushik A (2003). Seasonal variations in physicochemical characteristics of River Yamuna in Haryana and its ecological best designated use. Ms.c Thesis, Department of Environmental Sciences and Engineering, Guru Jambheshwar University, Hisar, India. 93 pp.
Sharma K (2009). Manual of Microbiology. Ane Books. Pvt. Ltd. New Delhi. 405 pp.
Shuaib CP (2004). The relationship between industrialization and water quality. Environ. Know. 16(2): 27-32.
Skoulikidis NT, Gritzalis K, Kouvarda T (2002). Hydrochemical and ecological quality assessment of a Mediterranean river system. Global Nest Int. J. 4(1): 29-40.
Venkatesharajuik K, Ravikumar P, Somashekar RK, Prakash KL (2010). Physicochemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. Kathmandu U. J. Sci. Eng.Tech. 6(1): 50-59.
Whitehead PG, Williams RJ, Lewis DR (1997). Quality simulation along river systems (QUASAR): Model theory and development. Sci. Total Environ. 194/195:447–456.
Wu C, Crescencia M, Yi W, Shouzheng X, Devra LD (1999). Water pollution and human health in China. Environ H. Persp. 107(4):251-256.
WHO (2010). Guidelines for drinking-water quality, 3rd Ed. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland 688pp.
Yakub AS (2004). Assessment of water quality and plankton of effluent receiving lower Awba stream and reservoir, Ibadan. Afr. J. App. Zool. Environ. Biol. 6: 107-110.
Zimmerman MC (1993). The use of biotic index as an indication of water quality. Williamsport, Pennsylvania. pp. 85-98.

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Full Length Research Paper

Effect of biochar on soil properties and lead (Pb) availability in a military camp in South West Ethiopia

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Application of biochar to soil can improve numerous physicochemical and biological properties of the soil. The method for lead metal (Pb) remediation in soil is a challenge worldwide. The excessive Pb accumulation in the soil can radically reduce the soil quality and fertility. This study was conducted to find out the efficiency of biochar in improving the physicochemical properties of soil and to evaluate its effect on Pb availability in a military camp soil. Soil sample was collected from military camp of Jimma town, southwestern Ethiopia and was incubated for 90 days with different application rates (0, 2.5, 5, 7.5, 10, 12.5 and 15 t/ha) of biochar. The results showed that the addition of biochar improved, pH, electric conductivity (EC), cation exchange capacity (CEC), organic carbon (OC), organic matter (OM), total nitrogen (TN), exchangeable cations and available phosphorous of the soil and had no significant effect on soil texture. Sequential extraction of Pb showed that at 15 t/ha (4.2 g/kg) application of biochar, the exchangeable form of Pb significantly transformed the carbonate bound, Fe/Mn oxide bound, organic bound and residual fractions to 66.79, 100.5, 112.7 and 112.1 mg/kg, which is reduced by 88.6, 88.9, 88.5 and 88.3%, respectively as compared to the control. It is concluded that the application of biochar could not only improve physicochemical properties of the soil but also stabilize Pb in a military camp soil.

Key words: Lead metal, biochar, soil properties, military camp.

INTRODUCTION

Application of biochar to soil can improve numerous physicochemical and biological properties of the soil such as increased soil pH, cation exchange capacity (CEC) and reducing nitrogen (N) leaching, thereby reducing fertilizer and lime requirements (Van Zwieten et al., 2010), and also enhance soil water holding capacity, soil water permeability, saturated hydraulic conductivity, reduce soil strength, modify soil bulk density and aggregate stability (Busscher et al., 2010). Cation exchange capacity of biochar has the capacity to exchange cations (such as N in the form of ammonium, NH_4^+) with soil solution, and thus store crop nutrients (Lehmann, 2007). Elevated CECs are due to increases in charge density per unit surface of organic matter which equates with a greater

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degree of oxidation, or increases in surface charge area for cation adsorption, or a combination of both (Atkinson et al., 2010).

Military camps are established in large areas around the world for weapons training and shooting activities. However, shooting activities could lead the soil contamination with heavy metals such as lead (Pb) from the used bullets (Dermatas et al., 2006). Nowadays, a large amount of Pb is being deposited in the military camps soil worldwide within annual deposition rates of 200 and 60,000 tons (Craig, 1999). Military camps are commonly considered as the second largest source of soil Pb after the battery industry (Cao et al., 2008). The contamination of military camp soil with Pb is well documented (Grubb et al., 2009; Hashimoto et al., 2009). Most of the studies indicated that Pb levels in the military camp soils exceed 1%, resulting in degrading soil quality and decreasing soil microbial activities (Belyaeva et al., 2005; Lee et al., 2002).

The remediation of military camp soil has received great interest in the past due to its adverse effects. There are several remediation technologies for remediating heavy metal contaminated soils, such as excavation and landfill, thermal treatment, washing, electro-reclamation and solidification/stabilization (Shi and Spence, 2004; Singh and Pant, 2006). However, because of the high cost and low efficiency, these conventional methods are not effective (Aboulroos et al., 2006). The end use of the contaminated soil after remediation is an important factor, which controls the selection of remediation technology (Mulligan et al., 2001). Several soil amendments such as phosphorous (P) containing materials and liming materials have been used to remediate the military camp soil by converting highly mobile and available forms of Pb into less mobile and available forms (Moon et al., 2010). However, phosphate-induced immobilization of Pb requires a high amount of available P to stabilize Pb which may result in the leaching of P into ground water and the surrounding environment (Dermatas et al., 2008). On the other hand, increase in the soil pH (>8) induced by the lime-based materials for Pb stabilization is not favorable for soil biota.

Biochar is a charcoal produced from the pyrolysis of biomass at relatively low temperatures (< 700°C) (Lehmann and Joseph, 2009). Biochar has received great interest during the last few years, due to its beneficial role in improving soil quality (Major, 2010; Novak et al., 2009). However, biochar has not been widely used so far as a soil amendment for military camp soils. Additionally, only limited studies have reported the effect of biochar on heavy metal availability and stabilization in soil. Cao et al. (2009) indicated that high content of P in the biochar is mainly responsible for Pb stabilization in the aqueous solution due to the formation of stable phosphate minerals. Uchimiya et al. (2010) also suggested several possible mechanisms for the stabilization of heavy metals in soil and water by using biochar, such as cation exchange, coordination by π electrons of carbon (C) and precipitation. However, most of these studies applied biochar to immobilize heavy metals in aqueous solutions or soils but only for a short incubation period (24 h). However, the effectiveness of biochar for the stabilization of heavy metals in soils has not been well studied. Therefore, the objective of this study was to evaluate the effects of biochar on soil physicochemical properties, and its performance on availability and stabilization of Pb in a military camp soil.

MATERIALS AND METHODS

Description of the study area

This study was conducted in an impact area of a military camp in Jimma town, south western Ethiopia. The study area is located at Latitude of 7° 33'N and Longitude of 36° 57'E (Figure 1). The altitude ranges from 1760 to 1920 m above sea level. The mean annual maximum and minimum temperatures are 26.8 and 11.4°C and the relative humidity are 91.4 and 39.92%, respectively. The mean annual rainfall of the study area is 1500 mm (BPEDORS, 2000) and soils are mainly of Nitisols (World Reference Base, 2006).

Preparation of biochar

Biochar of coffee husk was prepared in Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) by using a pyrolysis unit at 500°C temperature and 3 h of residence time. The resulting biochar material was grinded and sieved through a 0.25 mm square-mesh sieve.

Soil sampling and preparation

The soil sample was collected from top soil (0-30 cm) by using auger. The collected soil samples were air-dried, crushed by using mortar and pestle and then passed through a 2 mm square-mesh sieve.

Sampling procedure of physicochemical properties of biochar

Biochar sample was analyzed for physicochemical properties that included surface area, pH, electric conductivity (EC), exchangeable bases (EB) (Ca, Mg, Na and K), cation exchange capacity (CEC), organic carbon (OC), organic matter (OM), total nitrogen (TN) and available phosphorous (Av. P). The surface area was estimated according to Sears (1956) method for silica-based materials. The pH and EC were measured in distilled water at 1:10 biochar to water mass ratio after shaking for 30 min (ASTM, 2009). Biochar OC content was determined by the Walkley-Black method and TN by the Kjeldahl method as sited in Chintala et al. (2013). Av. P was determined by using the Olsen extraction method as sited in Shaheen et al. (2009). Total EB were determined after leaching the biochar with ammonium acetate. Concentrations of Ca and Mg in the leachate were determined by atomic absorption spectrometer. K and Na were determined by flame photometer. CEC was determined at soil pH 7 after displacement by using 1 N ammonium acetate method, and then estimated titrimetrically by distillation of ammonium which was displaced by sodium (Gaskin et al., 2008).

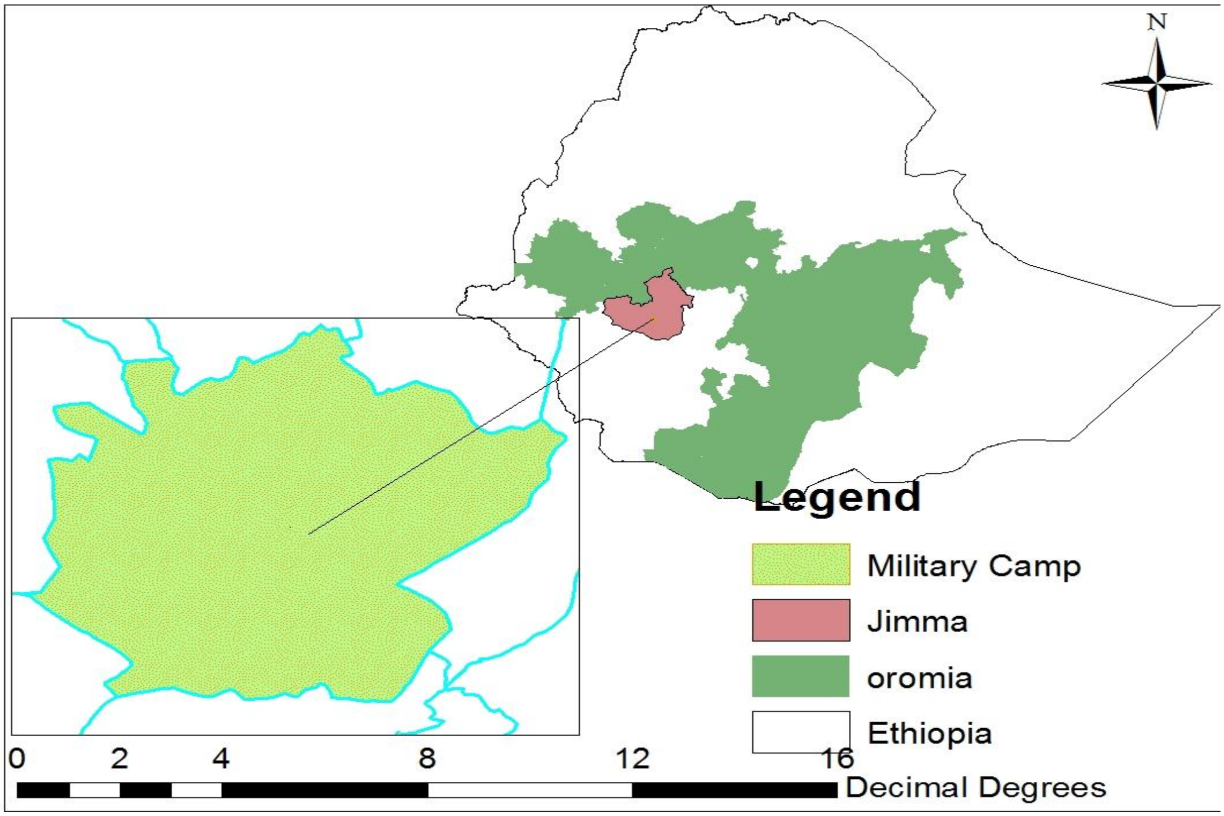

Figure 1. Map of the study area.

Incubation experiment

The effects of different levels of the biochar produced from coffee husk at 500°C temperature on physicochemical properties and availability and stabilization of Pb in a military camp soil were examined by a laboratory incubation experiment. 1 kg of air-dried soil (<2 mm) was weighed in different beakers and biochar was added at rates of 0, 2.5, 5, 7.5, 10, 12.5 and 15 t/ha (equivalent to 0, 0.7, 1.4, 2.1, 2.8, 3.5 and 4.2 g/kg soil) and thoroughly homogenized. The moisture content of the soil-biochar mixture was maintained at field capacity throughout the incubation period, by adding distilled water whenever necessary. Three replicates of each treatment were prepared, randomly placed and incubated in the laboratory at ambient temperature for 90 days. At the end of 90 days, samples were removed from all the treatments and analyzed for pH, OC, OM, TN, Av. p and other parameters were also analyzed as per the standard methods.

Physicochemical properties of soil sample and the soil-biochar mixture

The particle size distribution (texture) of the soil sample and the soil-biochar mixture was determined by the Boycouos hydrometric method (Van Reeuwijk, 1992) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexametaphosphate $(NaPO_3)_6$. Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights. The pH of the soil and soil-biochar mixture was determined in water suspension at 1:2.5 soil/soil-biocha r: liquid ratio (w/v) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 1992). Electrical EC was measured from a 1:5(w/v) soil to water ratio after a one hour equilibration time as described by ASTM (2009). The Walkley and Black (1934) wet digestion method was used to determine OC content and, percent OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. TN was analyzed using the Kjeldahl method by oxidizing the OM in (0.1N H_2SO_4) as described in Black (1965). CEC and EB were determined after extracting the soil samples by 1 N NH_4OAc) at pH 7. Exchangeable Ca and Mg in the extracts were analyzed using atomic absorption spectrometer (AAS), while Na and K were analyzed by flame photometer (Rowell, 1994). CEC was then estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Av. P was determined by using 1 M HCl and 1 M NH_4F solutions as an extractant by Bray II method for soils having pH values < 7 (Van Reewijk, 1992).

Sequential extraction of Pb

A sequential extraction procedure was adopted to classify and quantify the Pb fraction of the soil amended with biochar according to the procedure of Tessier et al. (1979). The sequential extraction consists of five Pb fractions (exchangeable Pb using 1 M magnesium chloride, carbonate-associated Pb using 1 M sodium acetate, Fe/Mn associated Pb using 0.04 M hydroxyl amine-hydrochloride in 25% acetic acid, organically associated Pb using 30% hydrogen peroxide and 0.02 M nitric acid, and residual Pb using aqua regia). The supernatant solution of each extraction was filtered through a 42 Whatman filter paper. Sequential extraction Pb

Table 1. Analytical results of the soil and biochar for the different physic-chemical properties.

Parameters	Soil	Biochar
Bulk density (gm/cm^3)	1.20	-
Specific surface area (m^2/g)	-	26.20
pH-H_2O (1:2.5)	6.12	11.00
EC (dS/m) (1:5)	0.03	6.40
Ca (cmol(+)/kg)	8.10	61.50
Mg (cmol(+)/kg)	1.20	8.21
K (cmol(+)/kg)	0.80	2.80
Na (cmol(+)/kg)	0.02	5.15
CEC (me/100g)	24.4	79.20
Organic carbon (%)	4.00	26.40
Organic matter (%)	6.90	46.40
Nitrogen (%)	0.34	2.30
Available P (mg /kg)	4.50	13.90
Total Pb (mg/kg)	3,958	BDL
Sand (%)	29.30	-
Clay (%)	30.70	-
Silt (%)	40.00	
Texture	CL	

CL = Clay loam, CEC= cation exchange capacity, EC= electrical conductivity, BDL= below detection level.

was measured by atomic absorption spectrometer.

Statistical analysis

The collected data were subjected to different statistical analysis such as analysis of variance (ANOVA) using SAS version 9.2 Software and MS Excel. One-way ANOVA was computed to show significant difference between each treatment for physico-chemical parameters and among each treatment using the general linear model (GLM) procedure of SAS 9.2. Mean separation was done using least significant difference (LSD) after the treatments were found significant at $P<0.05$.

RESULTS AND DISCUSSIONS

Soil and biochar properties

The selected physicochemical properties and biochar are presented in Table 1 below. The study area soil had a clay loam textural classes. Soil pH was slightly acidic (6.12) with 0.03 dS m^{-1} EC value. The low value of EC shows that the soil is non-saline which indicates that the total concentration of the major dissolved inorganic solutes like: Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, SO_4^{-2}, HCO_3^-, NO_3^- and CO_3^{-2} in the soil solution is low (Brady and Weil, 2002). Soil was relatively low in OC (4%), OM (6.9%), and Av. P (4.5 mg kg^{-1}) contents. The total Pb concentration in the soil was 3,958 mg kg^{-1} suggesting that the military camp soils were severely contaminated by Pb.

The coffee husk biochar produced at 500°C has a 26.2 m^2/g surface area which reflects its fine-pore structure generated though a well-controlled activation process. As shown in Table 1, this surface area of biochar produced from coffee husk at 500°C pyrolysis temperatures might be attributable to the removal of -OH, aliphatic C-O, and ester C=O groups from outer surfaces of the feedstock (Chan et al., 2008).

As indicated in Table 1, the coffee husk biochar was more alkaline and has higher base cation concentration. The high pH values of coffee husk biochar may be due to hydrolysis undergone by carbonates and bicarbonates of base cations such as Ca, Mg, Na and K, which were present in the feedstock material (Gaskin et al., 2008). The EC value of coffee husk biochar was found to be higher, indicating the existence of more water soluble salts in coffee husk biochar. The CEC of coffee husk biochar was also found to be higher. This may be due to high negative charge potential of surface functional groups in coffee husk biochar. Av. P, OC and TN were also found to be higher in coffee husk biochar.

Effect of biochar application on soil physico-chemical properties

Texture (particle size distribution)

The particle size distributions of the un-amended and soil-biochar mixtures of the analyzed and the results

Table 2. Effect of biochar application on soil texture (particle size distribution).

Rate (t/ha)	Sand (%)	Clay (%)	Silt (%)	Textural classes
0.0	28.00 ± 2.0	30.67 ± 1.1	41.33 ± 1.1	Clay loam
2.5	27.67 ± 1.5	33.33 ± 1.1	40.00 ± 0.0	Clay loam
5.0	27.67 ± 3.0	34.00 ± 2.0	39.33 ± 4.1	Clay loam
7.5	26.34 ± 1.1	34.33 ± 1.1	39.33 ± 1.1	Clay loam
10.0	26.00 ± 2.0	34.33 ± 1.1	39.67 ± 2.0	Clay loam
12.5	26.00 ± 2.0	35.00 ± 2.0	39.00 ± 2.0	Clay loam
15.0	25.00 ± 2.0	35.33 ± 1.1	38.67 ± 1.1	Clay loam
F-test	ns	ns	ns	
$LSD_{0.05}$	3.38	4.66	5.62	
CV (%)	7.56	4.78	6.64	

obtained are listed in Table 2 and tha sand, clay and silt fractions were not significantly (P >0.05) affected by the application of biochar.

Soil pH

Results of the study of biochar application effect on pH of the soil are given by in Table 3. Statistical analysis of the results revealed a non significant increase in pH as a result of the addition of biochar. However, relatively highest mean pH value was observed in the soil treated with 15 t/ha biochar, while the lowest values were recorded in the control. The lack of significant change in soil pH at the higher biochar rate may be due to the displacement of exchangeable acidity and the high buffering capacity of biochar, thereby retarding a further liming effect (Wang et al., 2014).

OC, OM, TN and Av. P

The application of different rates of biochar on the acidic soil significantly increased the mean soil organic carbon, organic matter and total nitrogen (Table 3) content. The untreated (control) acidic soil had 4.6 ± 0.4% of OC, 7.93 ± 0.3% of OM and 0.40 ± 0.0% TN level, however, due to the addition of biochar, the OC, OM and TN levels increased to a level ranging respectively from 4.6 - 7.1, 7.9 - 12.2 and 0.4 - 0.6% which corresponds to percentage increase of 35.0% OC, 35.1% OM and 34.43% of TN. The highest OC and OM levels and TN were recorded in the soil amended with 4.2 g/kg biochar after three months of incubation period. The high OC, OM and TN content in biochar might have enriched the soil with high organic carbon content and OM. Application of biochar has also resulted in marked changes in the TN content of the soil (Table 3). The TN content of the control soil which was determined to be 0.4 ± 0.0% was found. Due to application of biochar, the TN level increased to a level ranging from 0.4 ± 0.0-0.61 ± 0.00% TN after two months of incubation period and it increased by 34.43%. The highest increase was recorded in the soil amended with 15 t/ha coffee husk biochar. The observed increase in OC, OM and TN could be due to decomposition which might have occurred when biochar is added to soil (Liang et al., 2006).

The amount of Av. p in soil was also significantly increased by application of biochar (Table 3). The untreated (control) soil had 4.99 ± 0.2 of P after an incubation periods of three months. However, due to the incorporation of biochar, the available P level increased to a level ranging from 4.9-21.4 mg/kg after an incubation period of three months which corresponds to 76.7% increase of the available phosphorus. The highest values of available phosphorous were recorded when biochar was applied at a rate of 15 t/ha after three months of incubation periods. The observed increase in available phosphorus due to application of biochar could be attributed to the improvement in the soil pH which would ultimately reduce the activity of Fe and Al. Van Zwieten et al. (2010) and Chan et al. (2008) also reported the increase in available phosphorous after the application of biochar. The increase in available P with duration of incubation reported in this study is comparable to those reported by Laboski and Lamb (2003), Spychaj-Fabisiak et al. (2005) and Opala et al. (2012).

CEC and exchangeable Ca, Mg and K

The effect of biochar addition on CEC and the contents of exchangeable cations in the soil are presented in Table 3. CEC and exchangeable cations were found to increase upon amendment of the acidic soil with biochar. The untreated acidic soil had 24.95 ± 0.1 me/100 g level before treatment, however, due to the addition of biochar, the CEC level increased to a level ranging from 24.9-34.9 me/100 g after three months of incubation period and it increased by 28.7%. The highest increase in CEC was recorded in the soil amended with biochar at the rate of 15 t/ha (Table 3). The observed increase in CEC due to

Table 3. Effect of biochar application (t/ha) on selected soil chemical properties. Means followed by the same letter within a column are not significantly different from each other at P <0.05.

Rating (t/ha)	pH-H_2O	OC (%)	OM (%)	TN (%)	Av.P (mg/kg)	CEC	Ca	Mg	K
						cmol(+)/kg			
0.0	6.2±0.0[a]	4.6 ± 0.4[g]	7.93 ± 0.3[g]	0.40 ± 0.0[g]	4.99±0.2[e]	24.95 ± 0.1[e]	8.57 ± 0.7[e]	1.3 ± 0.1[e]	0.85 ± 0.0[g]
2.5	6.2±0.1[a]	6.58 ± 0.2[f]	11.34 ± 0.4[f]	0.57± 0.0[f]	11.35±0.2[cd]	26.33 ± 0.6[d]	9.98 ± 0.3[d]	3.45 ± 0.1[d]	1.46 ± 0.0[ef]
5.0	6.40±0.4[a]	6.79 ± 0.2[ef]	11.71 ± 0.5[ef]	0.59 ± 0.0[ef]	11.63±0.1[cd]	28.37 ± 1.1[cd]	16.8 ± 0.8[cd]	3.56 ± 0.1[cd]	1.55 ± 0.0[ed]
7.5	6.5±0.0[a]	6.86 ± 0.0d[ef]	11.83 ± 0.5[de]	0.59 ± 0.0[de]	14.41±0.5[bc]	29.27 ± 0.6[bc]	17.5 ± 0.5[bc]	3.63 ± 0.1[bc]	1.99 ± 0.2[bc]
10.0	6.5±0.2[a]	6.98 ± 0.2[cd]	12.03 ± 0.5[cd]	0.60 ± 0.0[cd]	17.92±2.2[bc]	30.7 ± 0.6[bc]	17.06 ± 0.5[bc]	3.66 ± 0.1[bc]	2.15 ± 0.2[bc]
12.5	6.5±0.2[a]	6.98 ± 0.2[cd]	12.03 ± 0.5[cd]	0.60 ± 0.0[cd]	19.06±0.9[ab]	32.03 ± 1.1[bc]	17.32 ± 0.8[bc]	3.63 ± 0.1[bc]	2.96 ± 0.0[a]
15.0	6.6±0.0[a]	7.08 ± 0.0[cd]	12.21 ± 0.5[cd]	0.61 ± 0.0[cd]	21.41±0.1[a]	34.99 ± 0.8[ab]	20.84 ± 0.5[ab]	3.83 ± 0.1[ab]	3.01 ± 0.1[a]
F-test	ns	**	**	**	**	**	**	**	**
LSD	0.38	0.30	0.43	0.025	0.19	2.80	2.18	0.29	0.68
CV	2.31	1.68	1.63	2.03	2.12	2.69	2.69	2.67	11.90

the application of biochar could have resulted from the inherent characteristics of biochar feedstock. Biochar has high surface area, is highly porous, possesses organic materials of variable charge that have the potential to increase soil CEC and base saturation when added to soil (Glaser et al., 2002). Available evidences also suggest that, the intrinsic CEC of biochar is consistently higher than that of whole soil, clays or soil organic matter (Sohi et al., 2009). Therefore, it is quite logical that soil treated with biochar had a highest CEC than the corresponding un-treated soil. Studies by Agusalim et al. (2010) and Chan et al. (2008) have also revealed the increase in soil CEC after the application of biochar. Application of biochar at a rate of 4.2 g/kg on the soil was found to increase the levels of exchangeable Ca and Mg significantly from 8.5 - 20.8 and 1.3 - 3.8 me/100 g, respectively which corresponds to increments by 58.8 and 66.1%, respectively for Ca and Mg. Application of biochar, on the other hand also, increased the values of exchangeable K from 0.85 - 3.0 me/100 g (an increment by 72.97%). The observed increase in exchangeable cations in the biochar treated soils might be attributed to the ash content of the biochar. The ash content of biochar helps for the immediate release of the occluded mineral nutrients like Ca, Mg and K for crop use (Scheuner et al., 2004; Niemeyer et al., 2005).

Lead (Pb) metal availability

Application of biochar to the soil has brought a linear reduction of the available Pb metal (Figure 2) as compared to the un-amended control. The total Pb pool of the soil reduced gradually from 3953.5 mg/kg (un-amended control) to a minimum of 453.8 mg/kg when the soil is amended with 15 t/ha of biochar after three months of incubation periods. Such a decrease may probablybe due to metal retention on the biochar surface.

To investigate the distribution of Pb among different soil pools, sequential extraction analysis was done using 0, 2.5, 5, 7.5, 10, 12.5 and 15 t/ha biochar amendments. The most abundant fraction of Pb in the un-amended (control) sample was the organic bound fraction at 983 mg/kg followed by residual 963 mg/kg and Fe/Mn oxide bound 874 mg/kg fractions (Figure 2). Application of biochar induced a shift in the exchangeable form of Pb from 545.8 to 61.7 mg/kg which shows a decrease of 89.5% towards the less available form; however, the reduction of exchangeable form of Pb was dependent on the rate of biochar application. At 15 t/ha biochar application, the exchangeable form of Pb significantly transformed the carbonate bound, Fe/Mn oxide bound, organic bound and residual fractions to 66.7, 100.5, 112.7 and 112.1 mg/kg, which corresponds to a reduction by 88.6, 88.9, 88.5 and 88.3%, respectively (Figure 3).

Cui et al. (2011) reported Cd metal reduction (by 40%) as a result of biochar application to a soil high in Cd concentration. Fellet et al. (2014) also reported a reduction of Pb available in soil from 80 to 51 mg/kg, by applying 3% biochar derived from waste orchard. Recently, Puga et al.

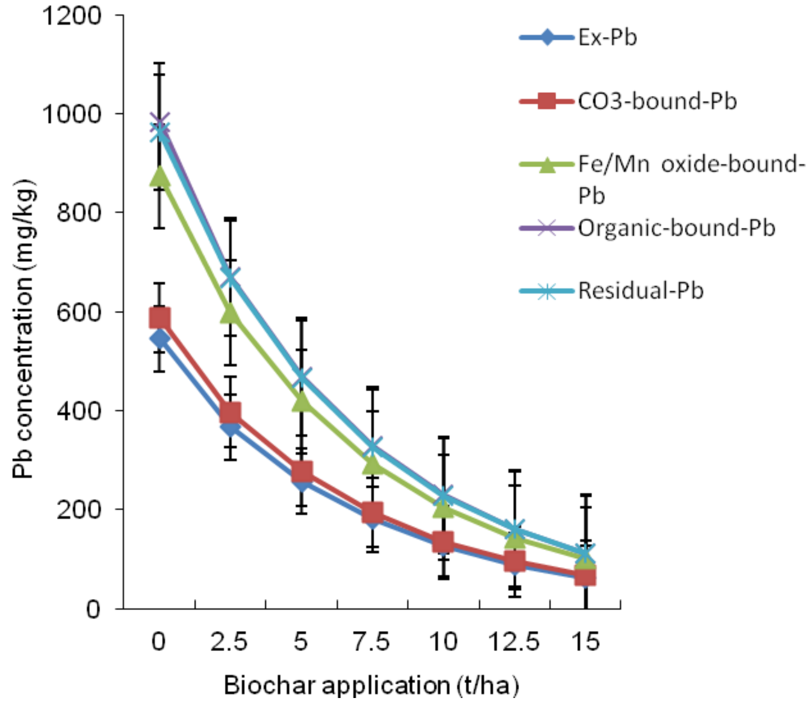

Figure 2. Effect of biochar application on the various Pb pools as determined through a sequential extraction. Vertical bars represent standard errors.

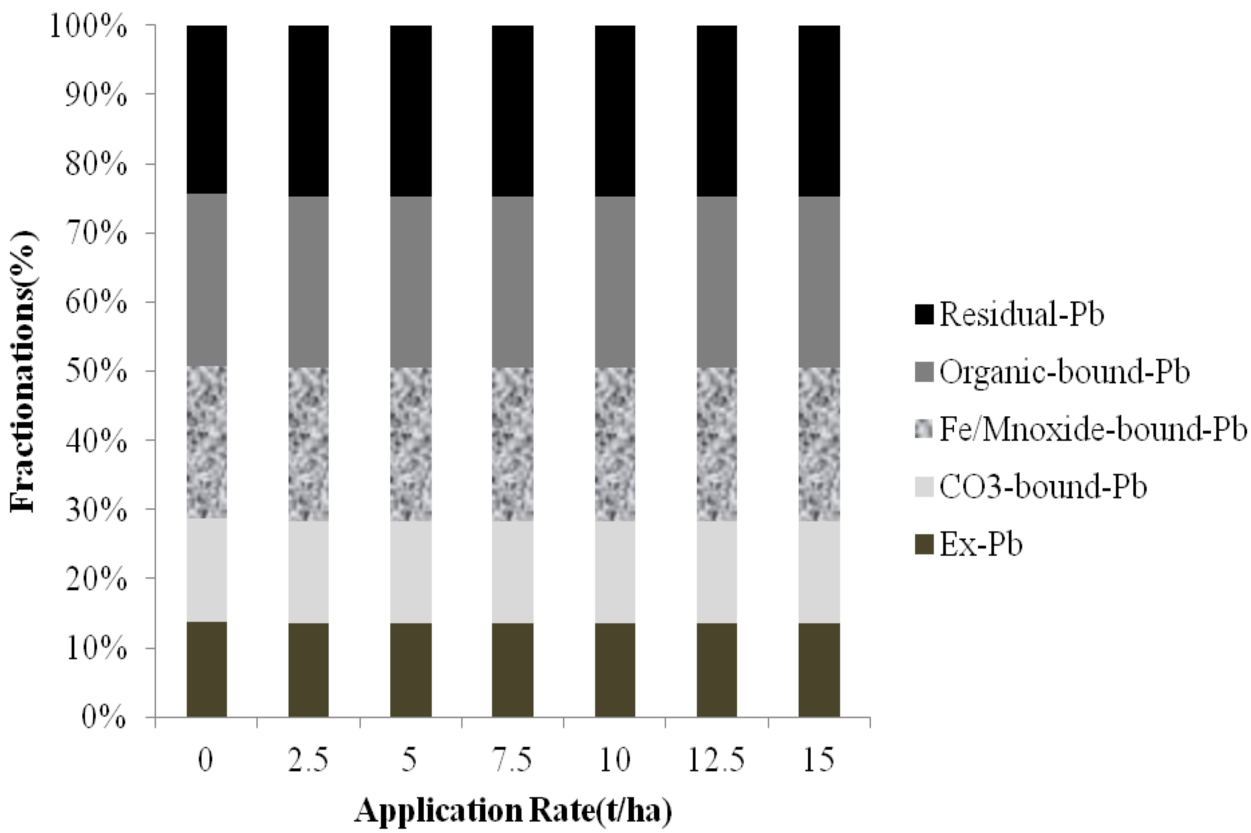

Figure 3. Fractions of Pb in soils amended with different application rates of biochar

(2015) reported a 50% reduction in the available concentration of Pb in Brazil. Therefore, it might be concluded that the results in the present study are consistent with regard to the reduction in the availability of the Pb metal in contaminated soils following biochar application.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Aboulroos SA, Helal MID, Kamel MM (2006). Remediation of Pb and Cd polluted soils using in situ immobilization and phytoextraction techniques. Soil Sediment Contam. J. 15:199-215.

Agusalim M, Wani HU Syechfani MS (2010). Rice Husk Biochar for Rice Based Cropping System in Acid Soil: The Characteristics of Rice Husk Biochar and Its Influence on the Properties of Acid Sulfate Soils and Rice Growth in West Kalimantan. Indonesia. J. Agric. Sci. 2(1):39-47.

ASTM standard (2009). Standard test method for chemical analysis of wood charcoal. American Society for Testing and Materials (ASTM) International: Conshohocken, PA.

Atkinson CJ, Fitzgerald JD, Hipps NA (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant Soil. 337:1–18

Belyaeva ON, Haynes RJ, Birukova OA (2005). Barely yield and soil microbial and enzyme activities as affected by contamination of two soils with lead, zinc, or copper. Biol. Fertil. Soils 41:85-94.

Black CA (1965). Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1572p.

BPEDORS (2000). Physical and Socio-Economical Profile of 180 District of Oromia Region, Ethiopia.

Brady N, Weil R (2002). The Nature and Properties of Soils. 13th ed. Upper Saddle River, N.J., Prentice Hall, Harvard.

Busscher WJ, Novak JM, Evans DE, Watts DW, Niandou MAS Ahmedna M (2010). Influence of Pecan Biochar on Physical Properties of Norfolk Loamy Sand. Soil Sci. 175:10-14.

Cao X, L Ma B, Gao W, Harris (2009). Dairy-manure derived biochar effectively sorbs lead and atrazine. Environ. Sci. Technol. 43:3285-3291.

Cao X, Dermatas D, Xu X, Shen G (2008). Immobilization of lead in shooting range soils by means of cement, quicklime, and phosphate amendments. Environ. Sci. Pollut. Res. 15:120-127.

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.

Chapman H (1965). Cation Exchange Capacity. In: C.A. Black, (Eds.), Methods of Soil Analysis. Agronomy, Am. Soc. Agro. Inc., Madison, Wisconsin, pp: 891-901.

Chintala R, Mollinedo J, Schumacher TE, MaloD D, Julson JL (2013). Effect of Biochar on Chemical Properties of Acidic Soil, Arch. Agron. Soil Sci. 60(3): 393-404.

Craig JR (1999). Surface water transport of lead at a shooting range. Bull. Environ. Contam. Toxicol., 63:312-319.

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

Dermatas D, Chrysochoou M, Grubb DG, Xu X (2008). Phosphate treatment of firing range soils: Lead fixation or phosphorus release? J. Environ. Qual. 56:37-47.

Dermatas D, Cao X, Tsaneva V, Shen G, Grubb DG (2006). Fate and behavior of metal contaminants in an organic matter-rich shooting range soil: Implications for remediation. Water Air Soil Pollut. 6:143-155.

Fellet G, Marmiroli M, Marchiol L (2014). Elements uptake by metal accumulator species grown on mine tailings amended with three types of biochar. Sci. Total Environ. 468-469: 598-608.

Gaskin JW, Steiner C, Harris K, Das KC, Bibens B (2008). Effect of Low Temperature Pyrolysis Conditions on Biochars for Agricultural Use. Transactions of the ASABE, 51(6):2061-2069.

Grubb DG, Moon DH, Reilly T, Vhtysochoou M, Dermatas D (2009). Stabilization/solidification (S/S) of Pb and W contaminated soils using type I/II Portland cement, silica fume cement and cement kiln dust. Glob. Nest. J. 11:267-282.

Hashimoto Y, Tahi T, Sato T (2009). Extractability and leachability of Pb in a shooting range soil amended with poultry litter ash: Investigation for immobilization potentials. J. Environ. Sci. Health A. 44:583-590.

Laboski CAM, Lamb JA (2003). Changes in soil test phosphorus concentration after application of manure or fertilizer. Soil Sci. Soc. Am. J. 67(2):544-554.

Lee IS, Kim OK, Chang YY, Bae B, Kim HH, Baek KH (2002). Heavy metal concentrations and enzyme activities in soil from a contaminated Korean shooting range. J. Biosci. Bioeng., 94:406-411.

Lehmann J, Joseph S (2009). Introduction. In: J. Lehmann, and S Joseph (eds.), Biochar for environmental management. Science and technology, Earthscan, London, UK. pp. 1-12.

Lehmann J (2007). Bio-energy in the black. Front. Ecol. Environ. 5:381-387.

Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad JO, Thesis J, Luizao FJ, Peterson J, Neves EG Black (2006). Carbon increases cation exchange capacity in soils. Soil Sci Soc Am J, 70: 1719-1730.

Niemeyer T, Niemeyer M, Mohamed A, Fottner S, Hardtle W (2005). Impact of prescribed burning on the nutrient balance of Heath Lands with particular reference to nitrogen and phosphorus. Appl. Veg. Sci. 8:183-192.

Major J (2010). A guide to conducting biochar trials. International Biochar Initiative. http://www.biochar-international.org

Moon DH, Cheong KH, Kim TS, Khim J, Choi SB, OK YS, Moon OR (2010). Stabilization of Pb contaminated army firing range soil using calcinated waste oyster shells. J. Korean Soc. Environ. Eng. 32:1353-1358.

Mulligan CN, Yong RN, Gibbs BF (2001). Remediation technologies for metal-contaminated soils and groundwater: an evaluation. Eng. Geol. 60:193-207.

Niemeyer T, Niemeyer M, Mohamed A, Fottner S, Hardtle W (2005). Impact of prescribed burning on the nutrient balance of Heath Lands with particular reference to nitrogen and phosphorus. Appl. Veg. Sci., 8:183-192.

Novak JM, Busscher WJ, Larid DL, Ahmedna M, Watts DW, Niandou MAS (2009). Impact of biochar amendment on fertility of a Southeastern Coastal Plain soil. Soil Sci. 174:105:112.

Opala PA, Okalebo J R, Othieno CO (2012). Effects of organic and inorganic materials on soil acidity and phosphorus availability in a soil incubation study. ISRN Agronomy, 2012: Article ID 597216, 10 pages,

Puga AP, Abreu CA, Melo LCA, Beesley L (2015). Biochar application to a contaminated soil reduces the availability and plant uptake of zinc, lead and cadmium. J. Environ. Manag.159:86-93.

Rowell DL (1994). Soil science: Methods & Applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350p.

Scheuner ET, Makeschin F, Wells ED, Carter PQ (2004). Short-term impacts of harvesting and burning disturbances on physical and chemical characteristics of forest soils in western Newfoundland. Canada. Europ. J. Forest Res. 123(4):321-330.

Sears GW (1956). Determination of Specific Surface Area of Colloidal Silica by Titration with Sodium Hydroxide. Anal. Chem. 28(12):1981–1983.

Shaheen SM, Tsadilas CD, Eskridge KM (2009). Effect of Common Ions on Phosphorus Sorption and Lability in Greek Alfisols with Different pH. Soil Sci. 174:21–26.

Shi C, Spence R (2004). Designing of cement-based formula for solidification/stabilization of hazardous, radioactive, and mixed wastes. Crit. Rev. Environ. Sci. Technol. 34:391-417.

Singh TS Pant KK (2006). Solidification/stabilization of arsenic containing solid wastes using Portland cement, fly ash and polymeric

materials. J. Hazard. Mater. 131:29-36.
Sohi S, Lopez-Capel E, Krull E, Bol R, (2009). Biochar, climate change and soil: A review to guide future research. CSIRO Land and Water Science Report.
Spychaj-Fabisiak E, Długosz J, Zamorski R (2005). The effect of the phosphorus dosage and incubation time on the process of retarding available phosphorus forms in a sandy soil. Polish J. Soil Sci. 38(1):23-30.
Tessier A, Campbell PGC, Bisson M (1979). Sequential extraction procedures for the speciation of particulate trace metals. Anal. Chem. 51:844-851.
Uchimiya M, Lima IM, Klasson KT, Chang SC, Wartelle LW, Rodgers JE (2010). Immobilization of heavy metal ions (CuII, CdII, NiII, and PbII) by broiler litter-derived biochars in water and soil. J. Agric. Food Chem. 58:5538-5544.
Van Reewijk LP (1992). Procedures for Soil Analysis, 3rd Ed. International Soil Reference Center (ISRIC), Wageningen, the Netherlands.
Van Zwieten L, Kimber S, Morris S, Chan KY, Downie A, Rust J, Joseph S, Cowie A (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant Soil 327:235-246.
Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.
World Reference Base (2006). World reference base for soil resources: A framework for international classification, correlation and communication. Food and Agriculture Organization of the United Nations. Rome, Italy.

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Assessment of sharps waste management practices in a referral hospital

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Sharps waste is part of infectious waste generated in health facilities, management of which is critical. This study aimed at assessing the sharps waste management practices in a referral hospital. The study was conducted at Muhimbili National Hospital (MNH) in Dar es Salaam, Tanzania. Data on sharps waste containers (SWCs) management in generation rates was collected for 60 days, while waste incineration data was collected from 65 randomly selected days. This study gives a picture on how sharps wastes are managed from generation to final disposal. The average weight per used safety box observed in this study (1.54 kg/box) was far above the average weight of a normally filled safety box (0.79 kg/box) indicating that most of the safety boxes are overfilled at MNH. The overfilling of SWCs at MNH was at an average of 10.7% of all the SWCs collected, with a maximum value of 30%, indicating a problem in sharps waste management within the hospital. The sharps waste generation rate observed in a referral hospital (40.8 kg/day) was higher than values reported in district hospitals, but the sharps waste proportion in the infectious medical waste incinerated at MNH was low (at 4% on average). Increasing sharps waste proportion in the waste load increased the incinerator performance in terms of fuel effectiveness. The amount of ash collected from the incinerator per day was observed to be minimal compared to literature data. The final ashes were 5.4% of the total waste loaded, which indicates that the incinerator is more effective in weight reduction, rated at 94.6% efficient.

Key words: Sharps waste, sharps waste container, overfilled safety box, sharps waste proportion, infectious waste, incinerator ash, fuel effectiveness.

INTRODUCTION

This paper presents a study conducted to assess the sharps waste management practices in a referral hospital. The study involved establishment of the sharps waste generation rate and the proportion of the sharp waste in the total infectious waste generated. Moreover, the effect of the sharps waste proportion on the incinerator performance was also studied. The study was conducted in different wards of Muhimbili National

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Hospital (MNH), located in Dar es Salaam, Tanzania.

MNH generates both infectious waste and non-infectious waste. Among the infectious waste category, sharps waste are the most hazardous because of the ability to puncture skin and cause infection. Sharps waste contain items that could cause puncture wound, cuts which include needles, syringes with needles, broken glass ampoules, scalpel and blades, infusion sets, etc. The sharps wastes are generated by nurses, laboratory technicians and doctors who are parts of waste management teams in the different areas of service delivery or waste generation points.

Sharps waste generated at MNH ranged between 30 and 50 kg while other infectious wastes generated range between 800 and 1000 kg per day based on literature data. Sharps waste is collected in sharps waste containers (SWCs) specifically designed for that purpose. The problem of overfilling the SWCs and mixing infectious waste with non-infectious waste is common at MNH.

Risks associated with over-filling the SWCs include creation of an occupational hazard for clinical staff and for waste management staff, whereby, the chance of needle picks increases during collection and handling, while spreading on the floor causes aesthetic conditions. The medical waste generated is treated by incineration within the premises (onsite treatment). Workers in service delivery areas, scavengers, and the public (specifically the children) are at risk from overfilled SWCs which lead to protrusion of needles and spreading of sharps on floors. Despite the high-tech incinerator (with automatic feeder, temperature control, automatic flame ignition burners, air pollution control device, etc.) the problem of air pollution caused by periodic operational problems of the incinerator (which leads to release of fumes and fine dusts into the surroundings) is also alarming.

Operational problems of the incinerator at MNH include sudden failure of burners and blower before a combustion cycle is completed, which leads to lower combustion temperature and release of toxic fumes, (Santoleri, 1985).

Efficient loading of the incinerator include avoiding too much of wet waste in a single batch, proper mixing of sharps with other infectious waste, avoiding overloading the primary chamber, etc. Loading properly segregated waste (rid of food and fruit remains) is also a key performance factor towards improved incinerator performance.

Though sharps waste constitutes a small fraction of the infectious solid waste generated at MNH it can cause morbidity and death due to transmission of blood borne pathogens (BBPs). In this study, the proportion of the sharps waste to the total infectious waste was determined by actual measurements. While former studies on the proportion of sharps waste was earlier determined and reported in district hospitals only (Manyele et al., 2011), this study will improve on this information as it provides data from a referral hospital. The information generated from this study will give an insight into understanding the hazards posed by improper sharps waste management and challenges facing collection, transportation and disposal of SWCs (Khan et al., 2005; Longe and Williams, 2006).

At MNH, the infectious medical waste (comprising of sharps and other waste) is treated by incineration while the non-infectious waste is disposed of in the municipal dumpsite. The hospital has engaged an environmental officer to oversee the safe management and disposal of medical wastes generated within the referral hospital.

MNH has an incinerator (Model: Pyrotec No.8) installed with air pollution control devices, temperature control, flame ignition transformer and burners. Loading is carried out by manually filling the waste into a 120 L bin, operated by the machine. The lifting equipment has a maximum capacity of 120 kg, however, the loaded weight range between 70 and 120 kg. The capacity is greater than the maximum load due to the low density of medical waste, whose large volume fills the bin while its weight is low. In some cases, the bin is not filled to capacity due to fixed weights of waste bags which cannot be opened, leading to loads of down to 50 kg only. The machine produces pollution and choking smell due to type of wastes incinerated, for example plastic materials, drinking water bottles, catheters, infusion sets, waste bags and sharps waste, although the chimney is at a recommended height.

The main objective of this study was to assess the sharps waste management practices in a referral hospital. Specifically, the following key components of the sharps waste management were assessed: procedures and guidelines, sharps waste components, characteristics of SWCs used for waste collection, management of SWCs, sharps waste generation rate, treatment method for sharps waste. Moreover, the final ash disposal after treatment was also assessed. Statistical analysis (using histograms and linear graphs) were used to express the results.

Effective sharps waste segregation at the generating area and use of proper waste containers provides a most effective safeguard against the hazardous effects of sharps waste (Blenkharn and Odd, 2008). Disease transmission from used sharps to healthcare workers or patients requires critical attention during management of the sharps waste (Allsopp et al., 2001). Proper management of sharps prevent HIV and other infectious diseases from being transmitted from patients to health service providers. Improved engineering controls to minimize needlestick injuries (NSI) include safety locking devices that prevent needle re-use and sharps disposal containers that deter access of contents. This study assessed utilization and management practices of sharps safety disposal containers in a referral hospital.

While incineration performs high temperature decontamination and destruction of infectious medical waste, sharps waste effectively decontaminated using other methods, such as, steam autoclave or microwave irradiation, can be disposed of in special areas in the landfills. The acceptable treatment method in Tanzania according to the National Healthcare Waste Management Guidelines is incineration at high temperature based on cost consideration, efficacy of treatment method, skills requirements and availability of technology. Despite wide acceptance of incineration method, the fumes generated from incineration of sharps waste can be hazardous to human health if not well treated. Treatment methods for such fumes include combustion at higher temperature in the secondary chamber (800-950°C) and connecting wet scrubbers to the chimney for acid-gas removal (Santoleri, 1985; Powell, 1987; Singh and Prakash, 2007).

Sharps waste collection in hospitals is done by using SWCs. Such containers must conform to safety performance characteristics, which are divided into four areas, namely: functional, accessible, visible, and accommodation. Containers should remain functional during their entire usage time, that is, they should be designed to permit safe disposal of sharps. The SWCs should be durable, closable, leak proof and puncture resistant until disposal. They should be simple and easy to operate. The disposal opening should prevent spills of the contents while in use, during closure and during transportation of the waste within the health facility before treatment. In all areas where sharps are used, a sufficient quantity of containers should be available in the appropriate size. At minimum, one sharp container should be provided at each working station where sharps are predictably generated, so as to minimize the possibility of overfilling the SWCs, which would compromise the safe operation of the container.

Containers should be visible and accessible to workers who use, maintain, or dispose sharp devices. The SWCs should be placed in a location to ensure they are visible and within easy horizontal reach of the user. Where containers are fixed to the walls or other permanent sites, the vertical height should allow the health service providers (HSP) to see the opening of the container. The SWCs should be placed in an area that is unobstructed by obstacles between work station and the container. Unsafe locations may force workers to make unnecessary movement while holding a used sharp that may result in injuries. Workers should be able to see the degree to which the container is full before sharps are placed in the container.

Sharps waste must be discarded at the point of use into SWCs. The latter should be sealed when full to avoid NSI (Henry and Campbell, 1995; Geberding, 1997). Improperly designed (provisional) and overflowing SWCs increase the risk of exposure to health workers, waste handlers and the community at large. Safe disposal of healthcare waste improves working conditions, reduces pollution and accidental injuries, increases public safety and reduces the chance of transmission of infectious diseases (Environment Canada, 2011).

According to a study reported by Manyele and Kagonji (2012), the district hospital incinerator at Temeke hospital was used to treat medical waste containing 25% sharps waste, the rest being other waste. During primary combustion process, some of the products of combustion are given off as combustible gases such as carbon monoxide. When combustible gases reach the secondary combustion chamber an additional supply of air to facilitating final combustion in the secondary chamber is supplied using burner and blower combination. The incoming gases burn and raise the secondary chamber temperature even higher, and reduce the gases to more stable compounds such as carbon dioxide.

The waste composition fed into the MNH incinerator is not always the same. It was hypothesized that the amount of waste and composition contributes to the incinerator performance. In this study, the effect of the proportion of sharps waste on incinerator performance was studied.

Most of incineration plants can be operated in 24 h a day, whereas the incinerator at MNH operate for only 8 h per day due to nature of waste incinerated and fuel consumption costs. Fuel control is an important area to consider during incineration of medical waste containing sharps waste. High fuel consumption occurs when burning extremely moist waste or when there is a lot of air added to the system. For example, a placenta's moisture must be evaporated before volatilization can occur. Since no heat can be released from such waste until it start to volatilize, the primary burner must supply extra energy, thus leading to higher fuel consumption than for dry waste. To reduce fuel consumption, the high moisture load must be reduced or mixed with more sharps waste to create quick combustion (Manyele and Kagonji, 2012). In case excessive moisture enters secondary chamber during incineration, the temperature will drop and the burner will need to operate much longer.

Air pollutants result from combustion constituents. This includes unburnt carbon, carbon monoxide, hydrocarbons, aldehydes, amines, organic acids, polycyclic organic matter and any other waste constituents or their partially degraded products that escape. Organic pollutants emitted as a result of incomplete combustion of waste material are often generated in the primary combustion chamber operating at low temperature. The control of the emission of these organic pollutants can be handled by continued combustion at high temperatures using afterburners (also termed secondary combustion chambers).

During incineration process, sharps waste plays a big contribution on the maximum temperature in the combustion chambers. This leads to effective destruction of organic waste into inorganic ashes, and hence high efficiency in terms of weight reduction and fuel effectiveness. The higher the temperature in the combustion

Figure 1. Sharps waste containers overfilled with disposable syringe at MNH incineration site.

chambers the shorter the incineration cycle time and the higher the fuel effectiveness (kg waste/L of diesel oil).

The final ash is removed daily after incineration and left to cool before transporting to the municipal dumpsite for final disposal (Giradakos et al., 2009; Zhao et al., 2010). Characteristics of incinerator ash are inherently related to the specific source and character of the waste fed to the incinerator. The dominant elements present are silicon, aluminium, iron, and calcium, much as normal soil (Walter, 2002), however, due to presence of sharps waste, in the incinerated waste, un-burnt sharps waste become visible, including broken glass, metals, un-burnt needles, and gravel/stones, indicating poor segregation of the waste at the source.

METHODOLOGY

The study was conducted in a referral hospital located in Dar es Salaam city, in Tanzania, by assessing the sharps waste management practices, from initial disposal into SWCs to transportation and incineration, and ultimately to dumpsite after treatment. Data was collected starting with sources of sharps waste. The initial disposal of sharps waste was assessed by determining the fraction of the SWCs filled beyond the ¾-fill level (denoted as overfilled SWCs). The sharps waste generation rate was established based on needle and syringe consumption as well as from direct measurements of weight of each used SWC (kg/box). Figure 1 shows the type of safety boxes used in this study.

The number of SWCs used per day (normal filling and overfilled) was recorded, followed by determination of weight per safety box . The SWCs were collected from Sewaji, Kibasila, Mwaisela, Pediatric and Labour wards only, although the hospital comprise of several other patient treatment wards. Collected SWCs were stored tempeorarily at the incinerator house before treatment. The waste load comprised of sharps waste and other infectious waste, both categories of infectious waste were weighed separtely to determine the total waste loaded into the incinerator, and also to determine the composition of the waste load, that is the fractions of sharps waste and the other waste. During incineration the total incineration time (called cycle time), maximum temperatures reached and fuel oil consumed were recorded. After incineration, the ash was collected and weighed before final disposal to determine the ininerator efficiency in terms of weight reduction. In this study, data was collected for a period of 65 randomly selected days. Each load was recorded separately, and quantities totalled for the selected period. In this study daily quantities were determined, although weekly and monthly amounts can also be determined.

The daily sharps waste management data collection included number of SWCs used and collected, filling conditions (normal and overfilled SWCs), weight of each safety box collected, weights of sharps waste and other waste loaded into the incinerator for each cycle. The sharps waste components were mainly disposable syringes and needles. Incineration data included combustion temperatures for primary and secondary chambers, cycle times, ash generated, and fuel consumption per day. The composition and proportion of sharps waste were determined from the measured weights of sharps and other waste designated for incineration. Qualitative methods included: site visits, interviews and review of documents including guidelines and procedure. Data was managed with MS Excel. After cleaning, data was then transferred directly into SPSS for analysis using descriptive statistic and focusing on frequencies. The output contains graphical presentations (histograms, linear graphs and pie charts), as shown in Figures 2 to 6.

Based on the total weight of loaded waste into the primary chamber, and weight of sharps waste, the mass fractions of sharps and other waste, Y and X, respectively were determined. The fuel effectiveness, defined as total waste incinerated per litre of diesel oil consumed, forms an assessment criteria for incinerator performance which represents moisture content and composition, burner efficiency, cycle time, burner efficiency, cycle time and chamber size. Another measure of incinerator performance was the waste destruction efficiency, which was determined based on weights of ashes collected and the loaded waste. The ash was left to cool completely before loading into special plastic bags ready for transportation to the municipal dumpsite for final disposal. Assessment of treatment method for sharps waste included detailed analysis of the incineration process (such as weighing and loading of waste, temperature profiles, and incineration time), maximum temperatures reached, and incineration cycle time.

RESULTS

Sharps waste generation rate

The sharps waste incinerated were collected from all generation locations within MNH. For the purpose of SWCs characterization (overfill percent and weight per safety box), data was collected from five wards. According to this study, the Labour ward generates highest amount of sharps waste followed by Paediatrics ward. Figure 2 shows the histogram of the daily sharps waste incineration rate (in kg/day) recorded for 65 days. All sharps waste generated at MNH is incinerated so that sharps waste generation is the same as sharps waste incinerated. The overall average sharps waste generation rate was established to be 40.8 kg/day, with wider daily variations between 10 and 90 kg sharps waste per day. Higher values of sharps waste generation observed indicates days with high demand on medical services due to emergency cases referred to MNH from Temeke, Amana, Mwananyamala and private hospitals located within the city and from the surrounding districts.

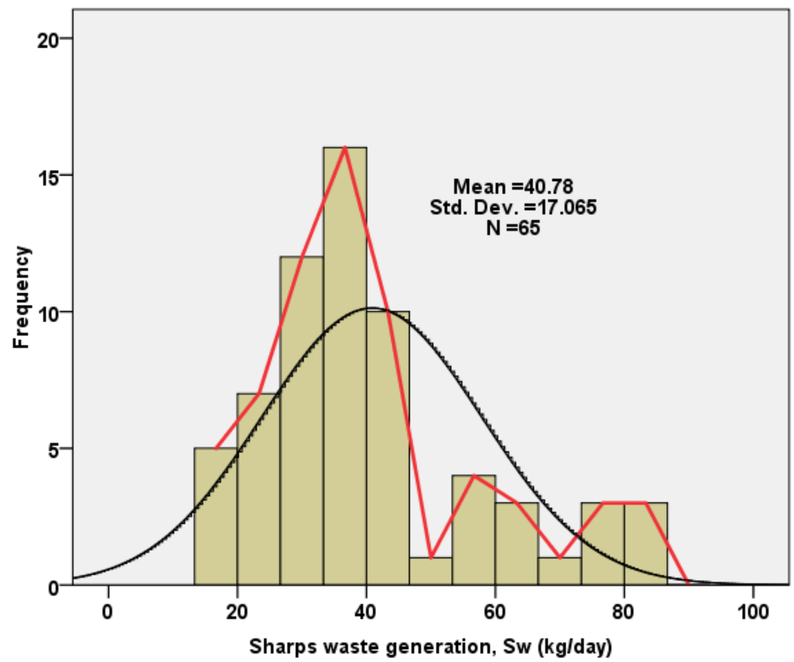

Figure 2. The probability density function of daily sharps waste generation rate.

Together with measuring the sharps waste generated by weighing SWCs before and loading into the incinerator, the generation rate was further analyzed based on needles and syringes consumed in the referral hospital. The SWCs were being supplied from Medical Store Department (MSD) at approximately 1000 boxes/month while the disposable syringes with needles amounted to 55,000 pieces per month. Syringes of different sizes (2, 5, 10, 20, and 50 ml are used in the hospital at varying amounts and in this order of preference, with a total consumption rate of about 45,730 pieces per month.

Distribution of total consumption of syringes by size in the surgical stores, for example, in the period of three months, indicted that 5-mL syringes are the most used sizes (42% of the time) followed by 2, 10, 20 and 50 mL, at 32, 18, 5 and 2%, respectively. Knowledge of syringe sizes is important as some of the applications could be combined to minimize the consumption and waste generation rate. When the rate of syringes consumption is too high, it leads to high consumption rate of SWC, high demand for collection of SWCs and hence overfilling of the SWCs.

Sharps waste segregation

During the study, it was observed that sharps wastes are segregated from other infectious waste immediately after use. The sharps wastes are collected using a puncture proof container placed in each ward or clinic. Written standard operating procedures for handling sharp are not available in most areas putting the health service providers at risk of injury by sharps (Malkan, 2005; Almuneef and Memish, 2003). The sharps waste management booklets (English and Swahili version) from Ministry of Health and Social Welfare (MoHSW) aimed at providing guidance to the health service providers are available to each ward in-charge but not accessible to other members of staff. During an interview, the hospital management reported that they provide training to patients every day regarding waste segregation, so that patients do not mix the waste with remaining food materials, although adherence is minimal.

Filling level and weight of SWCs

Figure 3 shows the histogram of the weight of the used or filled safety box. Several boxes were measured per day from which the average weight was recorded for a period of 60 days. The average weight per box when filled to ¾-level is about 0.79 kg while the average weight of overfilled sharps waste container based on overall data was determined to be 1.54 kg, indicating that a large number of safety boxes are filled beyond the mark. The histogram shows a bimodal behaviour, with peak frequencies at 1.1 and 2.2 kg per box, all peaks being in the weight range comprising of overfilled safety boxes. The causes of higher weight per safety box were attributed to the density of the materials dropped into the

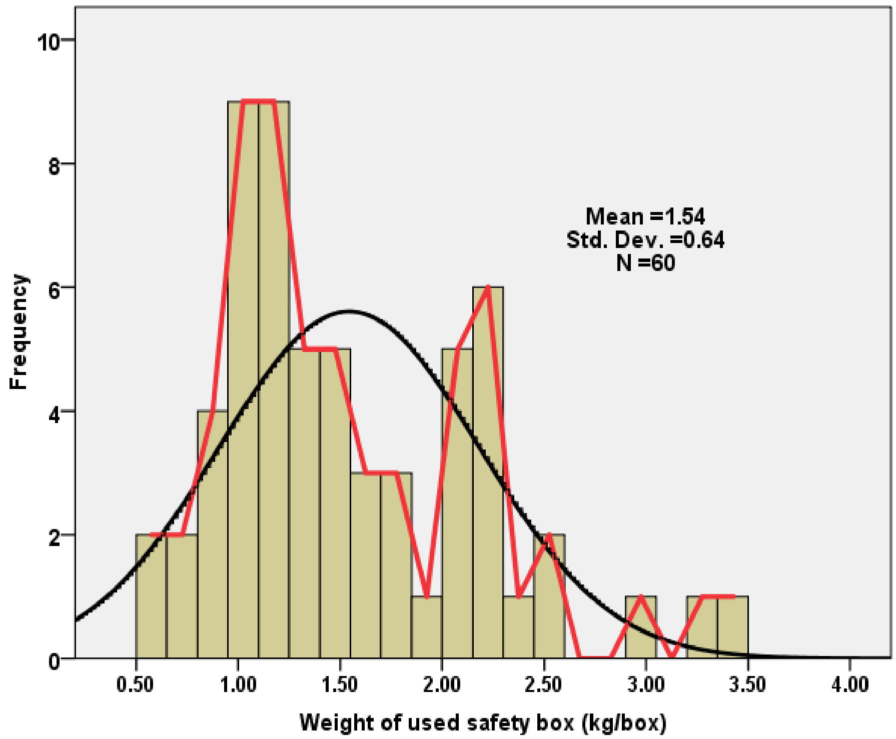

Figure 3. Probability distribution of weight per used safety box.

box and delays in collection of safety boxes from the service delivery areas.

Higher values of the weight per used safety box (beyond 0.79 kg/box) are an indication of the overfilled safety boxes. By using the filling level mark as the criteria for overfilled boxes, it was possible to establish data for the average percent overfilled safety boxes in different areas of MNH. When assessed based on SWCs collected from the wards, the results indicated that Pediatrics, Kibasila and Mwaisela wards had highest percent of overfilled SWCs (at 19.0, 15.6 and 11.4%, respectively). This was followed by Sewaji ward (10.8%) and Labour ward (6.6%). The highest average overfill rate was observed in the Paediatrics ward (19%). Further analysis of overfilled SWCs revealed that the mean percentage is 10.7% of all SWCs (with standard deviation of 6.25%). The data shows a lower right hand side skewness (Sk = 0.62), indicating that high percent overfilled SWCs exist within MNH for some days. Figure 4 shows the probability density function of the percent overfilled SWCs data, which was closely fitted using Rayleigh, Chi-Squared and Cauchy probability distributions (in this order of goodness of fit), out of 56 distributions tested using Easy-Fit software. The overall percent of overfilled SWCs reached the highest value of 30% when all the SWCs collected from the five locations were assessed.

The Rayleigh distribution function with a sigma parameter σ = 9.1076 and statistic value of 0.09144 was ranked first in describing the probability distribution of the percent overfill data. The fact that Rayleigh fits data with two degrees of freedom, two normally distributed orthogonal components or a distribution with added harmonic oscillations, indicates that there are two main factors leading to the observed overfilling of SWCs. Detailed research is required to establish these factors.

Sharps waste as a fraction of total infectious waste generated

Figure 5 shows the probability density function of the sharps waste proportion data. The average proportion was established to be 4%, with the data slightly skewed to the right hand side. The sharps waste proportion data ranged from 1.5 to 9%. The results show that there are no cycles which were operated without sharps waste. However, very low sharps waste proportion shows scenarios where the sharps waste were being collected while the incinerator is already operating, and cases where the waste bags were very voluminous allowing only little sharps waste to be added. An insert in Figure 5 is the pie chart showing the average proportion of the incinerated waste at MNH for the collected data from 65 combustion cycles which shows that 4% comprised of sharps waste and 96% other infectious waste.

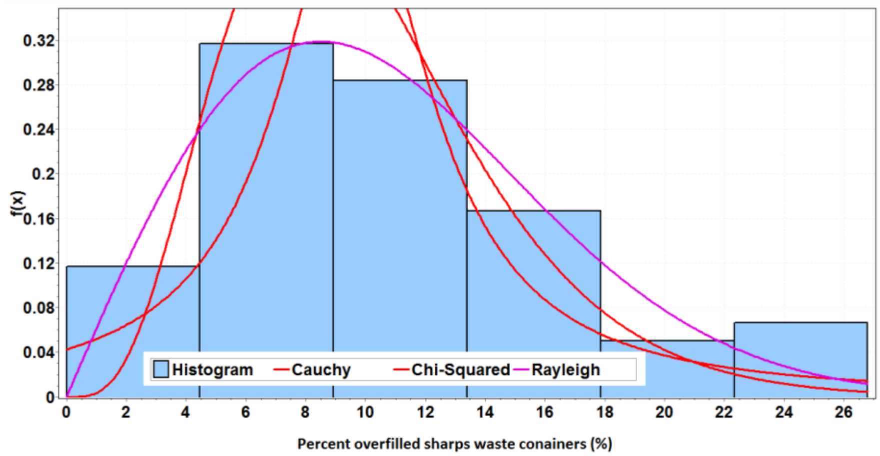

Figure 4. Probability density functions for overall percent overfilled SWCs data.

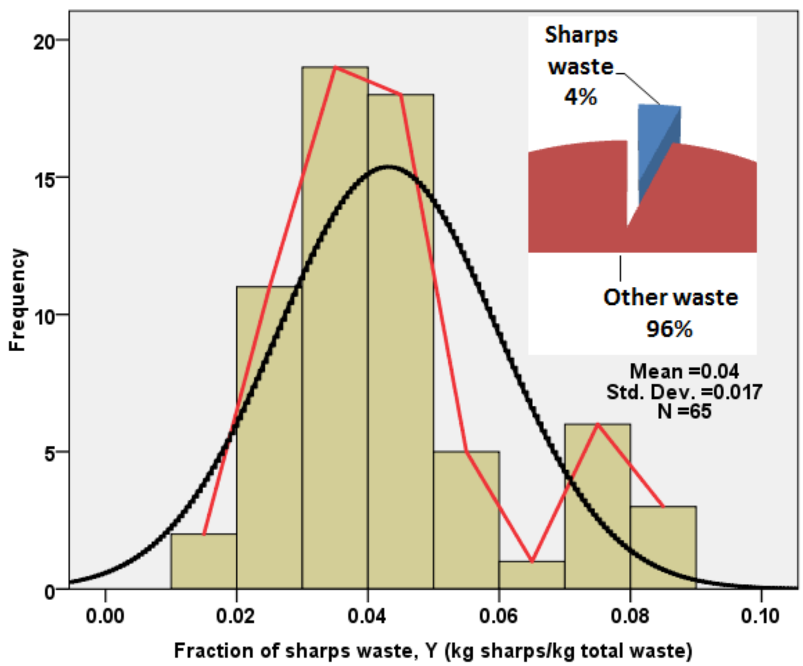

Figure 5. Histogram of the sharps waste proportion data.

While the percentage of infectious waste that ought to be incinerated vs. the non-infectious waste transported to dumpsite is quite interesting, this study focussed on collection of infectious waste which is incinerated despite that other non-infectious waste is also generated at MNH. The total infectious waste generated is about 10 tons per day, compared to 0.945 tons per day of infectious waste loaded into the incinerator. Thus, infectious waste generated at MNH is about 8.63%, the remaining being non-infectious. Since the sharps waste is only 4% of the total infectious waste, it implies that the sharps waste comprise of 0.35% of the total waste generated.

Effect of sharps waste proportion on the incinerator efficiency

In this study, the incinerator efficiency was measured based on combustion and destruction efficiency (determined from the fraction of the waste loss after combustion) and fuel effectiveness (defined as the kg waste incinerated per liter of fuel oil used, kg/L). Based

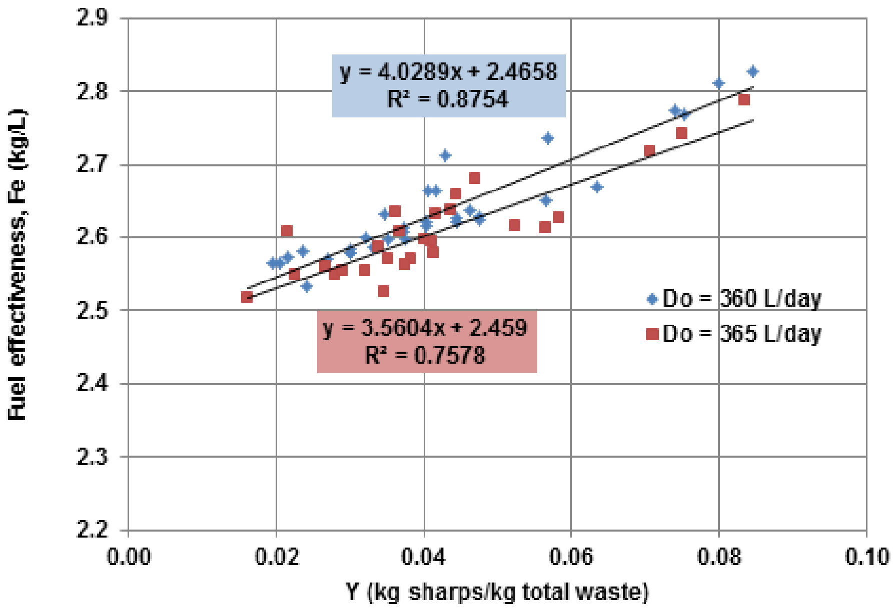

Figure 6. Effect of sharps waste proportion on fuel effectiveness during incineration of infectious medical waste.

on literature data, the destruction efficiency ranged between 85 and 98% (Manyele et al., 2011). In this study, however, the destruction efficiency was 94.6%, and ranged between 91 and 98%. This is higher compared to literature data. A second measure of efficiency of the incinerator, the fuel effectiveness was also determined based on daily incineration data. The values of fuel effectiveness for the MNH incinerator were lower, ranging between 2.5 and 3.0 only, compared to values reported for small scale incinerator of similar capacity (kg/h) which was about 2.5 to 5.5 (Manyele et al., 2011).

Figure 6 shows the effect of sharps waste proportion on the fuel effectiveness during incineration of infectious medical waste. Increasing Y (%) increases the fuel effectiveness or kg waste burnt per liter of diesel oil. While other studies focussed on the variation of fuel effectiveness with total waste incinerated and incinerator capacity, this study established the relationship between sharps waste proportion in the waste load and the fuel effectiveness. Two linear relationships were observed based on diesel oil consumption rate. At a diesel consumption rate of 360 L/day, higher values of fuel effectiveness were observed compared to the values observed at higher fuel consumption rate. Higher fuel consumption rate of 365 L/day corresponds to operations where burners were faulty leading to stoppage for service. Despite the lower fit (indicating that fuel effectiveness is also affected by other factors), the general trend shows that fuel effectiveness increases with sharps waste proportion. Other factors affecting the fuel effectiveness include moisture content in the waste load, poor segregation at the source, poor burner performance, etc.

The relationship between incineration cycle time on medical waste incinerated was also assessed. The more the other waste loaded into incinerator the longer the incineration process took place and the more the fuel consumption as reported also by Manyele and Kagonji (2012). Moreover, with lower sharps waste proportion in the loaded waste, thicker flue gas was produced requiring intensive scrubbing operation in the air pollution control devices (APCD). For a cycle with only other waste loaded it took 45 minutes to be destroyed. However, if sharps waste are introduced, the cycle time decreases to 25 minutes depending on the amount. Higher cycle times lead to more fuel consumption which in turn increases the running cost for the incinerator.

Final ash disposal

Final ash disposal after treatment was assessed by determining the daily quantities of ash collected and final disposal methods used. Results show that the average amount of bottom ash collected from the incinerator was 51.2 kg with a standard deviation of 14.2. The bottom ash collected ranged between 20 - 90 kg/day. On average, the ash generated was about 5.41% of the total waste incinerated per day, indicating that 95.59% was converted into gaseous byproducts. Thus, based on ash collection data, the incinerator efficiency (based on weight reduction) ranged between 90 and 98%, with average of 96.6%.

DISCUSSION

The reasons for overfilled SWCs observed include lack of enough containers in service areas, especially during weekends where containers are not issued. Also, in areas or times when waste handlers could not remove the containers in time according to the waste collection timetable, SWCs were overfilled. In some instances, the SWCs are left in service areas throughout the day and the waste handlers perform SWCs collection during night due to shortage of staff. The study revealed that overfill of SWCs occurs at Paediatric ward as it is always busy with a large number of patients from public district hospitals and private hospitals being referred to MNH for further treatment. Although the average SWCs overfill rate (10.7%) is low, this indicates safety hazard for anyone handling the containers as it can lead to needlestick injuries disease transmission and spread of waste on the floor.

Despite of higher genration of sharps waste for some days studied, all of the sharps waste was being incinerated. There is, however, a lack of appropriate sharps waste compartments in the storage bay, which leads to mixing of wastes after collection. The WHO recommends storage rooms for sharps waste of which unauthorized person are not allowed to enter, inaccessibility to animals, insects and birds, with enough ventilation. The storage rooms at MNH are not standard, allowing scavengers' to mix the sharps waste with other infectious waste. Moreover, appropriate sharps waste transportation trolleys are required at MNH. This will decrease the chances of injury for waste handlers due to protruding sharps during collection, transportation and loading into the incineration.

The factors determining the fraction of the sharps waste incinerated are amounts of other waste generated, sharps waste collection efficiency and loading preference by incinerator operators. The last two factors can be easily controlled during the waste management processes. As reported in the literature, the higher values of the sharps waste proportion increases the waste combustion efficiency due to faster volatilization of the plastic components of sharps waste. Thus, during loading of the waste into the combustion chamber, the sharps waste should be evenly distributed over all the waste incineration cycles carried out.

The variations in this fraction of infectious waste are important as it determines safety precautions during loading and destruction efficiency (combustion assistance of plastic materials and sharp objects remaining in the bottom ash). Moreover, studying the generation rates for sharps waste helps the hospitals in planning and directing proper human and financial resources in the management of the waste. When there is more sharps waste, the temperature will rise sharply and reach the highest value faster compared to cycles with lower proportion of sharps waste because the latter contains large amount of plastic which support burning at high temperatures. Other waste also contributes in attaining temperatures in both primary and secondary chambers, whereby, large quantities loaded lead to high maximum temperatures, but takes longer time to undergo complete destruction.

It has been established that the average proportion of sharps waste incinerated was 4% of the total waste, which is on the lower side compared to literature data, which can be associated with lower fuel effectiveness presented in Figure 5. Increasing the sharps waste proportion in the incinerated waste was observed to increase the fuel effectiveness with a linear relationship. However, its effect on maximum temperatures in the primary and secondary combustion chambers of the large scale incinerator requires further research. The values of sharps waste proportion observed in the referral hospital were lower compared to values reported in district hospital, mainly because the generation of other waste in the district hospitals is lower compared to referral hospital. This is because, while district hospitals were observed to generate 24.41 kg of sharps waste per day and other waste of 73.56 kg/day (Manyele et al., 2011), on average, the referral hospital generates 40.78 kg/day sharps waste and 945 kg other waste per day.

The results from this study have revealed sharps waste management aspects that are being well performed and aspects that need improvements. The aspects being well performed include incineration of all the sharps waste generated, which implies total decontamination and destruction. Also, waste collection efficiency is high and collection is well performed, such that all generated sharps waste reaches the incineration room. However, sharps waste management in the areas of generation should be improved by observing the filling lines, improving segregation, while storage bay and sharps waste transportation equipment require improvements in the referral hospital.

From the observation made on the ash contents, it was revealed that needles, surgical blades, blood slides, vacutainer tubes, vial bottles, ampoules are not completely destroyed though they are sterilized and denatured (Zhao et al., 2010). Thus, care should be taken when removing ashes in this case.

Conclusion

This study gives a picture on how sharps wastes are managed from generation to final disposal in a referral hospital. Based on the results, the following conclusion can be made:

1) The average weight per used safety box observed in this study (1.54 kg/box) was far above the average weight for a safety box not overfilled (0.79 kg/box) indicating that most of the safety boxes are overfilled at

MNH and/or there are signs of poor segregation at the source.

2) The overfilling of SWCs at MNH is at an average of 10.7% of all the SWCs collected, with a maximum value of 30%, indicating a problem in sharps waste management within the hospital, which requires attention by the MNH management. Areas observed to overfill the SWCs include Pediatrics, Kibasila and Mwaisela wards, which should be supported by supplying enough containers followed by implementation of the standard operating procedures.

3) The sharps waste generation rate observed in a referral hospital (40.8 kg/day) was higher than values reported in district hospitals. Within the MNH, the highest generation rates were observed in the Pediatric and Labour wards, which are still manageable by MNH.

4) Sharps waste proportion in the infectious medical waste incinerated at MNH is low (at 4% on average). Increasing sharps waste proportion in the waste load increases the incinerator performance in terms of fuel effectiveness.

5) The amount of ash collected from the incinerator per day was observed to be minimal compared to literature data. While final ashes are reported to be 10% of the total waste, this study revealed a value of 5.4%, which indicates that the incinerator is more effective in weight reduction, rated at 94.6%.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Allsopp M, Costner P, Johnston P (2001). State of Knowledge of the Impacts of Waste Incinerators on Human Health. Environ Sci. Pollution Res. 8(2): 141-145.

Almuneef M, Memish ZA (2003). Effective medical waste management: It can be done. Am. J. Infection Control 31(3):188-192.

Blenkharn JI, Odd C (2008). Sharps Injuries in Healthcare Waste Handlers. Ann. Occup. Hyg. 52(4):281-286.

Environment Canada (2011). Technical Document for Batch Waste Incineration, http://www.ec.gc.ca/gdd-mw/.

Geberding JL (1997). Accidental Exposure to blood and body fluids among health care workers in dental teaching clinics: a Prospective study. New England J. Med. 312(1):58-59.

Gidarakos E, Maria P, Kalliopi A, Karl-Werner S (2009). Characterization and Hazard Evaluation of Bottom Ash Produced from Incinerated Hospital Waste. J. Hazard. Mater. 172(2-3):935-942.

Henry K, Campbell S (1995). Needle stick/Sharps injuries and HIV exposures among Health care workers: National estimates based on a survey of U.S. Hospitals. Minnesota Med.78:1765-1768.

Khan MH, Khan H, Basit A, Ikram-ullah M, Babar TS, Habib H (2005). Sharps waste disposal practice among General Practitioners. Gomal J. Med. Sci. 3(1):2-5.

Longe E, Williams A (2006). A Preliminary Study of Medical Waste Management in Lagos Metropolis, Nigeria. Iranian J. Environ. Health Eng. 3(2):133-139.

Malkan, S (2005). Global Trends in responsible healthcare waste management-A perspective from Health Care without Harm. Waste Manage. 25:567-572.

Manyele SV, Kagonji IS (2012). Analysis of medical waste incinerator performance based on fuel consumption and incineration cycle times. Engineering 4(10):625-635.

Manyele SV, Kagonji IS, Mrisho J (2011). Assessment of medical waste incinerator performance based on physical characteristics of ashes. Eng. J. 3(10):1045-1053.

Powell F (1987). Air pollutant Emissions from the Incineration of Hospital Wastes-The Alberta Experience. J. Air Pollution Control Assoc. 37(7):836-839.

Santoleri JJ (1985). Design and Operating Problems of Hazardous Waste Incinerators. Environmental Progress 4(4):246-251.

Singh S, Prakash V (2007). Toxic Environmental Releases from medical waste Incineration. A Review, Environmental Monitoring 132:67-81.

Walter R (2002). Combustion and Incineration Processes, 3rd Edition, Marcel Dekker, New York, 2002.

Zhao LJ, Zhang F-S, Chen MJ, Liu ZG, Wu JZ (2010). Typical Pollutants in Bottom Ashes from a Typical Medical Waste Incinerator. J. Hazard. Mater. 173(1-3):181-185.

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Using geographic information system (GIS) to determine waste transfer stations in relation to location of landfill sites in Accra Metropolis

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The existing landfill sites in Accra are reaching full capacity and the acquisition of land for the construction of landfill sites has become very difficult due to rapid developmental activities in Accra. However, with the current rate of development which will cause the construction of landfill sites to be far from the source of generation, there is urgent need to get an intermediate facility, that is, waste transfer station where waste would be processed and compacted in long distance trucks to reduce the cost of waste transport and disposal. The objective of the study was to determine suitable places that could be used as waste transfer stations in relation to location of landfill sites using Geographic Information System (GIS). In this study, coordinates of all the container sites in Accra were determined with the Geographic Positioning System (GPS). The coordinates were then converted into points using ArcGIS and Microsoft Excel 2007 to help analysed the data collected. From the study, four transfer stations were located with the help of the GIS, namely: Ablekuman and Amomola (Transfer station 1),Oblogo and Weija (Transfer station 2),Ashongman and Agbogba (Transfer station 3), AshaleyBotwe and Ogbozdo (Transfer station 4).

Key words: Transfer, waste, landfill, station, geographical information system (GIS), geographical positioning system.

INTRODUCTION

In recent years, management of solid waste has become an issue of increasing environmental concerns of public debate (Rahman and Moten Ashraf, 2007). Historically, solid waste was collected in packer dump truck collection vehicles which delivered the waste directly to landfills. As landfills closed, haul distances became greater, giving rise to the use of transfer stations in which the waste is transferred to larger-capacity transfer trailers. The trailers are then hauled to the landfill site (US EPA, 1995).

The American Heritage Dictionary of English language defines waste transfer stations as a facility where solid waste materials, including yard waste, demolition materials, and household refuse, are transferred from small vehicles to large trucks for efficient transport to landfills, recycling centres and other disposal sites (AHDEL, 2011).

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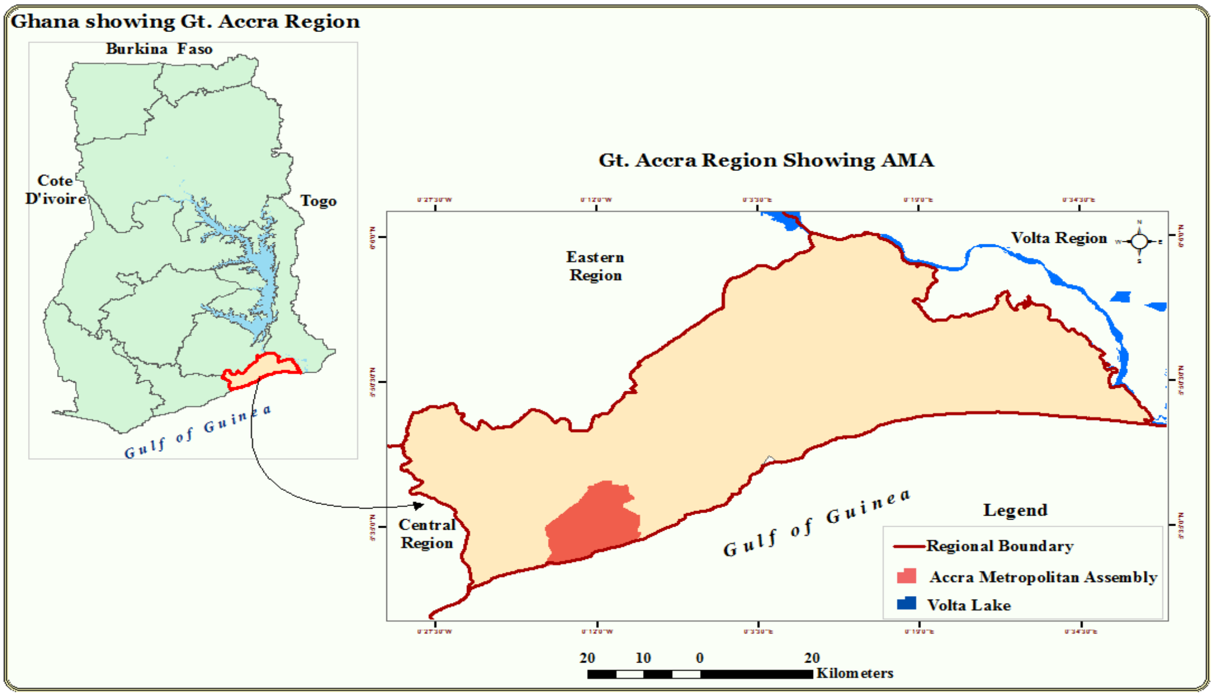

Figure 1. Map indicating the study area.

In recent years, transfer stations have also been used for diverting, collecting, and transporting recyclables as well as incorporating materials processing systems into the same facility (Zurbrugg, 2003). Transfer station currently being designed are typically enclosed in a building to reduce problems associated with noise, odour, and blowing litter and provide an aesthetically pleasing facility (Waste Transfer in Illiniois, 2001). Advantages As land becomes more urbanised, public resistance to new landfill sites increases. The current trend is to use network of transfer stations from which waste is transported to a remote landfill site, processing facility, or energy-recovery facility.(Ojdemark, 2005) Transfer stations can be located on relatively small parcels of land and perceived by the public as more compatible with urban development than landfill sites. This challenge has resulted in final disposal sites being established far from the source of waste generation.(Pieber, 2004) Hence, the need for waste transfer stations which can serve as an intermediate between the sources of generation and the final disposal sites. When this is established it will then ensure effective collection of waste from the city, because haulage distance will be reduced and the rate of waste collection by the trucks will increase (Bilitewski *et al*, 1994). Furthermore, the cost of collection, fuel and maintenance will reduce. Also, haulage distance would be reduced; thereby reduction in emission into the atmosphere by these trucks. (Böhmar, 1995).

To maximize waste collection efficiency, transfer stations should be located centrally to waste collection routes. As a rule of thumb in urban and suburban areas, transfer stations should be no more than 10 miles away from the end of all collection routes (Pieber, 2004).

The fast urbanization of the city of Accra has made finding a piece of land to be used as landfill site very challenging. There is greater demand of land for real estate development in Accra. These estates frown against landfills in their neighborhoods.

The estate developers take large land areas and their presence then become a great challenge in locating a landfill. The challenge of not being able to acquire land close to the generation points, affect waste collection. This occurs because of the estate developers acquiring large land areas; hence, landfills must be built further from the generation points. The problem this study sought to address is to identify suitable places that can be used as transfer stations in relations to the location of final disposal sites in Accra using Geographic Information System (GIS).

This research used GIS to identify possible locations that could be used for transfer station, considering all the factors needed to establish such a facility.

MATERIALS AND METHODS

Accra is the capital city of Ghana and also the regional capital of the Greater Accra Region. It is Ghana's primate city, serving as the nation's economic and administrative hub. It is furthermore a centre of culture and tourism, sporting a wide range of nightclubs, restaurants and hotels. Accra stretches along the Ghanaian Atlantic Coast, bounded to the east by the Ga East Municipal Assembly, to the west by the Ga West Municipal Assembly and to the South by the Ga South Municipal Assembly. Most of the people in Accra are

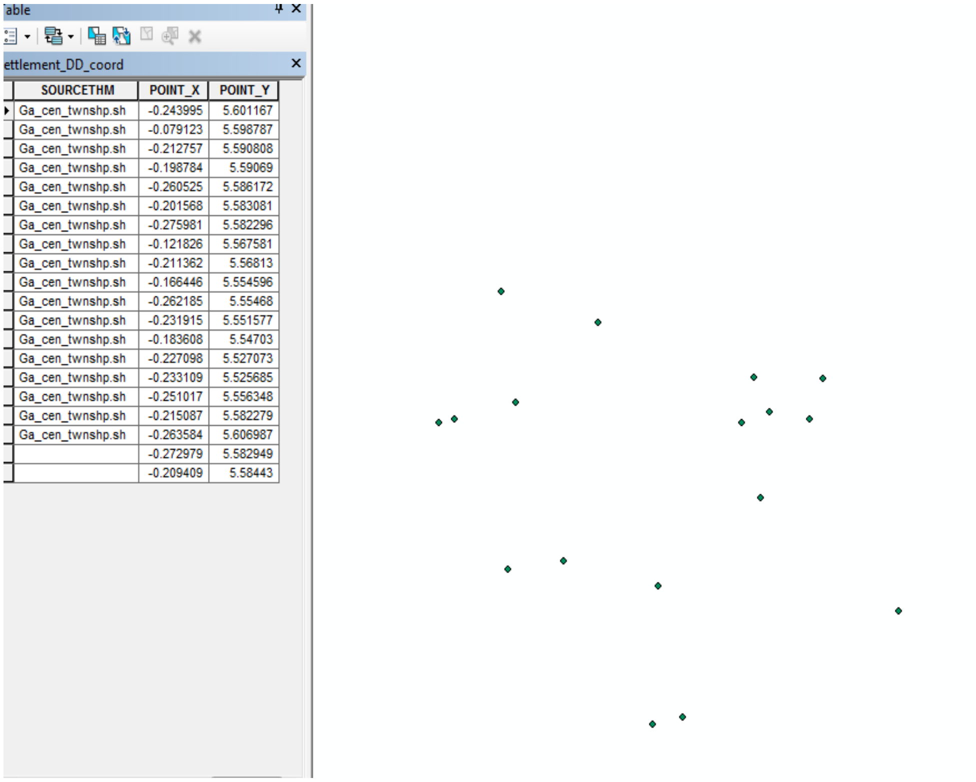

Figure 2. Points generated from the coordinates.

office workers, factory workers, Artisans and traders (Ghana Web, 2010). The study was conducted in the Accra Metropolitan Assembly which is made up of eleven sub-metros, namely: Ablekum Central, Ablekum North, Ablekuma South, Ashiedu-Keteke, Ayawaso Central, Ayawaso East, Ayawaso West–Wuogon, La, Okaikoi North, Okaikoi South, and Osu Klottey (Ghana Districts, 2006) (Figure 1).

Data collection

Geographical position System (GPS) was used to get the coordinate of all the container sites in the Accra Metropolis.

This involved taking the coordinates of all the waste container sites in Accra and also the final disposal sites. Furthermore, data on the traffic situation, population density, land use, natural condition (vegetation, water bodies, etc.) and human settlement will be obtained from the appropriate agencies.

The coordinates of the various places designated to be used as final disposal sites, namely: New Bortianor and Adjen-Kotoku were also taken by using the GPS and the coordinates of the current dump sites were also taken.

Analysis of data

These coordinates were then converted into points, using ArcGIS and Microsoft Excel 2007 to analyse the data collected.

The coordinates were converted into degree decimals, by dividing the minutes by 60 and dividing the seconds by 3600 e.g. 5° 33´ 30´´ becomes 5.55833 and the figures typed in Excel.

The excel table was opened in ArcGIS as a dbf file and exported as shape file which was displayed as points in ArcGIS as shown in Figure 2.The Sub-Metro boundary was obtained from Accra Metropolitan Assembly and using ArcGIS software the various buffers (3, 6, and 9 km) were created from the external boundary of the merged sub-metro as shown in Figure3. The average distances amongst the various container sites were determined with the help of the GIS.

Also, the average distance between these container sites and the final disposal sites were also determined to help determine the possible places that could be used as waste transfer stations.

During the analyses, the following were considered to help determine those suitable places that could be used as transfer stations: closeness to water body and settlement, accessibility, closeness to school, health facility, closeness to source of drinking water, and traffic situation within the study area condition of roads, e.g. first class, second class and possible shortest distances to the final disposal sites. To establish the aforementioned factors in the analysis, digitized data of all the mentioned layers were obtained from Centre for Remote Sensing and Geographic Information System (CERGIS)-Legon, and Ghana Statistical Services and Survey Department.

All the various datasets were converted into same projection, to facilitate super imposing one on the other, for the purpose of analysis (Figure 4).

RESULTS AND DISCUSSION

In using the ARCGIS software, the various distances along roads to final disposal, transfer stations sites were generated.

There were 101 communal container sites identified during the time the coordinates were taken in the whole

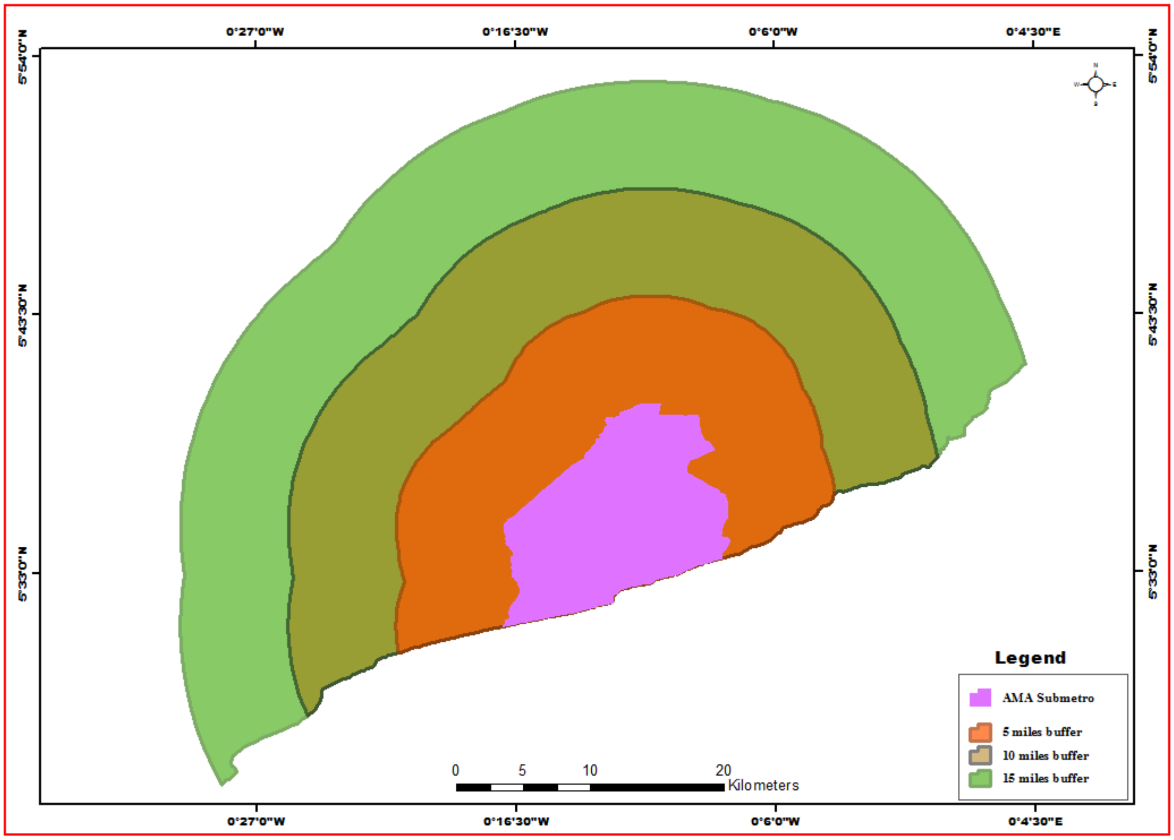

Figure 3. The 5, 10 and 15 miles buffer created from the external merged boundary of the sub-metro.

Accra Metropolis. These communal containers are placed to support the management of solid waste generated in the communities. Through the survey work, it was realised that these containers are placed to serve mainly the markets, communities, and institutions upon request. However, the household are supposed to register with private waste companies to collect their bins on an agreed day and at a fee.

Waste transfer stations are usually established to ensure effective collection and also help in reducing the cost of operations. It is generally less expensive to deliver collected Municipal Solid Waste (MSW) to transfer stations where it can be consolidated into large loads that can be transported by trailer trucks, rail cars, or barges to large-scale management facilities than transporting the same amount of MSW in substantially smaller vehicles. The latter increases fuel consumption and number of trips needed to transfer waste to final disposal sites. To establish the construction of waste transfer station, distance is very important. In view of this, the sub-metro boundary obtained from the AMA with the help of ArcGIS software, various buffers (3, 6, and 9 km) were created from the external boundary of the merged sub-metro as shown in Figure 3. These were done to inform decision or policy makers as to the acceptance of the concept of waste transfer stations. Technically, it has been established that ideally transfer stations are considered when the source of waste generation is 6 km from the final disposal site, which then makes it economically more viable (US EPA, 1995).

However, from the categorisation made on the maps, it was realised that most of the current dumping sites are within the 6 km range except the compost and recycle plant being constructed by Zoomlion Ghana Ltd. at Adjei Kotoku which was beyond 6 km. But most of the dump sites currently being used are full and looking at the rate at which Accra is developing, there is greater tendency that landfill or dump sites to be acquired will go beyond the 6 km. This information then prompts the need to consider waste transfer station concept to enable solid waste to be managed effectively.

In the location of the various transfer stations depended on the necessary factors used to selected a suitable place for the establishment of a waste facility. In this research, maps of all these information were collected and super imposed on the map of Accra to get the maps in Figures 5 and 6.

From Figure 5 as shown in the map, four suitable waste transfer stations were located with the help of the GIS. These transfer stations from the map were located around: (a) Ablekuman and Amomola (Transfer station 1); (b) Oblogo and Weija (Transfer station 2); (c) Ashongman

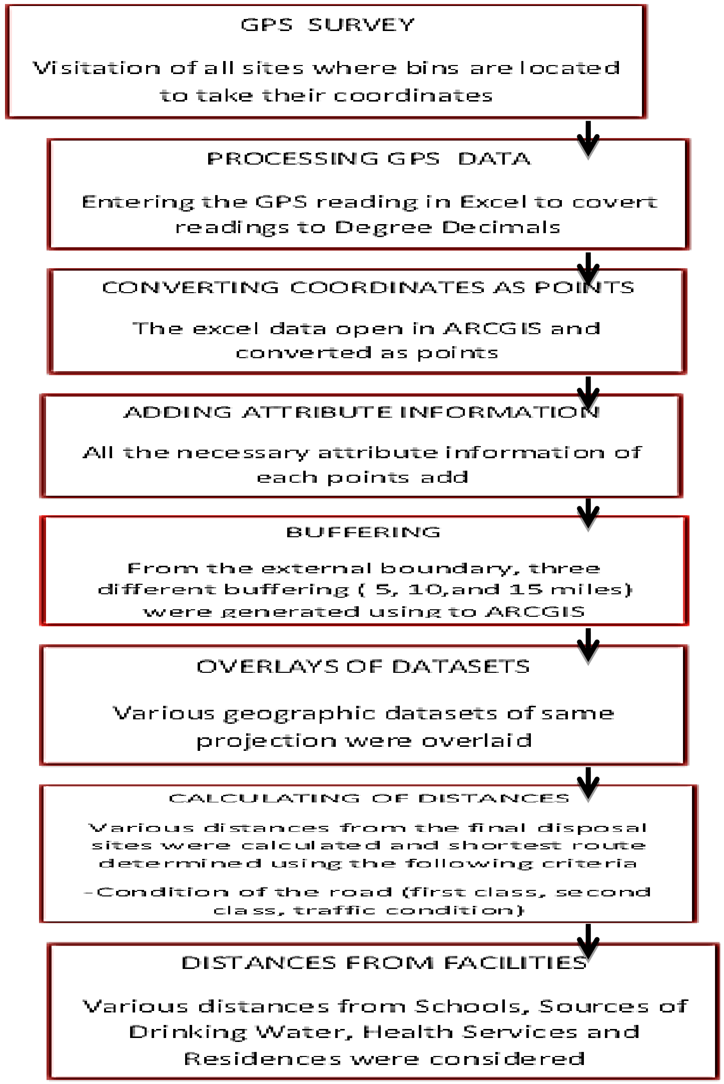

Figure 4. Flow chart of the methodology.

and Agbogba (Transfer station 3); (d) Ashaley Botwe and Ogbodzo (Transfer station 4). These four places where identified with the assistance of the GIS, which through queries in relations to the information fed in relations to the necessary factors for the establishment of suitable place for a waste facility, namely: nature of vegetation, closeness to water body, closeness to settlement, and traffic condition. It was identified that averagely all these places identified met the criteria for the establishment of a waste facility, when the query was carried out through the GIS. This can be identified through the maps in Figures 5 and 6.

Assessing the location of the various proposed transfer stations identified with the help of the GIS, they are all placed at vantage points. The establishment of these transfer stations at the proposed locations will go a long way to help salvage some of the challenges we have in the collection and transportation of solid waste in the capital city.

The average distance that a truck needs to travel between all the sub-metro to the final disposal sites in relation to traffic condition ranges between 22 and 37 km and the average distance a truck needs to travel to a nearby transfer station in relations to traffic condition ranges between 6and15km from Table 1. This then shows a drastic reduction in distance that a truck has to travel to dispose waste, because the truck needs not to travel between 22 and 37 km to dispose waste, but rather 6and 15km.

Also, it could be observed from the map shown in Figure5 that all the transfer stations are located outside the jurisdiction of the Accra Metropolitan Assembly, which then place the establishment of these transfer stations in an advantageous position, because most of these places are not so much developed. Furthermore, the establishment of these transfer stations in these areas

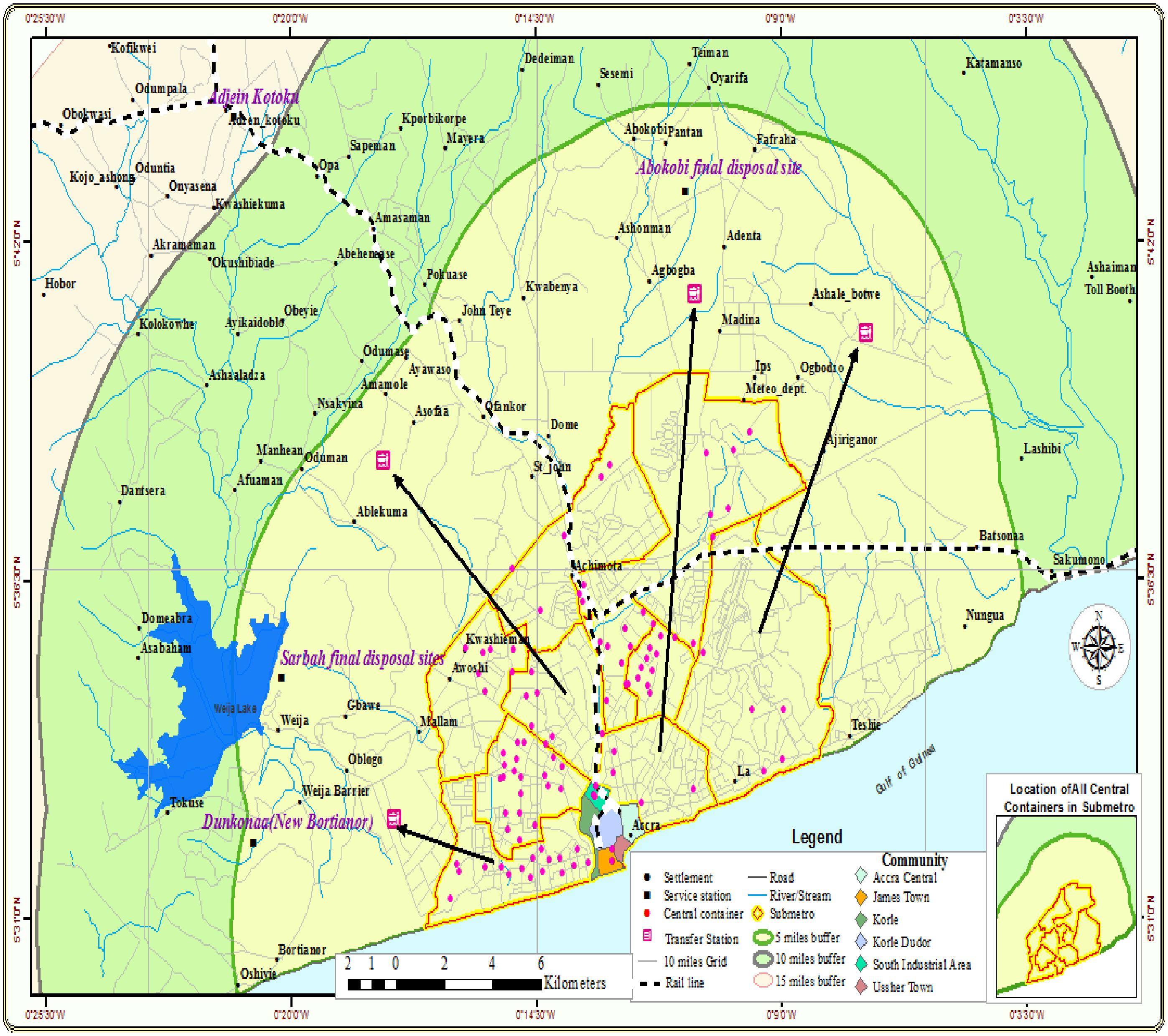

Figure 5. The arrows in the map indicate location of all container sites in the sub-metros and location of transfer stations.

would hasten the development and thereby improve economic activities.

From Table 1, La sub-metro has the longest average distance in relations to traffic condition to the final disposal site, whiles Okaikoi North has the shortest average distance in relations to traffic condition to the final disposal sites. This could be due to the location of the sub-metro and also the distances of the location of container sites within the sub-metros.

The identified waste transfer stations were all within the 3 km buffer which implies that their establishment would help solve the challenge with the rate of waste collection due to distance landfills.

Conclusion

The GIS was used to identify four waste transfer stations of which from the analysis it can serve all the various container sites in the AMA and even other Municipal and Districts Assemblies.

The coordinates of the entire communal container sites in the AMA which are known through the work, could help the assembly in monitoring of location of communal container sites and also how to effectively allocate communal containers.

The four suitable waste transfer stations identified are all outside the jurisdiction of the AMA. This then indicates

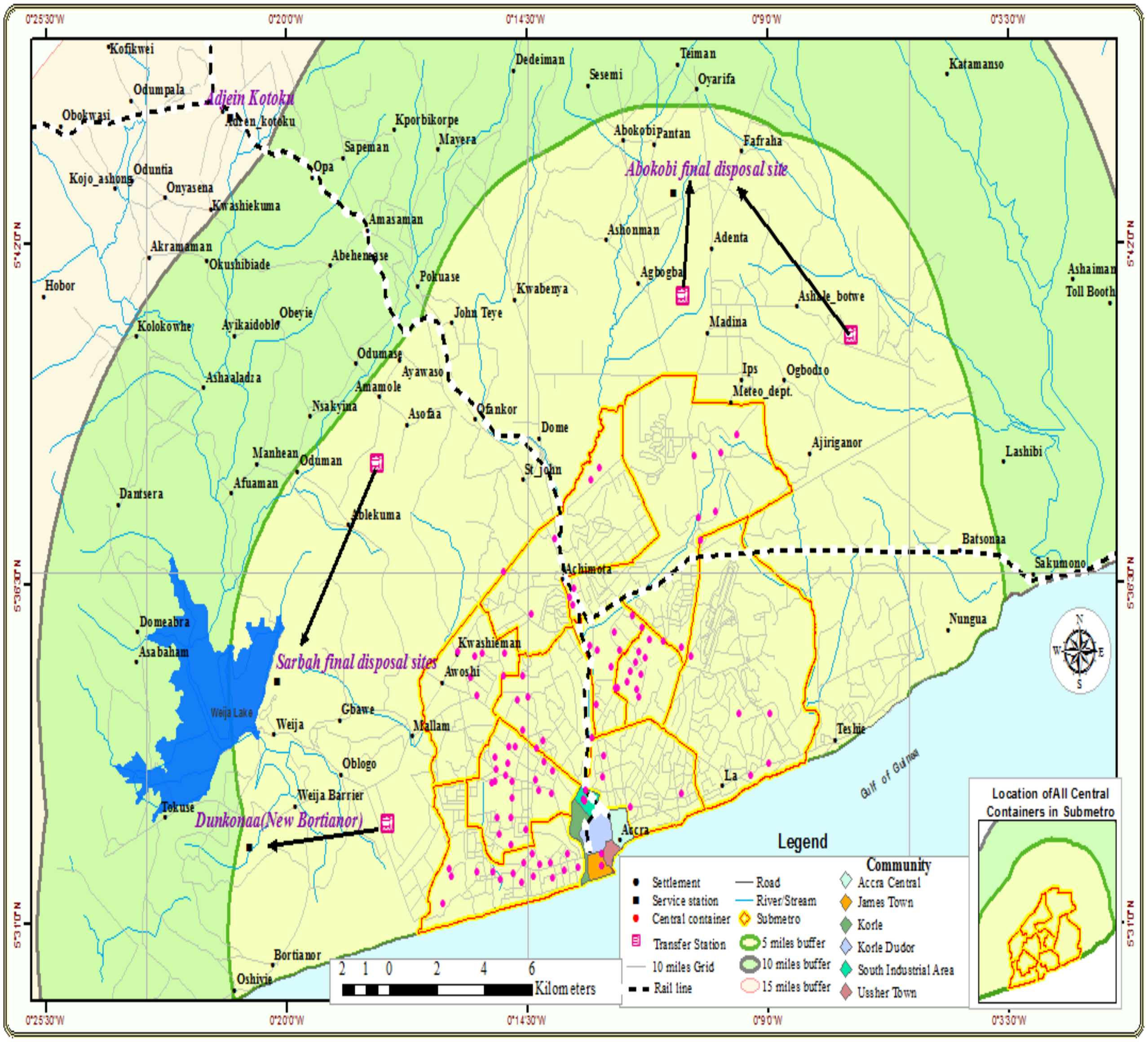

Figure 6. The arrows in the map indicate locations of transfer stations and landfill sites.

Table 1. The average distances to final disposal site, nearby transfer Stations, and transfer stations to final disposal site.

Sub-metro	Average distance to final disposal site	Average distance to nearby transfer station	Average distance from transfer station to final disposal Site
Ablekuma North	28	8	20
Ablekuma South	33	8	25
Ablekuma Central	31	6	25
AshieduKeteke	36	10	26
Ayawaso Central	26	13	13
Ayawaso East	28	15	13
Ayawaso West	29	7	22
La	37	13	24
Okaikoi North	22	11	11
Okaikoi South	32	11	21
OsuKlottey	32	16	16

indicates that, there is urgent need to establish waste transfer stations in the identified places to avoid development catching up with these areas.

It could be concluded from the analysis that fuel consumption would reduce, because the distance to travel will be reduced, because final disposal of waste will be done by large capacity trucks or trailers.

Conflict of interests

The author did not declare any conflict of interest.

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REFERENCES

American Heritage Dictionary of English Language (2011). Houghton Mufflin Harcourt publishing company. http://www.ahdictionary.com[accessed 13 June, 2012].

Bilitewski G, Hardle K, Merek A, Weissback A, Boeddicker H (1994). Waste Management. Spring-verleg Berlin, Germany.

Zurbrugg C (2003). Urban Solid Waste management in Low Income countries of Asia, how to cope with the garbage Crisis. Duebendorf, Switzerland.

Ojdemark CHA (2005). Modern Concept for Waste Collection in Cities.13th European Water, Wastewater and Solid Waste Symposium at IFAT Munich, VKS service GmbH. pp.127-138.

Böhmar G (1995). Solid Waste and the Hierarchy in Solid Waste Management System, Diphomarbeit van der WirtschaftSuniversität Wien. p. 105.

Ghana Districts (2006). http://www.ghanadistricts.com.gov.gh.Accra Metropolitan, Greater Accra.[accessed 12 November,2011].

Ghana Web (2010). http://www.ghanaweb.com[accessed 12 November, 2011].

Pieber M (2004). Waste Collection from Urban Household. In Europe and Australia, Waste Management World. P144.

Rahman A, Moten Ashraf M (2007). Privatization of solid waste management in Pakistan. pp. 1-2.

USEPA-United State Environmental Protection Agency (1995). Collection and Transfer: In Decision Maker's Guide to Solid Waste Management. Office of Solid Waste.2nd Edition, Washington DC.

Waste Transfer Station (2001). A Manual for Decision Making EPA 530-D-01-005.

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