

A laboratory study of the leachate composition of selected metals in cemeteries (South Africa)

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ABSTRACT

Considerable research has been conducted on the physical and chemical corrosion of metals under various environmental conditions, but less attention has been given to the impact of corrosion on the environment. One such potentially hazardous situation may occur in cemeteries where metals and coatings used in the manufacturing of coffins may corrode, seep into the soils, and could end up in nearby water sources. The aim of this project was to determine whether burial materials corrode and leach into groundwater under controlled laboratory conditions. This was achieved by burying samples of burial materials in containers with three different soil types, namely sand, silt and clay. The experimental containers were exposed to various conditions simulating typical South African temperatures, rainfall intensities and with different pH values. A total of 24 simulations and 3 controls were tested. The leachates of each sample were collected every eight weeks over a period of 6 months and tested for aluminium, iron, copper and zinc. In this experiment it became evident that coffin materials do corrode and become mobile, however, they react differently in different soil media and under diverse environmental conditions. In general, the most corrosive conditions are high temperatures and acidic rainfall. Zn is the most corroded and mobile metal, with Fe being the least. It is notable that Al, Fe and Cu continue to leach out of the soils even after a period of 6 months. This may pose a health and environmental problem and a program of groundwater quality monitoring should be undertaken in the vicinity of cemeteries.

Keywords: Cemeteries; Burials; Coffins; Metals; Corrosion

1. INTRODUCTION

It has long been the practice that cemeteries were located outside city limits. This was probably due to the perceived health risks associated with bad odour arising from decomposing bodies. It was not until 1839 that Dr George Walker provided proof of the potentially hazardous nature of cemeteries due to biological contaminants (Walker 1839). This was followed by a spate of research on biotic contamination associated with burials (e.g. Abia et al. 2018; Dent & Knight 1998). However, recent research has indicated that cemetery soils also contain raised levels of inorganic salts and metals (e.g. Amuno 2013; Aruomero & Afolabi 2014; Dent et al. 2003; Dippenaar 2014; Fiedler & Graw 2003; Fineza et al. 2014; Jonker & Olivier 2012; Paíga & Delerue-Matos 2016; Żychowski et al. 2015). Although some of these undoubtedly emanate from bodies, a large component of metals might originate from the corrosion of burial materials such as coffins.

In South Africa, most coffins are constructed of wood that has been treated with preservatives, and then either varnished or painted. These substances may contain potentially harmful minerals such as lead, arsenic, mercury, nickel, copper, vanadium, cadmium, zinc and chromium (Gondal et al 2011; Janin et al, 2011). The metals used on coffins for handles, screws, hinges and ornaments include zinc and its alloys, as well as silver and bronze. It is thus likely that high amounts of metals might accumulate in large cemeteries over time. There is some evidence for this since it was estimated that the Zandfontein Cemetery, which is one of the oldest cemeteries in the City of Tshwane (Pretoria) with 60 000 graves, could produce a burial load of up to 108,000 kg of metals (Jonker & Olivier 2012). This was calculated by assuming that each coffin had six metal handles weighing 300 g each, which excludes the weight of screws, nuts, nails and any other coffin accessory. If these heavy metals corrode and are introduced to the environment, they may accumulate and/or become mobile and leach into subsurface water resources, especially if the water table is high.

Some heavy metals are potentially toxic (World Health Organisation, 1996) and may pose a health risk. The likelihood of this becoming an important problem is increasing since the death rate, and hence the number of burials, is mounting due to the growing population and the high incidence of HIV in South Africa (Dambudzo, 2012). Growing urbanisation and the associated encroachment of urban and semi-urban settlements upon previous rural areas may further compound the problem. However, the extent of the impact of burial materials is not known since there is only limited understanding of how coffin materials break down, mobilise and influence proximal receptors. Furthermore, it is difficult to determine the relationship between the degrading of coffin materials, the corrosivity of different soils and subsequent water contamination *in situ*. It is suggested that a laboratory study under controlled environments may provide a clearer picture of the corrosion and mobility of coffin materials in soils.

Various factors may affect the rate of corrosion and transport of corroded materials in cemetery soils. The most obvious are the type of metal present in the burial load, the soil in which interment takes place and climatic factors such as temperature and rainfall. In addition to the amount of rainfall, the intensity and pH thereof may also play a role.

This paper follows on results published by Van Allemann (2017) and Van Allemann et al. (2018), aiming to determine how materials in cemeteries corrode and whether they leach into groundwater under controlled laboratory conditions. The objectives of the study were to:

- (a) Determine whether and, if so, the rate of mobility and leaching of coffin/burial materials (specifically aluminium, iron, zinc and copper)
- (b) Assess whether soil type, rainfall intensity and pH, and temperature in cemetery soils play a role in rate of corrosion and leaching of the four metals.

2. LITERATURE REVIEW

The potentially hazardous nature of corrosion of materials in cemeteries has been largely disregarded as cemeteries are commonly considered fairly low risk compared to other anthropogenic sources of contamination. However,

following burial, the body's chemical components, as well as metal body parts of the deceased (e.g. tooth implants, old mercury-containing fillings and orthopaedic materials made of stainless steel, cobalt, chrome, and titanium) may leach into the surrounding soil or into groundwater. Coffins and other grave contents have also been proven to play a vital role in contamination of soil in cemeteries (Aruomero & Afolabi, 2014) as the construction of coffins include metals which are used for handles, screws, hinges and other ornaments on the coffin. These metals are often spray-painted, vacuum metalized or electroplated onto mild steel fabricated components, which are then used for the decoration and fabrication of coffins (Jonker & Olivier, 2012).

A number of different types of corrosion are recognised, *inter alia*, crevice corrosion, pitting corrosion, hydrogen blistering and high-temperature oxidation depending on the type of material and its surrounding environment (Corrosion Control in Southern Africa, 1994). A less commonly recognised type of corrosion is due to the action of micro-organisms that produce acid on metal and non-metal surfaces, consequently deteriorating them (Javaherdashti, 2008).

As indicated, the primary environmental factors that influence the corrosion rate of a material includes the medium (gas, liquid or solid) it finds itself in, the chemical composition of the material and medium, and the temperature (ASM International, 2000). The corrosivity of soils depend on their resistivity (related to the electrical conductivity), water content, pH, dissolved oxygen levels, dissolved salts (chlorides, sulphates, calcium, magnesium) (Corrosion Control in Southern Africa, 2004) and infiltration rates (Tibbett, 2010). The corrosivity of a system depends largely on the solubility of a corrosion product (usually the oxide or hydroxide) formed on the metal surface (Corrosion Institute of South Africa, 2004) as an increase in the solubility of a corrosion product will increase its mobility within the soil. Chlorides are usually highly soluble whereas the presence of calcium and magnesium bicarbonates in soil retard corrosion. These substances form a protective layer on metals, which decreases the corrosion rate (Revie & Uhlig, 2008). An increase in temperature may increase the corrosion rate of metals (Pourbaix, 1974).

3. MATERIALS AND METHODS

All experiments were conducted at a paint or coating, corrosion, environmental and materials testing facility located in Gauteng (South Africa).

Twenty-seven (27) containers measuring 170 mm diameter by 190 mm height, each with a small tap at the bottom from which the leachate could be collected and a material sieve to prevent blockage at the bottom, were filled and compacted with different soil types.

3.1. Soil samples

Samples of the three major soil types (sand, silt and clay) were collected from Klerksdorp located in North-West Province (South Africa). Soil types were defined according to particle size as follows: 0.5–2.0 mm for sand; 0.002–0.05 mm for silt and less than 0.002 mm for clay (Table 1) and based on standard soil texture classes (Brady

& Weil 2008). All samples were also analysed by means of X-Ray Fluorescence Spectroscopy (XRF) to determine their chemical compositions. Of relevance for this study are aluminium, iron, copper and zinc. Aluminium and iron are abundant to the extent that it can affect results, exceeding 23 000 mg/kg for the prior and 8800 mg/kg for the latter (Table 1).

Table 1 Properties of the relevant soil types

Mineral	Sand	Silt	Clay	Method
Particle size range (mm)	0.05-2.00	0.002-0.50	< 0.002	Grading (sieve and hydrometer)
Aluminium (Al) (mg/kg)	23928	31509	30205	XRF
Iron (Fe) (mg/kg)	8809	49729	17385	XRF
Copper (Cu) (mg/kg)	8	8	8	XRF
Zinc (Zn) (mg/kg)	0	0	0	XRF

3.2. Coffin materials

Coffin samples were collected from one of South Africa's largest and oldest coffin manufacturers (Figure 1). A typical coffin consists of the following: 65 kg chipboard or 85 kg solid wood, four 9 g hinges, six standard (combination of plastic and metal) 45 g handles or six handles with two 268 g aluminium rods of 1.2 meter, four 84 g plastic ornaments for the corners of the coffin and 94 g screws. In addition to inspecting the material safety data sheets (MSDSs), the materials were analysed by means of Energy-Dispersive X-ray Spectroscopy (EDS). The MSDS and EDS analysis indicated that the plastic handles and ornaments comprise of polypropylene and contained traces of acrolein, aluminium, silicon, chlorine, calcium, chromium, titanium and formaldehyde. EDS analysis also indicated that the varnish comprised of 31.63% silicon and 68.37% sulphur and the plastic coating of 46.61% aluminium and 9.57% silicon. The aluminium bar consisted of 100% aluminium and the metal screws contained 12.61% chromium, 24.29% iron, 5.89% copper and 55.21% zinc.



Figure 1 Coffin samples collected from one of SA's largest coffin and casket suppliers

The ratio of each material was calculated according to the weight in an average coffin. Thereafter the coffin samples were broken up into smaller pieces and divided into 27 equally constituted samples, containing 150 g wood (solid and chipboard), 1 g hinges, 3 g plastic handles, 10 g aluminium rods, 3 g plastic ornaments and 3 g

screws. Each sample was buried in a soil column at a depth of 100 mm together with a cloth soaked in 5% formaldehyde (used as embalming fluid to preserve the corpse) and *E. coli* bacteria with a nutritional medium, simulating the decomposition of a body which may influence the corrosion rate of the materials. The cloth and bacteria were placed on opposite sides of the soil column to ensure minimum contact.

3.3. Environmental variables

The soil columns (containers) were subjected to different sets of environmental conditions simulating hot vs mild temperatures; flash flood vs continuous rainfall, and acidic vs slightly acidic rainfall (Figure 2).

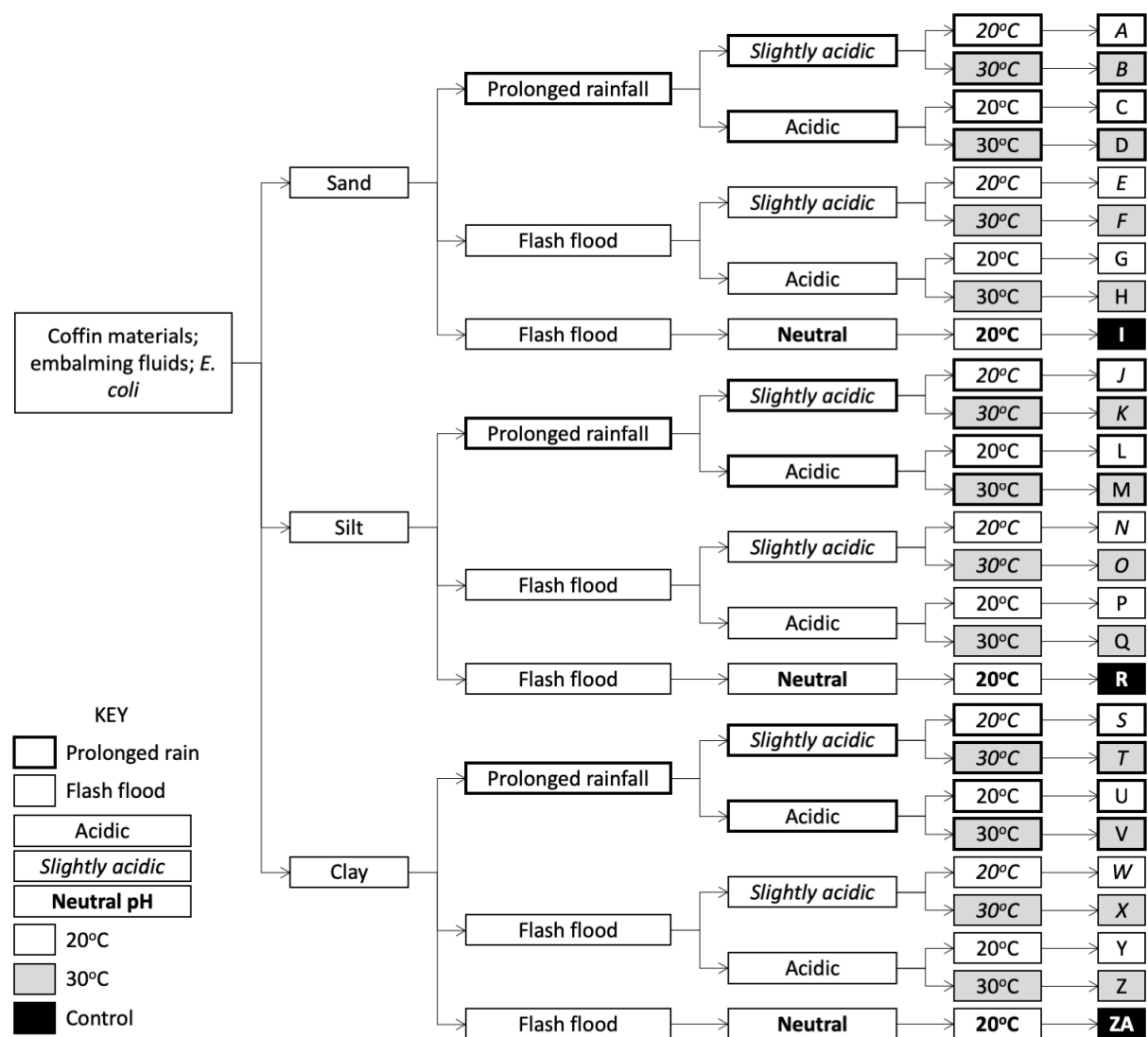


Figure 2 Layout of experimental containers (excluding controls) with far-right showing short notation for each experimental column (A, B, C, ..., ZA)

A total of 24 soil columns were constructed to allow for differentiation between (i) the different types of soil with pH values ranging from 8.0 to 9.2 (sand, silt and clay), (ii) at different rainfall pH levels (slightly acidic, 6 and acidic, 4), (iii) with varying rainfall (prolonged rainfall and flash floods), and (iv) at different temperatures (hot, 30°C and mild, 20°C).

The three remaining containers (indicated as I, R, and ZA on Figure 2), filled with sand, silty and clay without the addition of coffin samples, embalming fluids or *E.coli*, represented controls and were exposed to flash floods with neutral pH water (ranging from 6.5 to 7.2) at moderate temperatures of approximately $25 \pm 3^\circ\text{C}$.

3.4. Sampling and analyses

At the start of the experiment, water was added to the containers as indicated in Figure 2. Thereafter, the samples were left to dry for a period of two weeks to promote oxidation, after which the cycle was repeated. The conditions were varied as follows at the beginning of the two-week cycle (Figure 2):

- Different temperature regimes were created by placing half of the soil columns into a $30 \pm 3^\circ\text{C}$ chamber and the other half in an air-conditioned room which was set at $20 \pm 3^\circ\text{C}$.
- Distilled water was used in the experiments to simulate rainfall. For the samples subjected to prolonged rainfall periods, 1 L of water was added slowly over a period of 4 days (i.e. 250 ml per day using a water can with a perforated nozzle) to waterlog the soil for prolonged periods. The samples exposed to flash floods were given 1 L of water once off, allowing changing degrees of saturation, which will subsequently change conditions between aerobic and anaerobic, and between oxidising and reducing.

The pH was decreased by adding small quantities of hydrochloric acid (HCl) to achieve a pH of 6 (slightly acidic) and pH 4 (acidic).

Interment continued for a period of six months during which time leachate was collected on the same day every eight weeks. The leachate was bottled, labelled and analysed, with samples of weeks 8, 16 and 24 analysed for Al, Cu, Zn and Fe.

The amount of aluminium in the leachate was determined using a Hanna aluminium portable photometer (with a detection range of 0.0 to 5.0 mg/L), which involves the reaction between aluminium and reagents causing a reddish tint of the sample. Iron was analysed by a Hanna iron low range test kit with a checker disc (with a detection range of 0.0 to 5.0 mg/L), which also causes a red discoloration of the samples when iron reacted with the reagent. During this procedure, ferric ions are first reduced to ferrous ions by sodium sulphite. Phenanthroline is then added, which complexes with ferrous ions to form an orange coloured solution, which is proportional to the concentration of iron (Hanna Instruments, n.d.).

A Hanna handheld colorimeter, with a detection range of 0.0 to 5.0 mg/L was used to determine the concentration of copper in a solution. This reaction involves copper and a bicinchoninate reagent, which causes a purple tint in the solution. As for zinc, a Hanna zinc test kit with a checker disc with a detection range of 0.0 to 20.0 mg/L was used. Zinc reacts with the zincon reagent (ZnSiO_4) to form a brownish solution. Cyanide is then also added to the solution since other metals can form coloured complexes in zircon. Zinc and other heavy metals start to complex, after which cyclohexane is added to selectively free zinc from its complex and form a final brown-violet solution, which is proportional to the concentration on zinc (Hanna Instruments, n.d.).

4. RESULTS AND DISCUSSION

The results are shown in Table 2 and Figure 3. The different rows on Figure 3 refer to the experimental column numbers in Table 2 and Figure 2 as follows:

- Slightly acidic (sand A,B,E,F; silt J,K,N,O; clay S,T,W,X) versus acidic (sand C,D,G,H; silt L,M,P,Q; clay U,V,Y,Z).
- 20° C (sand A,C,E,G; silt J,L,N,P; clay S,U,W,Y) versus 30° C (sand B,D,F,H; silt K,M,O,Q; clay T,V,X,Z)
- Prolonged (sand A-D; silt J-M; clay S-V) versus flash (sand E-H; silt N-Q; clay W-Z).

Table 2 Aluminium, iron, zinc and copper concentrations leached after weeks 8, 16 and 24; samples are once-off retrieved at the end of the relevant cycle.

Sample Identification	Al (µg/L)				Fe (µg/L)				Zn (µg/L)				Cu (µg/L)			
	8	16	24	Mean	8	16	24	Mean	8	16	24	Mean	8	16	24	Mean
COFFIN SAND																
A slightly acidic 20 prolong	370	560	100	343	200	0	100	100	1000	1000	1300	1100	50	18	55	41
B slightly acidic 30 prolong	450	730	210	463	100	400	500	333	1500	2000	0	1167	47	144	86	92
C acidic 20 prolong	250	630	450	443	30	500	450	327	1000	0	500	500	303	0	74	126
D acidic 30 prolong	500	1580	680	920	0	100	650	250	1500	1500	1200	1400	50	220	321	197
E slightly acidic 20 flash	50	100	300	150	50	50	100	67	500	1000	0	500	99	5	324	143
F slightly acidic 30 flash	90	200	420	237	50	300	400	250	1500	2500	1000	1667	116	17	453	195
G acidic 20 flash	20	180	100	100	100	100	200	133	1500	300	500	767	275	300	264	280
H sand acidic 30 flash	10	100	500	203	850	800	950	867	3000	2000	500	1833	398	554	324	425
I sand control	0	0	0	0	400	350	0	250	0	0	0	0	0	0	0	0
COFFIN SILT																
J slightly acidic 20 prolong	0	50	320	123	150	500	650	433	1500	1500	0	1000	6	166	327	166
K slightly acidic 30 prolong	20	380	1700	700	100	200	750	350	0	1500	500	667	13	80	876	323
L acidic 20 prolong	100	370	950	473	100	100	50	83	500	1000	0	500	8	19	43	23
M acidic 30 prolong	100	280	2400	927	50	100	50	67	0	1500	0	500	0	0	1754	585
N slightly acidic 20 flash	40	50	500	197	50	200	50	100	0	500	0	167	78	80	213	124
O slightly acidic 30 flash	200	10	600	270	50	100	1500	550	0	1000	500	500	41	120	235	132
P acidic 20 flash	100	50	320	157	0	150	50	67	1000	500	0	500	111	20	785	305
Q acidic 30 flash	100	50	480	210	750	700	1400	950	0	500	1000	500	214	1030	756	667
R silt control	10	0	0	3	300	300	0	200	0	0	0	0	0	0	0	0
COFFIN CLAY																
S slightly acidic 20 prolong	50	500	430	327	50	100	650	267	0	500	1000	500	13	18	54	28
T slightly acidic 30 prolong	20	450	670	380	20	100	800	307	500	1500	500	833	123	100	826	350
U acidic 20 prolong	20	90	400	170	50	100	450	200	0	0	500	167	10	117	645	257
V acidic 30 prolong	10	560	2650	1073	400	50	2450	967	0	3000	800	1267	187	150	1526	621
W slightly acidic 20 flash	10	50	400	153	50	500	300	283	0	500	500	333	156	100	321	192
X slightly acidic 30 flash	20	100	700	273	100	100	600	267	500	1800	2500	1600	15	111	754	293
Y acidic 20 flash	10	200	560	257	50	200	300	183	0	1000	500	500	84	0	670	251
Z acidic 30 flash	30	800	1500	777	100	200	50	117	500	1500	500	833	15	185	111	104
ZA clay control	20	0	0	7	0	200	0	67	0	0	0	0	0	0	0	0

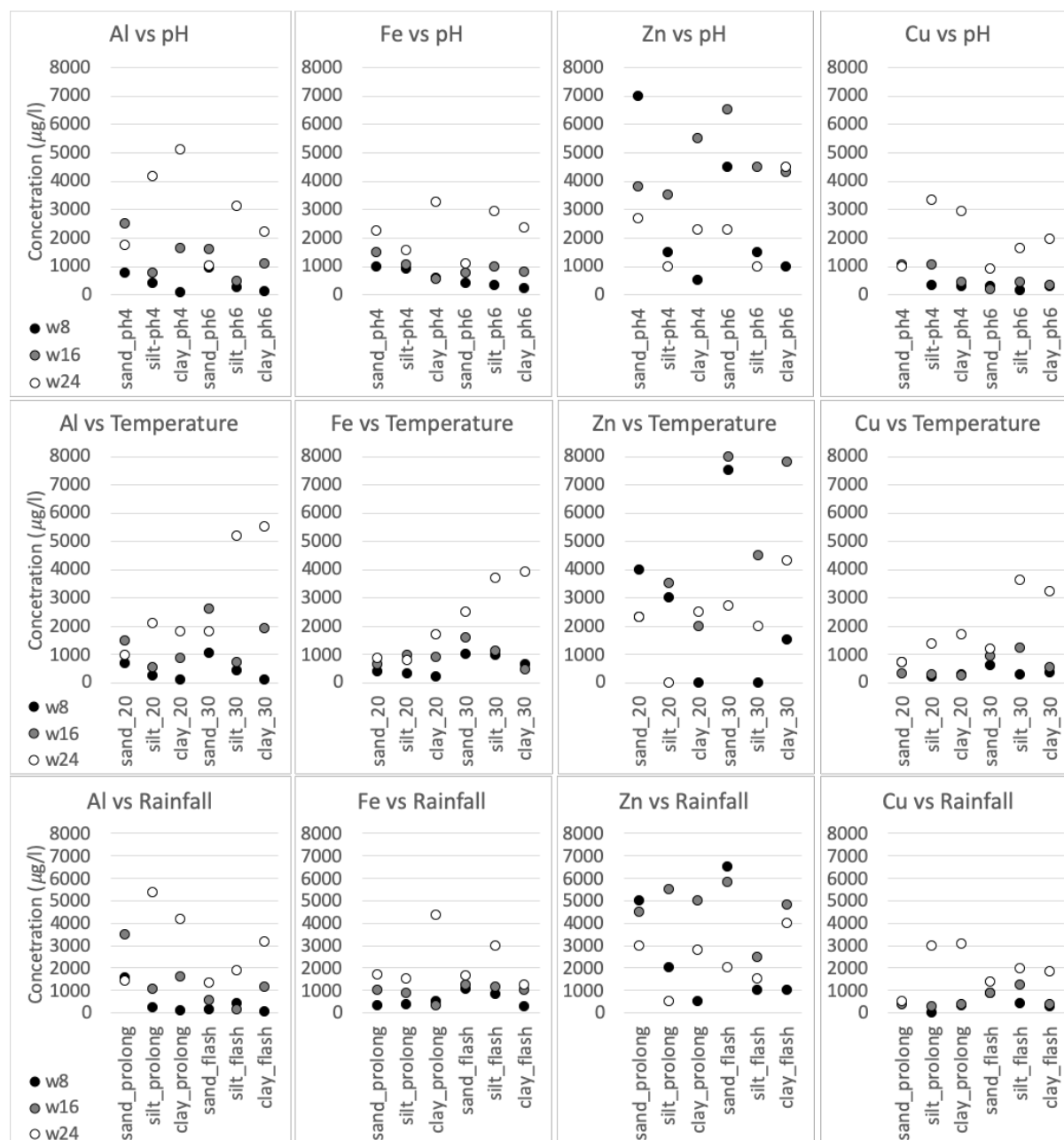


Figure 3 Aluminium, iron, zinc and copper leached from the sample columns at the end of every eight weeks (w8, w16, w24 – weeks 8, 16, 24 respectively) at different pH values (4 as acidic and 6 as slightly acidic), temperatures (20 and 30°C) and rainfall intensities (prolonged versus flash events)

4.1. Aluminium (Al)

Aluminium concentrations observed in leachate sampled at the end of week 8, 16 and 24 respectively indicate that:

- pH: Concentrations increase over time from w8 to w24, and is evidently consistently higher for lower pH values.
- Temperature: concentrations increase over time from w8 to w24, and is higher for high temperatures at late times.

- Rainfall: concentrations generally increase over time from w8 to w24 with the exception of well drained sand under prolonged supply, and is higher for prolonged supply rather than flash floods.

4.2. Iron (Fe)

Iron concentrations observed in leachate sampled at the end of week 8, 16 and 24 respectively indicate that:

- Iron takes fairly long to start corroding and only truly reflects iron in the leachate at week 24.
- pH: Clay and sand flushed out more iron at acidic rainfalls. Controversially, silt with a slightly acidic pH leached out more iron than silt with increased acidity. This was a plausible result, particularly when considering that iron and steel tend to develop corrosion products that are insoluble in the pH range of 4 to 14 (Integrated Publishing, 2017) (Corrosion Institute of Southern Africa, 2004) even though, the t-test calculated that the effect of pH on the leaching rate of iron was insignificant at $p=0.504$ ($p>0.05$), which accepts the null hypothesis.
- Temperature: increases resulted in increased corrosion in all soil types; the Student's t-test confirmed this with a calculated p-value of 0.016, which is significant at $p \leq 0.05$, thus rejecting the null hypothesis
- Rainfall: The student's t-test with a p-value of 0.912 at $p>0.05$ showed that the effect of rainfall on the leaching rate of iron was insignificant, thus accepting the null hypothesis. By further analysis it became apparent that the different soil types masked the effect of rainfall intensity in sandy soils. When calculating the p-value for each soil type, sand had a p-value of 0.031, which shows the effect of rainfall on sand was significant, thus the null hypothesis was rejected. The opposite was true for silt and clay

The highest amount of Fe was found in sample V, i.e. the leachate collected during week 24 in clay during high temperatures, prolonged rainfall and acidic conditions (2 450 $\mu\text{g/L}$) despite the fact that silt appears to be the most corrosive medium over the long term.

4.3. Zinc (Zn)

Zinc concentrations observed in leachate sampled at the end of week 8, 16 and 24 respectively indicate that:

- Sand is not only the most corrosive soil type, but corrodes zinc at a faster rate. During the first 8 weeks, around 43% of the zinc is leached out of sand. The corresponding figures for silt and clay are 23% and 8%, respectively. In both silt and clay, maximum leaching of Zn takes place between weeks 8 and 16, after which the corrosion rate decreases.
- The zinc samples corroded much more than aluminium and iron within the first six months of interment. Although zinc is more corrosion resistant than other metals when exposed to the atmosphere, without proper oxidation, zinc performs poorly in soils and have increased corrosion rates (Total Materia, 2016).
- Temperature: Increased temperatures had a significant effect on the leaching rate of zinc, which was confirmed with a t-test p-value of 0.004 ($p<0.05$), thus rejecting the null hypothesis.
- Rainfall: Flash floods resulted in the accelerated corrosion of zinc in clay, whereas in sand and silt, continuous rainfall (increased periods of wetness) allowed for higher corrosion rates.

- pH: pH does not affect the corrosion of Zn ($p > 0.05$) and thus accepts the null hypothesis. This is contrary to expectation since Chapman et al (2013) found that Zn is sensitive to pH and that Zn ions are stabilised at higher pH values (Garverick, 1994). This might be explained by the fact that the original soil samples had high pH values (8.0; 8.3 and 9.2 for sand, silt and clay, respectively, which may have had a neutralising effect on the rain water. Zinc is also an amphoteric metal, i.e. producing soluble oxides at both low and high pH values (Corrosion Institute of Southern Africa, 2004), and tends to be less sensitive to pH variation between 6.0 and 12.5.

4.4. Copper (Cu)

Copper concentrations observed in leachate sampled at the end of week 8, 16 and 24 respectively indicate that:

- There was considerably less corrosion of Cu in sand in comparison to that in silt and clay soils. Copper barely corroded within the first 16 weeks of interment, however, at week 24, there was a considerable rise in the amount of the metal in the leachate in all three types of soil. Since a considerable amount of copper was still leached out during week 24, more corrosion products of copper could be expected in the long term.
- Temperature: Higher temperatures led to higher corrosion rates.
- Rainfall: Corroded products were flushed out of sand during flash floods while the flushing process was enhanced during prolonged wet conditions in clay. The intensity of rainfall did not appear to affect the rate of leaching in silt.
- pH: Similar to Zn, the pH of the rain did not affect the corrosion and subsequent leaching of Cu from any of the soil types.

5. SUMMARY AND CONCLUSION

5.1. Assumptions and limitations

The authors duly note the limitations of the student, including but not limited to, the following:

- Evaporation from containers may influence concentrations measured.
- Concentrations are not absolute amounts, but are rather relative to original interred weights and other metal concentrations leached.
- The laboratory experiment was conducted for a fairly short period of time.
- Variables could not be tested indefinitely, and the decision was made to control a certain set of variables to identify some definite controls on the corrosion and leaching of certain metals.

5.2. Main findings

The results presented above clearly indicate that coffin materials do corrode and leach out through the soil column. However, the corrosion rates vary between different soils and under diverse environmental conditions. Influences of burial conditions on the corrosion of the metals interred are summarised in Table 3, showing combined results

for eight experimental columns per soil type, and the control experiments. In all instances, fine soils (notably clays and to a lesser extent silts) promoted corrosion and leaching.

Table 3 Parameters with **inducing** (*and limiting*) influence of corrosion of selected metals.

	Al	Fe	Zn	Cu
Temperature	high (<i>low</i>)	high (<i>low</i>)	high (<i>low</i>)	high (<i>low</i>)
Wetting	prolonged (<i>flash flood</i>)	indistinct	indistinct	indistinct
pH	acidic (<i>more neutral</i>)	acidic (<i>more neutral</i>)	indistinct	acidic (<i>more neutral</i>)

Comparison of the amount of metals in leachates reveals that Zn is most easily corroded and mobile coffin material in all types of soils. This metal moves more easily through sandy soils followed by clay. By contrast, relatively less Fe is corroded from coffin material and seems to move slowest through sandy soils.

Of interest that sands shows the highest concentrations of the different metals in the leachate, especially at early times. At later times, from week 16 to week 24, concentrations increase in clayey soils. This can very likely be ascribed to the retardation due to retention of moisture (containing the mobile metals) in fine-grained soils as compared to well-drained sandy soils. In general, it is well understood and accepted that clayey soils are generally more corrosive to metals than well-drained sandy soils.

As expected, acidic conditions and higher temperatures increased the corrosion and leaching rates of the various metals. The slightly higher corrosion rates of Zn in slightly acidic soils in comparison to that in more acidic soils is not statistically significant but could possibly be explained by the fact that Zn is an amphoteric metal and tends to be less sensitive to pH variation between 6.0 and 12.5. It should also be kept in mind that the original pH values of the different soils could have had a neutralising effect on the ‘rainfall’.

It is noticeable that considerable quantities of Al, Fe and Cu were still being leached out after the 6-month experimental period. It is, therefore, plausible to expect more World Health Organization (1996) limits to be reached or exceeded within the following months of interment.

In many cases, especially in clays, higher amounts of metals were leached out in week 24 than in week 16. This suggests that these metals will continue to be leached out for a considerable period after interment. The only exception is Zn, the corrosion rate of which appears to decrease after week 16.

It is concluded from the results obtained, that coffin materials do in fact corrode and seep into the soil under controlled laboratory conditions. The rate of corrosion and leaching of coffin materials are often influenced by periods of prolonged rainfall, rainfall with an acidic pH, warmer temperatures and soils with smaller particle sizes such as silt and clay.

The age of the cemetery, the burial load and the status of the cemetery whether it has been closed or whether burials still occur, will also influence the pollution potential. The contamination of metals in cemeteries remains a topic of concern since it is evident that burial grounds are sources of pollution, which percolate various contaminants that become mobile under controlled laboratory conditions. This could potentially contaminate surrounding cemetery soils, water reservoirs and biotic receptors within close proximity.

5.3. Future work

Although this paper presents a fairly small subset of possible environmental variables in highly controlled experimental environments, the results highlight the importance of understanding said environmental variables on the corrosion, leaching and mobility of selected metals. Beyond the relevance of cemeteries, the results can be expanded to landfills, steel reinforcement in infrastructure, and so forth. The results, in its present form, hope to encourage further experimental work on the corrosion of different metals in different environmental conditions.

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