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Comparative assessment of trace metals in soils associated with casket burials: Towards implementing green burials

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Abstract

Casket burials has been one of the most prevalent methods of disposing of the dead for several centuries. However, its increasing use in many countries has engendered serious environmental and epidemiological concerns due to documented evidences of leaching of toxic metals and pathogens as human remains and grave contents decompose over time. In this paper, a comparative trace element study of surface soils samples collected from two municipal cemeteries located in Macao SAR (China) and Akure (Nigeria) was undertaken to investigate their contamination potential. Soil contamination assessment based on index of geo-accumulation indicate that the soils associated with the Macao cemetery have been significantly contaminated with Ag, Cd, Hg, Pb, Se and Zn, while that of Akure site did not show significant pollution. From a comparative perspective, it was observed that the levels of Pb and Zn observed in the Macao cemetery soils was higher than the maximum values reported for selected cemetery soils in Brazil, South Africa, Rwanda, and the United States of America. For the Akure site, none of the samples showed significant pollution as the levels of trace elements were within the uncontamination threshold. Inconsistent levels of trace metals levels observed in the soils of the two cemeteries is likely to have resulted from the differences in the number of burials, soil characteristics, type of materials used for construction of coffins. The findings therefore suggest the need to improve awareness of eco-friendly burials to protect and conserve the environment.

Keywords: Casket burials, trace elements, green burials and environmental protection

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Introduction

Cemeteries have been perceived as sources of environmental contamination (Engelbrecht, 1998; Konofes and McGee, 1996; Pacheco et. al, 1991). Coffins and other grave contents play a major role in the contamination potential of cemeteries. During the construction of coffins, metals such as steel, bronze, lead, nickel, silver, gold, zinc, copper, iron, and selenium are typically used for decoration and to improve the durability finished caskets (Hacker-Norton and Trinkley, 1984; Hiscox 1968:69). Other synthetic materials such as paints, velvet, taffeta, rubber, hinges, brass handles, galvanized nails, wood screws, glues and embellishments are also used in the making of sophisticated caskets (Uslu and Erdogan, 2009;Jonker and Olivier, 2012). Empirical studies have shown that as human bodies and casket components degrade and decompose over time they could discharge inorganic and organic constituents that can contaminate different environmental media, such as ground water, soils, vegetation and surface water eventually causing human health problems (Fogli 2004; Zychoswki 2012; Dent 2000; Engelbrecht, 1998).

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Previous studies have shown that a human corpse will decay within a period of 10-12 years without coffins or embalming fluids, with over half of the pollutant load leaching within the first year (Üçisik and Rushbrook, 1998). The study conducted by the United Kingdom Environmental Agency (2004) estimated that over half of the pollutant loading arising from the decomposition will be leached within the first year, and will decline in subsequent years. The time taken to for these contaminants to be removed from the soil environment is greatly dependent on several factors such as rate of precipitation, soil characteristics and infiltration rate of the burial site (UK Environmental Agency, 2004). For example, warm temperatures will accelerate decomposition of cadavers whilst freezing conditions will inhibit the process (Üçisik and Rushbrook, 1998; UK Environmental Agency, 2004). On the other hand, a well-drained soil, such as coarse soil will accelerate decomposition, whereas a poorly drained soil will have a reverse effect (UK Environmental Agency, 2004; Uslu and Erdogan, 2009; Üçisik and Rushbrook, 1998).

Other sources of cemetery pollution may result from the leaching of toxic chemicals used the embalmment of bodies and preservation of wood coffins. For example, the use of Chromated Cooper Arsenate (CCA) as wood preservatives may influence anthropogenic input of copper, chromium and arsenic into the soil environment of cemeteries as coffins sprayed with such chemicals compounds degrade under burial conditions. The Casket & Funeral Supply Association of America estimates that of the 1.7 million caskets sold in 2007 the production by type was about

- 10.8% Cloth covered caskets (including products used in cremation)
- 15.6% Non-gasketed steel
- 17.8% Hardwood
- 47.3% Gasketed Steel
- 4.0% Stainless Steel
- 2.2% Copper or bronze 1.9% Infant & Children (14 and under)
- Less than 1% of all caskets are made from composite materials.

The use of gasket steel and hardwood coffins for burial may continue to contribute to the contamination potential of cemeteries. In the last five decades, there have been several studies devoted to the issue of contamination from cemeteries.

For example, Van Haaren (1951) evaluated the contamination of ground water from a cemetery in Holland. The study observed a higher concentration of saline plume that was characterized by chloride, sulfate and bicarbonate ions in the ground water beneath the grave. Similarly, the investigations carried out by Knight and Dent (1996) at the Botany Bari cemeteries in Australia identified plumes with high concentration of Cl, NO_4, NH_4, PO_4, Fe, Na, K and Mg in ground water immediately adjacent to graves. The concentration of these major elements significantly diminished rapidly with distance from the grave.

In Brazil, Rodrigues and Pacheco (2003) analyzed the effects of a local cemetery on ground water. The results showed that the ground water within the vicinity of the burial site have been contaminated with inorganic metals as well as harmful pathogens. The results of the study were also found to be consistent with the findings of Pour and Khezri (2010) that analyzed the cemetery ground water contamination in the Beheshte Zahra cemetery located in Tehran, Iran.

In recent years, other studies investigating soil contamination from cemeteries have also emerged in empirical literatures. For example, Barros et al (2008) investigated heavy metal contamination in Santa Candida municipal cemetery in Brazil. Their study showed significant contamination of the associated soil with Cr, Pb and Ni. The elevated contents of these metals were attributed to the type of materials used for interment of the deceased. Kemerich et. al (2012) investigated heavy metal contamination in soils of a 1930 municipal cemetery in Brazil. The study similarly showed that the soils of the municipal cemetery were contaminated with Cu, Cr and Zn. In South Africa, Jonker and Olivier (2012) analyzed the distribution of trace metals in cemetery soils of the Zandfostein burial site. This study only indicated that trace elements concentrations in the cemetery soils were higher than offsite soils. The research findings were similar to that reported by Spongberg and Becks (2000). In Rwanda, Amuno (2013) investigated the potential ecological risk of heavy. The result of his preliminary studies indicated that the soils of the genocide cemetery located in Kigali were enriched with As, Pb and Cr at levels not expected to cause raise ecological concerns.

The aim of this paper is to carry out a comparative trace element study of surface soils associated with casket burials in Asia (Macao, China) and Africa (Akure, Nigeria) to determine their contamination levels.

Material and Methods

Geography of Study Areas

Study Area- I (Macau Protestant Cemetery), Macao, China

Macau is located in the southern part of China's Guangdong Province, near the the peninsula formed by the Zhujiang (Pearl River) estuary on the east and the Xijiang (Figure 1). Macau is generally a flat terrain resulting from extensive land reclamation, but numerous steep hills mark the original natural land mass. A large portion of the region is from land reclamation. The Macau protestant cemetery was built in 1821 (Figure 2). The general soil profile is from marine deposit, followed by alluvium of alternating sand and silty clay which overlies the completely decomposed granite and the bedrock. The layer of marine deposit is typically normally consolidated, whose properties are important to local engineering practice (Hao and Lok, 2008). Although Macau is located in the tropics, it has a humid subtropical climate classified under Köppen climate classification as Cwa, because of the Siberian pressure system. Its average year-round temperature is 22.7 °C (72.9 °F). Summers are very hot and humid: the July average temperature is 28.9 °C and the highest daytime temperature could reach 35 °C. There is about 2,120 mm of rainfall annually.

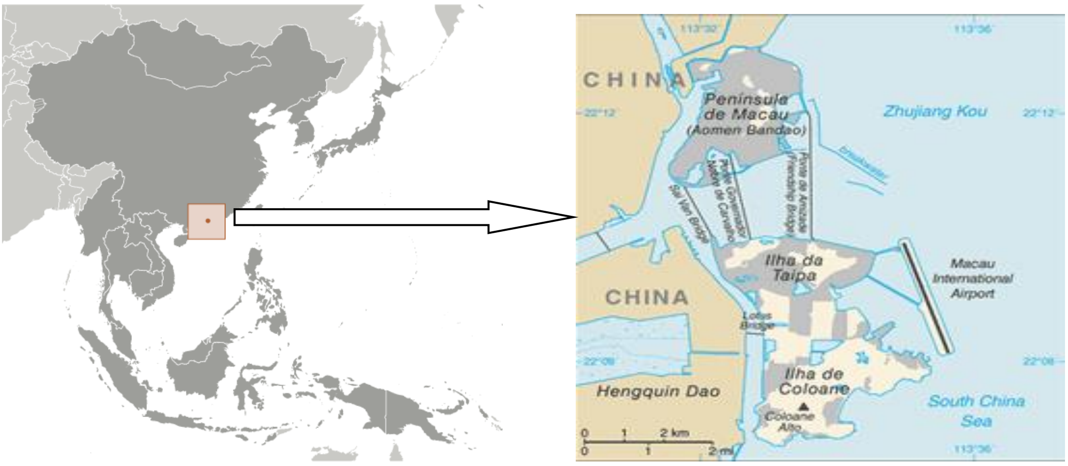

Figure 1. Study Area (Macau Protestant Cemetery)

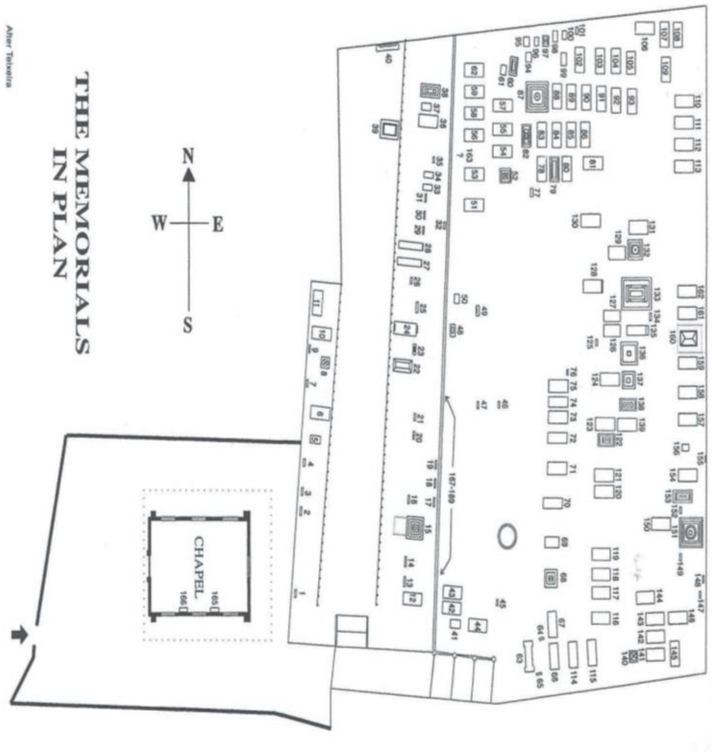

Figure 2. Layout of sampling locations within Macao protestant cemetery

Construction of the cemetery was influenced by the challenge of finding a place to bury the protestant minority living in the Portuguese colony. The protestant cemetery was in use until 1858, after which it was referred as the Old Protestant Cemetery. It is one of the sites recognized as a UNESCO World Heritage Site. The cemetery occupies an area of approximately 2,800 square metres with 162 tombs. The cemetery is divided into two levels: the upper level and the lower level. The upper level has an area measuring 30 meters long by 10 meters wide, and has forty tombs sheltered by lush trees and a pathway. The lower level, measuring 60 by 30 meters, is surrounded by tall trees and has tombstones lined on both sides, leaving a spacious lawn in the middle. The memorial takes varied forms. There are flat shapes, chest-tombs, pedestal tombs, headstones and wall tablets (Lindsay and Ride, 1996).

Nature of Burials: Based on historical accounts, the individuals buried in this site were westerners. Burials were conducted through the use of caskets that were constructed of metal or wood to give befitting burials to the deceased. At this time, giving befitting burials meant using well decorated, and durable coffins with wooden or metallic exteriors that were either painted, polished, or brushed. Some of the metal caskets were made from steel, copper, or bronze; with variations in the thickness and quality of the metal used.

Study Area- II (St. Thomas Cemetery) Akure, Nigeria

The St. Thomas Anglican Church Cemetery was built around 1960. The site (Figure 3) is located at Isikan, Akure, Nigeria. The site of the cemetery is located in a sub-urban area of Akure, Nigeria. The site falls within the tropical rain forest. The rainy season starts from March/April to October, with rainfall of about 1,524mm per year. Local temperatures vary from 28°C to 31°C with a mean annual relative humidity of about 80%. The natural vegetation of the study area is highly forested. With respect to local land use information, swift pace of urbanization in and around Akure city has been causing rapid increase in built up areas which has resulted in significant depletion of the dense forest of the study area. In terms of local geology, Akure is underlain by Precambrian basement complex rocks of Southwestern Nigeria that lies within Pan African mobile belt, East of West African Craton (Ademeso, 2009). The local lithological units identified around the site include the Migmatite–Gneiss complex rocks, biotite gneiss and granitic rocks (Figure 4). The soils found in the study area are derived from the basement complex rocks, which are typically well drained with medium texture. The topsoil of the study site ranges from sandy clay to dark loamy soil.

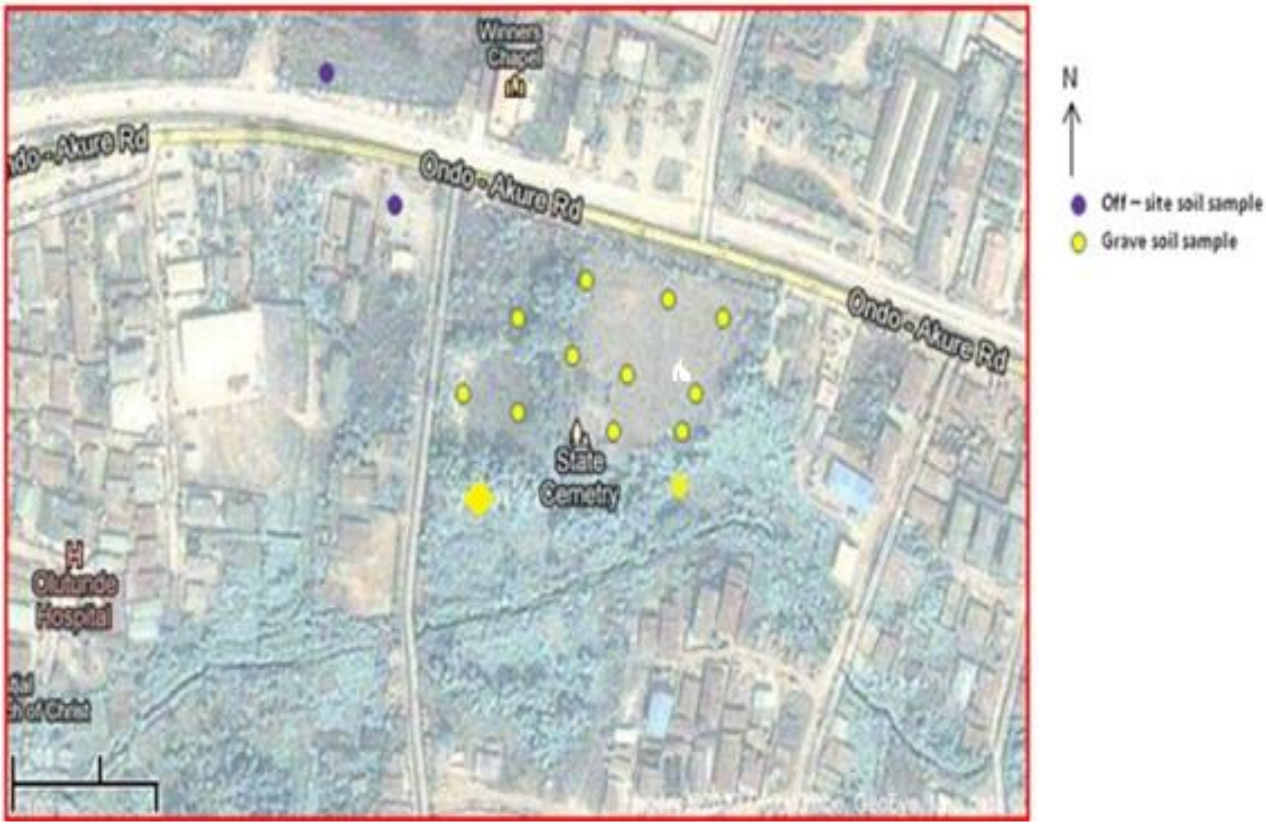

Figure 3. Map showing sample locations across the Akure site

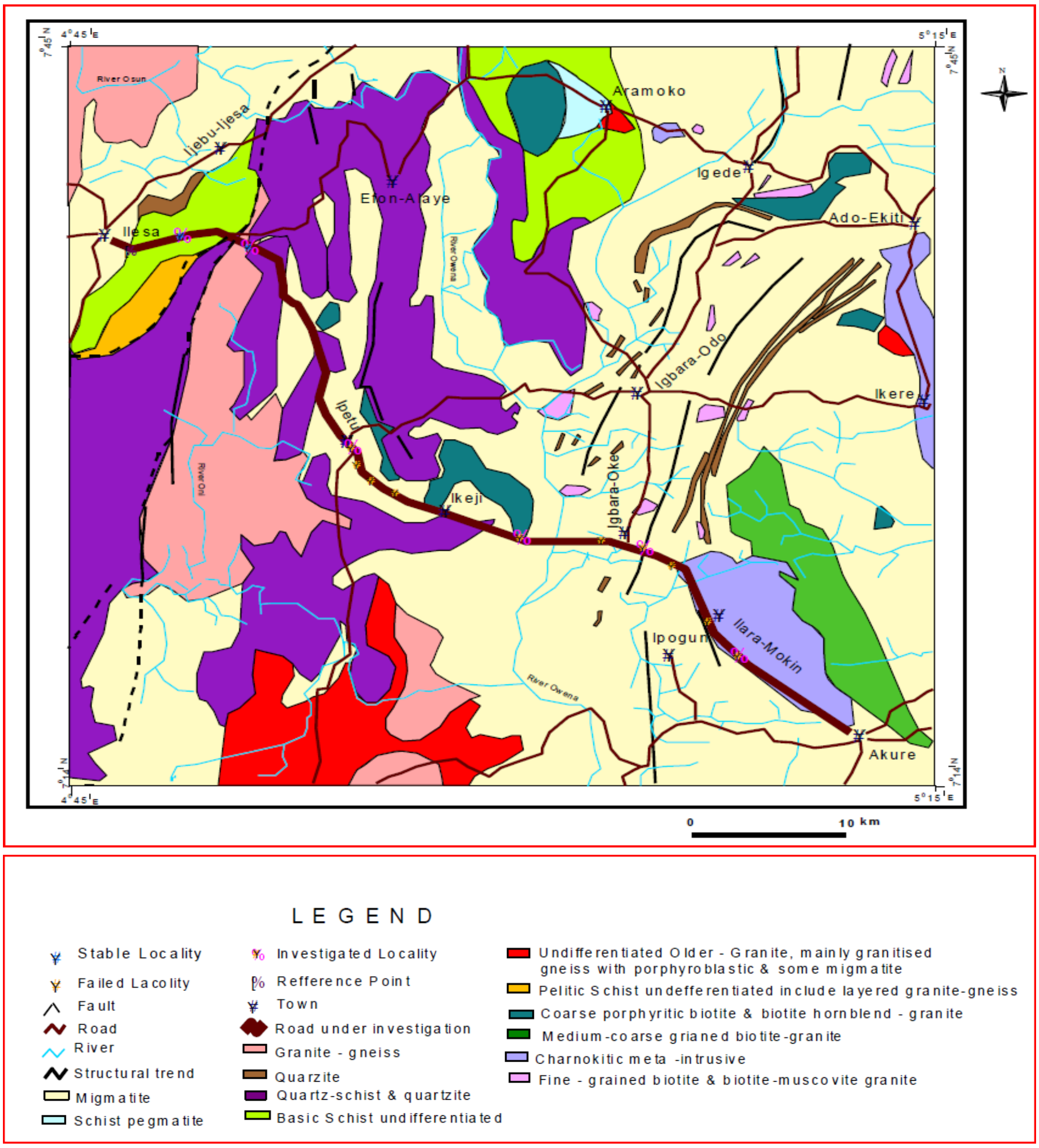

Figure 4. Geological map of the Akure study Area (Akintorinwa et. al. 2010)

Nature of Burials: Historical accounts suggest that the individuals buried at this site were indigenes of Isikan, Akure, Nigeria. While the occupation of the people interred ranged from agriculture (farming) to trading, they generally were not in the wealthy class that could afford exotic metal based coffins. The coffins used at this site were simple without exterior ornaments, relatively cheaper and made from processed wood that were polished.

Sample Collection and Laboratory Methods

The fieldwork for this study was conducted from June to July 2013. Fifteen topsoil samples (0-20cm) were collected from within and around the vicinity of the Macau protestant cemetery. Two offsite control soil samples were collected from near the entrance of the site and labelled. Collection of soil samples at deeper soil profiles (>20cm) was not allowed by the cemetery board due to the sensitivity of the site as a UNESCO heritage site. The soil samples were collected with the aid of Teflon-coated soil auger and placed in a well washed polyethylene containers and sealed. For the study area in Akure, Nigeria, a total of fifteen (15) soil samples at depth 10cm were collected from within and around the vicinity of St. Thomas's Anglican cemetery. Soil samples at deeper profiles (>20cm) could not also be collected due to regulatory conditions from the church authority in Akure, Nigeria. The samples were air dried at room temperature ad later oven dried at a temperature 200^{o}C to remove moisture and sieved with nylon mesh (2mm) and sieved. The soils were analysed using inductively coupled plasma mass spectrometry (ICP-MS) in ALS Geochemical laboratory in Hong Kong.

All of the samples were analyzed for priority pollutants, such as As, Be, Cd, Cr, Cu, Pb, Ni, Se, Ag, Zn, Hg. In order to verify the sensitivity and efficiency of the method used in metals analysis, recovery and reproducibility studies were conducted. 5 mg/kg concentration of heavy metals in soil matrix was acid digested by aqua regia method and then followed by ICPMS analysis. The recoveries of metals ranged from 91.2 % to 108%.

Results and Discussion

A general statistical representation of the selected trace metals across both sites are presented in Table 1. The standard deviation for the trace metals varied across the sites which followed the sequence of Zn>Pb>Cu>Cr>Ni>As>Se>Hg>Ag>Be>Cd for the Macao site. For the Akure site it followed the sequence of Cr>Zn>Pb>Cu>Ni>As>Be>Se>Ag>Cd. For the Macao site, mean concentration for As (6.1mg/kg) did not significantly exceed the offsite values with 5mg/kg. Mean onsite concentration for Cu (142.7mg/kg) exceeded the offsite concentration (95mg/kg). Similarly, the onsite value for Pb (142.7mg/kg) exceeded the average concentration (95mg/kg) offsite. Onsite Ag values (0.71mg/kg) exceeded the offsite values of 0.41mg/kg. Mean Zn (184mg/kg) onsite also exceeded the mean offsite values (119mg/kg). Elevated onsite concentration of the selected trace metals in the Macao study area is consistent with previous findings from Amuno (2013), Jonker and Olivier (2012), Kemerich et al. (2012), Barros et al. (2008) and Spongberg and Becks (2000). Only Pb, Zn and Hg exceeded their respective target values as indicated in the soil quality guidelines shown in Table 1.

For the Akure site, the mean onsite concentration for the selected trace metals were not significantly different the offsite area, thereby indicating no contamination. Differences in trace metal contents as observed from both sites may have been influenced by the type casket used, number of burials as well as other geographical parameters such as the soil type.

The levels of trace elements from both sites were compared with values obtained from published works on cemetery soils in Kigali, Rwanda (Amuno, 2013), Ohio, USA (Spongberg and Becks 2000) and South Africa (Jonker and Olivier, 2012), Brazil (Kemerich et al. 2012; Barros et al. 2008) as indicated in Table 2. From the results, it can be observed that mean onsite concentration for As (6.1mg/kg) in the Macau Protestant Cemetery soil was significantly lower than observed in the cemetery soils of Kigali (21.9mg/kg) but higher than the soils from Ohio, USA (4.62 mg/kg) and Zandfonstein cemetery soils (0.39mg/kg) in South Africa. Cr contents of the protestant cemetery soil was lower than observed in the Zandfostein cemetery (321.07mg/kg), Kigali (77mg/kg) but higher than the cemetery soil of Ohio, USA (0.16 mg/kg). Mean concentration of onsite contents of Pb (142.7mg/kg) in the Macao site was higher than observed in the cemetery soils of Rwanda, USA and South Africa. Concentration of Ni (44.63mg/kg) in Zandfonstein cemetery, South Africa was higher than observed in the Macao site (5.4mg/kg). Mean concentration of Zn (184.5mg/kg) in the Macao site was higher than the cemetery soils of Kigali, USA and South Africa. Hg in the Macao study area (0.89mg/kg) was higher than observed in South Africa (0.02mg/kg). Maximum concentration of Pb (329mg/kg) and Zn (323mg/kg) in the Macao study area was greater than the values observed for the Santa Candida cemetery, Brazil for Pb (260.2mg/kg) and Zn (137mg/kg). However, maximum concentration of Cu (597mg/kg), Cr (211.5mg/kg) except for Zn (229.67 mg/kg) in the Santa Candida cemetery, Brazil was greater than maximum values observed in the Macao study area.

For the Akure site, it was observed that concentration of As was higher than values observed in cemetery soils from South Africa but lower than concentration observed in USA. Concentrations of Ni, Pb and Cr at the Akure site was lower than observed from the soils in Kigali, South Africa and Brazil. Concentration of Zn in the Akure soils was lower than Kigali but significantly higher than observed in the soils from South Africa and USA.

How does Cemetery soils compare with landfill and urban soils:

Given the similarities of in the leachate chemistry of cemeteries with landfills (Fieldler et al, 2012), an attempt was also made in this paper to compare the results of this present study with that from selected landfill soils in different tropical countries like Malaysia, Ivory Coast and Nigeria as indicated on Table 2. For the sites in Macao and Akure, values for As was lower than observed from landfills in Malaysia. Cd was generally higher in the selected landfill soils than observed in cemetery soils except for the Macao site that showed a concentration value of 0.35mg/kg that was similar to the reported values from Uyo landfill

Table 1. Onsite/Offsite concentration of trace elements in Macao and Akure soils (*Standard deviation)

	MACAO										
	As	**Be**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**	**Zn**	**Hg**
Mean (onsite)	6.13	0.55	0.35	9.93	31.1	142.7	5.4	1.5	0.713	184.5	0.88
Min	4	0.25	0.1	5	13	75	3	0.5	0.3	54	0.4
Max	10	0.9	1.1	18	54	329	9	2	1.3	323	1.8
StD*	1.9	0.21	0.2	4.2	12.4	66.5	2.16	0.5	0.28	94.8	0.43
Mean (offsite)	5	0.5	0.3	11	24	95	6	2	0.4	119	1.07
	AKURE										
	As	**Be**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**	**Zn**	**Hg**
Mean (onsite)	1.03	0.71	0.04	30.1	13.6	16.7	7.56	0.49	0.06	31.9	-
Max	4.5	1	0.1	101	20.5	28	17	0.6	0.39	64	-
Min	0.4	0.5	0.02	14	9.4	10.9	5	0.3	0.01	21.4	-
StD	1.03	0.16	0.02	21.9	3.1	4.56	3	0.09	0.09	10.9	-
Mean (offsite)	0.7	0.6	0.03	28.7	17.7	20.5	8.6	0.3	0.019	37.2	-
	Soil Quality Guidelines										
	As	**Be**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**	**Zn**	**Hg**
Target Value (optimum)	29	-	0.8	100	36	85	35	-	-	140	0.3
Intervention Value (Action)	55	-	12	380	190	530	210	-	-	720	10

Table 2. Comparative Levels of trace metals in soils from cemeteries, landfills and urban areas

	Cemetery Soils							Landfill Soils					Urban Soils				
	Present Study		**Previous Studies**														
	Macao	**Akure**	**Kigali**	**USA**	**South Africa**	**Santa Candida, Brazil**	**Sao Jao Batista, Brazil**	**Malaysia** [1]	**Ivory Coast** [2]	**Aba, Nigeria** [3]	**Uyo,Nigeria**[4] **(Rural Area)**	**Uyo,Nigeria**[4] **(Muncipal Area)**	**Hong Kong Kowloon**	**Mexico**	**Central Jordan**	**Madrid**	**Residential**
As	6.1	1.03	21.9	4.62	0.39	-	-	15	10.5	11.6	12.2	-	-	-	-	-	20
Cd	0.35	0.04	ND	-	0.04	-	-	0.15	0.09	0.09	0.37	1	0.62	-	4.98	-	2
Cr	9.9	30.1	77	0.16	321.07	79.2-516.3	66.92-211.5	90	54.17	42.4	10.8	ND	23.1	117	83.9	74.7	150
Cu	31.1	13.6	19.57	0.27	17.39	0.38-67.1	151.87-597	30	18.9	14.8	72	73	23.3	100.8	-	71.7	120
Pb	142.7	16.7	28	0.41	26.92	4.67-260.2	-	35	19	14.9	141	294	94.6	140.5	62.17	161	100
Ni	5.4	7.5	-	-	44.63	0.12-1.4	-	100									
Zn	184.5	31.9	51	2.64	7.76	0.56-137	85.73-29.67	85	59.8	45.9	163	183	125	306	146.9	210	150
Hg	0.89		-	-	0.02	-	-	0.15	0.04	0.03	0.19	-	-	-	1.81	-	1

[1] Agamuthu & Fauziah, 2012 / [2] Kouame et al, 2010 / [3] Akobundu & Nwankwoala, 2013 / [4] Ebong et al, 2007

in Nigeria. Levels of Cr was generally higher in the landfills than the cemetery soils. Levels of Cu in the Macao site was higher than observed in most of the selected landfills except for Uyo, Nigeria. Pb levels in Akure soils was very low, while values from Macao exceeded the values observed in the selected landfills except for Uyo, Nigeria. Concentration values of Hg and Zn in the Macao soils exceeded most values observed in the soils of the selected landfills.

Since there are no standard reference values for cemetery soils, background soil data from different urban cities such as Hong Kong SAR (Li et al, 2004), Central Jordan (Banat et al, 2005), Mexico (Morton-Bermea et al, 2009), Madrid (De Miguel et al 1998) and residential (Banat et al, 2005; Zhongping et al, 2011) were also compared with the cemetery soils as indicated on table 2. The results indicate that values of Cr in the Akure soils was lower in comparison with urban soils of Mexico, Central Jordan and Madrid. The concentration of Cu in the Macao cemetery soils was higher than values observed in urban soils of Hong Kong, but lower than Mexico and Madrid. The levels of Pb in the Macao soils was higher than Hong Kong, Mexico, Central Jordan but lower than Madrid. The values of Zn in the Macao soils was higher than Hong Kong, Central Jordan but lower than Mexico and Madrid.

Pollution Assessment

In order to assess the extent of soil pollution due to the influence of casket burial, an attempt was made in this study to utilize the index of geo-accumulation (Igeo) and Change of public health indices for the study. Igeo was introduced by Muller (1969) and enables the assessment of contamination by comparing current and pre-industrial concentration of heavy metals. This index is computed by the following equation below:

$$Igeo = Log\,2\frac{Cn}{1.5\,Bn} \quad \dots\dots\dots\dots..(1)$$

Where Cn is the concentration of element “n” in sample; Bn is the background concentration of element in undisturbed or pre-industrial, which is in this study is represented by average shale values, according to Taylor and Mclenan (1995). The factor 1.5 is used to address possible variations due to lithogenic effect (Stoffers et al 1986; Nikolaidis et al 2010). Muller (1969) also suggested six descriptive classes of Igeo values as shown in Table 3.

Table 3. Classes of contamination based on index of geo-accumulation

Igeo Value	Igeo class	Designation of Soil Quality
> 5	6	Extremely contaminated
4-5	5	Strongly to Extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to Strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

The results as already indicated in table 1 shows that for the Akure site, none of the soil samples exhibited significant pollution as their respective Igeo range were within the uncontamination threshold. The reason for the low concentration of trace metals in the soils associated with the Akure site may have been due to the relative low number of burials interred in the site, soil characteristics and less sophistication of the caskets used for burial.

On the other hand, Igeo values for Cd, Cu, Pb, Se, Ag, Zn and Hg was high for the Macao site, suggesting the prevalence of anthropogenic activities. It was also observed that Hg was the most polluting element in the Macao site with Igeo values ranging from 3.8 to 6.05, suggesting moderately polluted to extremely polluted. Hg may have originated from the use of mercury compounds for the embalmment of the dead (Cutler, 2004). The embalmment of the dead with mercury compounds was still a regular practice during the 19th century. Chemically treated wood, jewelries, paint pigments used in coffin making may also contribute to the input of Hg in the cemetery soils (Chemical Hazards, 2003; Ohio Environmental Protection Agency, 2010). Decomposed textiles and jewelleries containing cinnabar used in dressing and decoration of the deceased may be another likely source of Hg in the study area (Cutler, 2004; Ohio Environmental Protection Agency, 2010; Huggins, 1993). For Ag, Igeo values ranged from 1.32 to 3.43 suggesting moderately to strongly contaminated. Silver find its way into the soil environment of cemeteries from decom position of metallic silver used in casket manufacturing and ornaments used for the decoration of the dead (Hacker-Norton and Trinkley, 1984). Pb also ranged from 1.05 to 3.19 corresponding to moderately to strongly contaminated. The maximum concentration of Pb in the Macao site may have originated from the use of metallic railings for the protection of a sarcophagus in the site. Other possible sources of Pb include degradation of paint pigment and accessories used in casket construction. Se also showed Igeo values ranging from 3.4 to 8.4. Previous studies have shown that Se may come from the degradation of glass, and alloys that use selenium. Igeo values for Zn ranged from -1.85 to 0.72, suggesting unpolluted to moderately polluted of the samples. Zn has been widely used in the galvanization of iron or steel to protect metals against corrosion. Other sources of Zn in study area may have originated from the degradation of brass coffins and other metallic structures used for the interment of remains. Igeo vaues for Cd ranged from -1.5 to 1.8 which is within the threshold of uncontaminated to moderately contaminated. Cd might have leached into the surrounding soils from pigments used for painting chest tombs, or wooden or metallic structures from coffins. In general it can be observed that trace metal geo-accumulation from the Macao site show contamination with Pb, Se, Ag, Zn and Hg. For the Akure site, none of the samples showed significant pollution as their respective igeo values for were within the uncontamination threshold.

Total Contamination index and Change of public health

An assessment of the total contamination index based on change of public health was also conducted. Dumčius et. al, (2011) suggested four descriptive classes of contamination and health change that may result due to potential exposures to trace metals as shown in Table 5. This index is computed by the following equation below:

$$Zd = \sum_{i=1}^{n} KK_i - (n-1), where\ KK_i = \frac{C_i}{C_f} \dots\dots\dots\dots\dots (2)$$

where Ci : chemical element concentration in the soil sample, Cf : background amount of chemical element in contaminated soil, n: number of chemical elements.

Based on the results generated from the calculation (Table 4), it can be observed that total contamination levels for both sites indicated that their pollution category is not likely to trigger any health disorders as the total values (Zd) was below 16. Based on the findings of this study and prior investigations, it is evident that casket burials contributes to soil pollution, although at varying degrees depending on local geology and type of materials used for interment. While casket burial use is still prevalent in many cultures, there is a need to embrace more environmental friendly burial methods.

Conclusion

This study has investigated the status of contaminants in soils associated with casket burials in Macao, China and Akure, Nigeria. The results of the soil analyses confirms that soils associated with ornamental coffins, particularly those made with painted metals/gasketted steel and processed wood showed significant elevation of trace metals. The result of soil analyses from the Macau Protestant Cemetery confirmed elevated concentration of Ag, Cd, Cu, Hg, Pb, Se and Zn, while that of the Akure site did not show any anomaly. The contents of Pb and Zn observed in the study area (Macao) was higher than maximum values reported in selected Brazilian, South African, Rwandan, and USA cemetery soils. Higher levels of trace metals in the Macao soils may have been influenced by the nature of burials, type of materials used and local geology. The results of this study partly provide only some evidence on the source apportionment of cemetery pollution that may be further investigated. There is a need for more detailed or extensive research utilizing more advanced comparative geochemical and mineralogical data, metal speciation or stable isotope analyses to determine the extent of lithogenic and anthropogenic sources of contaminants in the study areas. In general, the findings suggest the need for pollution monitoring in order to ensure that water sources around the sites are not endangered due to the release of toxic heavy metals as human remains and grave contents decompose over time.

Table 4. Variation of index of geoaccumulation, contamination factor and total contamination index in Macao and Akure cemetery soils

	As	Be	Cd	Cr	Cu	Pb	Ni	Se	Ag	Zn	Hg
MACAO											
Igeo*	-1.7;-0.4	-4.2;-2.4	-1.5;1.8	-4.8;-3	-1.7;0.2	1.05;3.19	-4.7;-3.14	-1.84;0.15	1.32;3.43	-1.85;0.72	3.8-6.05
Kkf* *(average)	0.211494	-	0.441667	0.099333	0.864815	1.679216	0.154286	-	-	1.318095	2.964444
Total Contamination Index (Dumčius et al, 2011)											
ZD***	-42.5847	I. Permissive <16 Children's lowest sickness rate and a minimal frequency of functional disorder									
AKURE											
Igeo (min,max)	-5.6;-2.1	-3.1;-2.1	-4.4;-2.1	-3.2;-0.4	-2.8;-1.7	-1.4;-0.09	-3.9;-2.1	-1.5;-0.5	-3.2;-1.8	-2.7;-1.1	
Kki (avg)	0.035517241		0.05	0.301	0.377778	0.196471	0.216			0.227857	-
Total Contamination Index (Dumčius et al, 2011)											
Zd	-40.59537725	I. Permissive <16 Children's lowest sickness rate and a minimal frequency of functional disorder									

*index of geo-accumulation;**Contamination factor,***Total contamination Index

Table 5: Total contamination category and health impact

Contamination category, degree	Zd	Change of public health indices in contamination sources
I. Permissive	<16	Children's lowest sickness rate and a minimal frequency of functional disorder
II. Moderate hazard	16–32	General increase of sickness rate
III. Hazardous	32–128	General increase of sickness rate, increase in the number of frequently sick children and children ill with chronic diseases, having heart and blood vessel functional disorders
IV. Highly hazardous	>128	Increase of children sickness rate, disorder of women reproductive function (increase of the number of pregnancy intoxications, premature babies and dead newborns, and increase of newborn hypotrophy)

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