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MIGRATION CHARACTERISTICS OF
METAL CONTAMINANTS
THROUGH A PEAT SOIL

By

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ABSTRACT

Migration of contaminants from illegal dumping of industrial wastes has the potential to give rise to problem of groundwater pollution. Thus, a study involving adsorption batch tests and leachability column tests were performed to determine the effects of soil acidity on potential of leachability of metal contaminants. Two different types of soil were utilized in this study, namely acid sulphate soil and peat soil obtained from Parit Ngamarto in Batu Pahat and Kampung Parit Mansor Benut in Pontian, respectively. In addition to chemical tests, basic engineering tests to determine the engineering properties were also undertaken. Three types of metal namely copper (Cu), aluminium (Al) and lead (Pb) were utilized as metal contaminants. It was found from this study that both acid sulphate and peat soil have low permeability, 6×10^{-6} m/s and 2×10^{-6} m/s, respectively. This study also shows that the acid sulphate and peat soils have certain adsorption capacity towards Cu, Al and Pb. The adsorption capacity of peat soil is higher than that of acid sulphate soil. In addition, acidity from acid sulphate and peat soils contribute to the leaching of the metals. Acid sulphate soil generated higher acidity than peat soil, hence, causing higher concentration of metals being leached out. The effect of the acidity is higher for Al as compared to Cu.

ABSTRAK

Pergerakan bahan cemar dari aktiviti pelupusan sisa industri secara haram berpotensi untuk menyebabkan pencemaran air bumi. Satu kajian yang melibatkan ujian penjerapan dan turus pelepasan telah dijalankan untuk menentukan kesan keasidan tanah ke atas potensi larut lesapan bahan cemar logam. Dua jenis tanah digunakan dalam kajian ini iaitu tanah gambut yang diperolehi dari Kampung Parit Mansur, Benut dan tanah asid sulfat dari Parit Ngamarto, Batu Pahat. Ciri-ciri kejuruteraan kedua-dua tanah juga ditentukan di samping ujian ke atas ciri-ciri kimia tanah. Tiga jenis logam iaitu tembaga (Cu), aluminium (Al) dan plumbum (Pb) digunakan sebagai bahan cemar. Hasil ujian menunjukkan kedua-dua tanah asid sulfat dan tanah gambut mempunyai kebolehtelapan yang rendah iaitu masing-masing 6×10^{-6} m/s and 2×10^{-6} m/s. Keputusan kajian juga menunjukkan tanah asid sulfat dan tanah gambut mempunyai keupayaan penjerapan yang tertentu terhadap ketiga-tiga bahan logam tersebut. Keupayaan penjerapan tanah gambut lebih tinggi dari keupayaan tanah asid sulfat. Di samping itu, keasidan kedua-dua tanah tersebut menyumbang kepada larut lesapan bahan logam yang digunakan. Tanah asid sulfat menjana keasidan yang lebih tinggi dari tanah gambut menyebabkan larut lesapan bahan logam yang lebih tinggi. Kesan keasidan terhadap larut lesapan Al adalah lebih tinggi dibandingkan dengan Cu.

1.0 Introduction

Illegal dumping of industrial wastes as reported by the media has given rise to concern on the environmental aspect related to the well being of human, animal and other living things. Since such wastes contain contaminants that have the potential to diffuse and disperse through the porous media (soil), the contaminants are anticipated to pose threats to the cleanliness of water bodies such as groundwater and rivers. Consequently, fish and other aqua-habitants as well as human beings are directly affected by the polluted water. Hence, in-situ testing and laboratory experimental work were proposed to study the impacts of soil types (i.e. acid sulphate soil and peat) on metal contaminants.

Illegal dumping of chemical sludge poses great hazard to the environment particularly to the soil and groundwater. The situation will worsen if the soil has characteristics that can increase the mobility of the contaminants in the sludge.

In this study, focus was given to the effect of acidity contribution from acid sulphate soil and peat soil to the mobility of selected hazardous metals, namely Cu, Al, and Pb. Both soils are considered as acidic soil with the former being more acidic than the latter. In addition to their acidic nature, both soils may also have adsorption capacity which retards the contaminants to certain extent. This study explores the effect of both possibilities.

2.0 Objectives

In view of the dumping of industrial wastes on non-gazetted hazardous landfill area, this research was generally focused on the impact of the soil acidity on leachability of metal. In addition, the fundamental engineering properties of the soils would also be investigated. Hence, the objectives of this study are as follows;

- a) to determine the fundamental chemical and engineering properties of an acid sulphate soil and a peat soil
- b) to determine the chemical contents of the outflow fluid

- c) to establish the mechanistic of contaminant leaching from acid sulphate soil and peat soil

3.0 Methodology

This research was based mainly on laboratory experimental work. Acid sulphate soil was collected from Parit Ngamarto, Batu Pahat while peat soil was collected from Kampung Parit Mansor, Benut. Figure 1 and Figure 2 show the locations from where acid sulphate soil and peat soil were obtained, respectively.

3.1 Determination of Engineering Properties

Determinations of engineering properties of the soils were conducted based on the British Standard and other methods proposed by previous researchers. In addition to the obtained samples, in-situ testing such as permeability and vane shear tests were performed.

3.2 Experimental Procedures of Chemical Tests

Three types of experimental work were conducted to investigate the adsorption capacity and effects of acidity on leachability of the soils. Those tests were (i) adsorption-batch test, (ii) adsorption-column test, and (iii) sludge leachability-column test. Copper nitrate ($\text{Cu}(\text{NO}_3)_2$), aluminium sulphate ($\text{Al}(\text{SO}_4)_3$) and lead nitrate ($\text{Pb}(\text{NO}_3)_2$) were of reagent grade and were used as the synthetic samples. Distilled deionized water was used throughout the experiments. The concentration of the metals were analysed using HACH DR5000U. The methods used were Method 8506 (for Cu), Method 10215 (for Al) and Method 10216 (for Pb) (HACH, 2005).



Figure 1 Location of Parit Ngamarto site (samples were obtained from within the oil palm plantation area)



Figure 2 Simpang Rengam - Benut road leading to Kampung Parit Mansor (the site is on the left of the wide earth drain)

3.2.1 Adsorption-batch test

The adsorption-batch tests were conducted using conical flasks. 10 mg/L of Al was added into five flasks, each containing 500 mL of deionized water. Then, different quantity (10g, 25g, 50g, 75g, and 100g) of acid sulphate soil were added separately into each flask. The content in the flasks were mixed by putting the flasks on a shaker and mixed at 200 rpm for 48 hours. After 48 hrs, the content of each flask was centrifuge and the supernatant was analyzed for the residual metal. The same procedures were repeated for Cu and Pb, with peat and acid sulphate soil. A total of 30 flasks were used in the study.

3.2.2 Adsorption-column test

The adsorption column tests were conducted in 18 acrylic columns of 5 cm diameter and 30 cm height each. The schematic diagram of the column is shown in Figure 3, while Figure 4 shows the experimental set up of the experiment. The columns were filled up with 200 g of soil (9 with acid sulphate soil and 9 with peat soil). PVC wool was put at the bottom of the soil to prevent them from leaving the column. Distilled water spiked with of 10 g/L of a particular metal was poured into an acid sulphate soil column and peat soil column separately until the water was about 1 cm above the soil surface. The water was retained in the column for certain period (i.e. 12, 36, 72 hours). A metal clip was used to hold the water in the column. The column was then drained and the leachate was analyzed for the residual concentration of the metal. The detail experimental runs are shown in Table 1.

Control runs were conducted to determine the concentration of metals that are naturally present in the soils. These were carried out by retaining deionised water in two separate columns containing acid sulphate soil and peat soil. 20-mL of the water was sampled at the pre-set intervals (i.e. 12, 36, 72 hours) and analysed for the Cu, Al, and Pb.

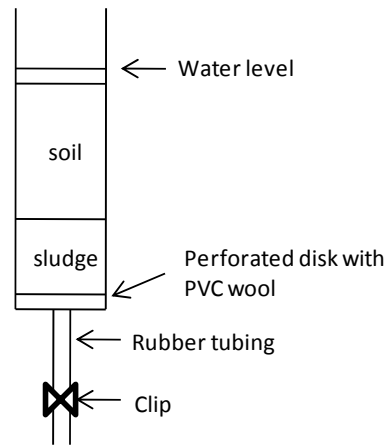


Figure 3. Schematic diagram of leachability column test



Figure 4 Experimental setup of leachability column test

Table 1. Setup of the adsorption test column.

Column No	Soil type	Metal type	Retention time, hr
1, 10	Acid sulphate, peat	Copper	12
2, 11	Acid sulphate, peat	Copper	36
3, 12	Acid sulphate, peat	Copper	72
4, 13	Acid sulphate, peat	Aluminium	12
5, 14	Acid sulphate, peat	Aluminium	36
6, 15	Acid sulphate, peat	Aluminium	72
7, 16	Acid sulphate, peat	Lead	12
8, 17	Acid sulphate, peat	Lead	36
9, 18	Acid sulphate, peat	Lead	72

3.2.3 Sludge leachability column test

The test was conducted in the same column as describe earlier. Aluminium and copper sludge were prepared by reacting $\text{Cu}(\text{NO}_3)_2$ and $\text{Al}(\text{SO}_4)_3$ with NaOH producing copper and aluminium complexes. Sludge (50g) was put on top of the PVC wool and then covered with 150 g of soil shown in Figure 3. Distilled water was added into the column until the water was about 1 cm above the soil surface. The water was retained for certain period. Then, the water was drained out from the soil and the leachate was analysed for the residual Cu and Al. Table 2 tabulates the experimental runs carried out for the leachability column test study.

Control runs were also carried out for this test. It comprised of two columns filled up with 200g of sludge only. Deionised water was added into the columns as explained earlier. Water samples were then taken at certain interval and analysed for Cu and Al.

Table 2. Experimental runs for leachability column test

Column No	Soil type	Sludge type	Retention time, day
1, 7	Acid sulphate, peat	Copper	1
2, 8	Acid sulphate, peat	Copper	3
3, 9	Acid sulphate, peat	Copper	7
4, 10	Acid sulphate, peat	Aluminium	1
5, 11	Acid sulphate, peat	Aluminium	3
6, 12	Acid sulphate, peat	Aluminium	7

4.0 Results and Analysis

4.1 Engineering properties

Based on laboratory and in-situ testing, the basic engineering properties of the soil being investigated are as tabulated in Table 3 and Table 4. The particle size distribution of the acid sulphate soil is as shown in Figure 5.

Table 3 Engineering properties of peat used in the study

Bulk unit weight, γ (kN/m ³)	8.63
Specific gravity, G_s	1.39
Natural moisture content, w (%)	200
Liquid limit, LL (%)	NA
Plastic limit, PL (%)	NA
Shear strength (based on vane shear test), c_u (kN/m ²)	30
Unconfined compressive strength, q_u (kN/m ²)	65
Permeability (based on falling head test), k (m/s)	2×10^{-6}
Permeability (based on field permeability test), k_f (m/s)	NA

Note: NA = not applicable/available

Table 4 Engineering properties of acid sulphate soil used in the study

Bulk unit weight, γ (kN/m ³)	12.04
Specific gravity, G_s	2.38
Natural moisture content, w (%)	60
Liquid limit, LL (%)	55
Plastic limit, PL (%)	32
Shear strength (based on vane shear test), c_u (kN/m ²)	20 ~ 60
Unconfined compressive strength, q_u (kN/m ²)	11 ~ 17
Permeability (based on falling head test), k (m/s)	6.5×10^{-6}
Permeability (based on field permeability test), k_f (m/s)	NA

Note: NA = not applicable/available

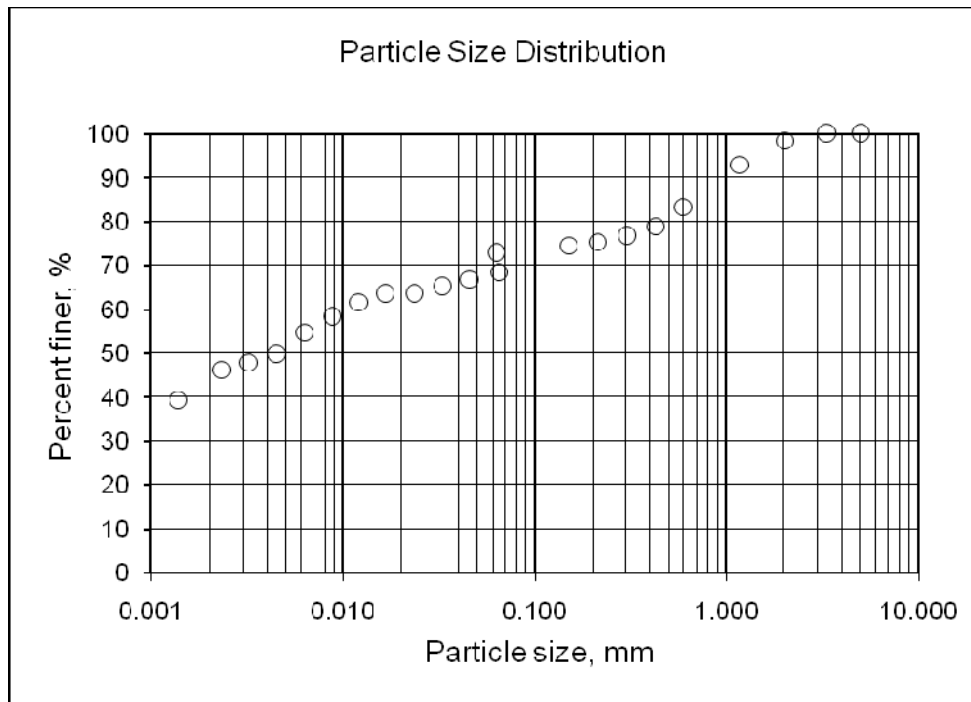


Figure 5 Particle size distribution of acid sulphate soil obtained from Parit Ngamarto

Considering peat soil is generally made of decomposed vegetative residues (organic materials), the low specific gravity and bulk unit weight of 1.39 and 8.63 kN/m³, respectively are anticipated. The bulk unit weight obtained in this study shows that the value is within the range of values for peat in West Malaysia as reported by Huat (2004) which is between 8.30 and 11.50 kN/m³. On the other hand, Yulidasari (2006) reported higher value of bulk unit weight of Pontian peat (10.02 kN/m³) than that obtained in this study. In addition, the specific gravity of the Benut peat is within the range of values reported by Huat (2004) which is between 1.30 and 1.90 but slightly lower than the value obtained by Yulindasari (2006).

Due to its nature which resembles sponge with high total volume of voids, peat has the ability to store high volume of water as shown by the high value of moisture content, $w = 200\%$ and this natural water content is within the range of natural water content for peat in West Malaysia. The liquid and plastic limits of the soil could not be determined due to the absence of clay minerals that contribute to plasticity of soils.

In terms of the shear strength, in-situ testing using a shear vane showed that the undrained shear strength of the peat was 30 kN/m^2 . This value is higher than that obtained by Yulindasari for Pontian peat which is 10 kN/m^2 . On the other hand, unconfined compressive strength test performed on the sample showed that the unconfined shear strength was 65 kN/m^2 . Such difference was anticipated due to the difference in the stress condition during the tests where the in-situ soil was confined by the surrounding soil. The disturbance during sampling and transportation of samples to the laboratory would also influence the results of the tests besides disturbance during sample preparation for laboratory shear strength tests.

Series of variable head permeability tests yielded an average coefficient of permeability of $2 \times 10^{-6} \text{ m/s}$, which falls within the range of permeability of fine sand and peat (Berry and Reid, 1987). The obtained value however is lower than the value reported by Yulindasari (2006) which is $1.20 \times 10^{-4} \text{ m/s}$. The low value of permeability for the soil used in this study is an indication that the peat possesses one of the characteristics of amorphous peat as shown by Hobbs (1986) in the relationship between void ratio and permeability. Such property can be physically examined on the soil used in this study as it shows fine material characteristic. Attempts to determine the in-situ permeability using Guelp Permeameter Model 2800 normally utilized in the agriculture activities were unsuccessful. Such failure might be caused by the “smear effect” during the creation of the well-hole in the soil.

As for the acid sulphate soil, it was found that the bulk unit weight of the soil was relatively low, 12.04 kN/m^3 . This value may represent unconsolidated or uncompacted soil. In addition, the relatively low value of the specific gravity, 2.38 compared to the typical value of 2.7 which might be due to the absence of heavy minerals in the soil could result in such low unit weight.

Based on in-situ vane shear test, the undrained strength of the soil at depth of 1m to m from the ground surface was between 20 kPa to 60 kPa, higher than the value obtained based on laboratory unconfined compressive strength test which was between 11 kPa to 17 kPa. Such big difference might be due to disturbances in soil sampling for laboratory testing. The high strength of the in-situ soil on the other hand might be caused by the presence of vegetative roots, i.e. oil palm.

Attempts to determine the in-situ permeability using Guelp Permeameter Model 2800 normally utilized in the agriculture activities were unsuccessful. Such failure might be caused by the “smear effect” during the creation of the well-hole in the soil. The falling head permeability tests performed in the laboratory yielded an average value of 6.5×10^{-8} m/sec, represents the value for silt (Berry and Reid, 1987).

4.2 Chemical properties

In addition to engineering properties, some of the chemical contents of the acid sulphate soil were determined and such values are as shown in Table 5.

Table 5 Chemical properties of acid sulphate soil used in the study

Aluminium	1.40×10^5 mg/kg
Iron	1.80×10^5 mg/kg
Sulphate	2.70×10^3 mg/kg
pH	3.39

4.2.1 Adsorption-batch test

The results of the adsorption-batch test are given in Table 6. After 48 hours of contact time, there are significant different between the adsorption of Cu, Al, and Pb by both acid sulphate and peat soils. In all cases, peat soil has better adsorption capacity as compared to acid sulphate soil. As for peat soil, Cu is being adsorbed the most, followed by Pb and Al. For acid sulphate soil, Pb is being adsorbed the most, followed by Cu. However, the concentration of Al in the water after in contact with the soil is much higher than the initial concentration in the water. This is suspected to be caused by the leaching of Al there are naturally present in the soil. Previous study conducted by IPASA (2006) shows a high concentration of Al in acid sulphate soil reaching up to 155 mg/g.

The results also show that in most cases, the increase of the soil mass from 10 g to 100 g has insignificant effect on the adsorption of the metals. This is with the

exception for adsorption of Al by peat soil where increase of soil mass from 10 g to 25 g reduces the residual Al from about 12 mg/L to 4.5 mg/L. However, increasing the soil mass further has trivial effect on the residual Al concentration.

Table 6. Results of adsorption-batch test

Soil conc. (g/L)	Residual concentration (mg/L)					
	<i>Cu</i>		<i>Al</i>		<i>Pb</i>	
	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>
10	3.2	0.14	26.9	12.5	1.33	0.24
25	3.0	0.19	32.4	4.6	0.83	0.30
50	1.8	0.11	31.1	2.7	0.61	0.31
75	2.4	0.10	35.8	3.4	0.53	0.32
100	1.6	0.11	27.7	4.4	0.45	0.32

4.2.2 Adsorption-column test

The results of the adsorption column test are shown in Table 7. The residual concentrations given in the table have take into consideration the concentration of the metals that are naturally present in the soil.

Table 7. Results of adsorption-column test

Retention time (hrs)	Residual concentration (mg/L)					
	<i>Cu</i>		<i>Al</i>		<i>Pb</i>	
	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>	<i>Acid Sulphate Soil</i>	<i>Peat Soil</i>
12	5.4	0.61	33.4	1.84	5.07	0.11
36	6.0	0.68	31.3	7.40	1.40	0.15
72	3.2	0.25	13.6	8.40	0.23	0.10

Initial metal concentration is 10 mg/L

The effect of water retention time in the column on the metal leachate concentration is ambiguous. As for acid sulphate soil, the concentration of Cu, Al and Pb in the

leachate reduces with the increase in water retention time. However, as for peat soil, while the concentration of Al increases as retention time increases, the effect on Cu and Pb cannot be clearly defined.

Similar to the adsorption batch test, peat soil has better adsorption capacity as compared to acid sulphate soil for all the metals tested. However, in contrast to the adsorption batch test results, Pb is adsorbed better by the peat soil as than Cu.

Adsorption of the Al is the worst among the three metals. Adsorption by the acid sulphate soil follows the following order: $Pb > Cu > Al$. As for Al, the concentrations of the residual are higher than the concentration in the water sample. This is expected to be due to the Al that is already present in the soil. The contact of the soil with water has increased the mobility of the metal causing the metal to leach out when the water was drained from the column. Similar findings were obtained by Said (2007) during his leaching study with acid sulphate soil.

4.2.3 Sludge leachability column test

Only two metals were studied in leachability column test, i.e. Cu and Al. In the control study, only 0.01 mg/L and 0.03 mg/L of Cu and Al, respectively were found in the leachate after 7 days of water retention time.

As for the peat soil, about 0.2 to 0.3 mg/L of Cu was leached out from the Cu sludge buried within the peat soil depending on the water retention time in the column. Since about 0.1 to 0.15 mg/L of Cu was previously determined in the leachate of the control run (adsorption-column test; peat soil + deionized water), the concentration of Cu in the leachate of this study can be considered as trivial. In the Al sludge study, the concentration of the Al in the leachate is in the range of about 4 mg/L. This is considered as significant as the Al concentration from leaching test of peat soil only was in the range of less than 0.5. It is anticipated that the low pH of the peat soil water (about 4.5) has caused the leaching of the Al from the Al sludge in the column.

As for the acid sulphate soil, much higher concentration of Cu and Al was found in the leachate. In addition to higher acidity contribution to the water by the acid

sulphate soil, the natural content of the metals also contribute to concentration in the leachate. The results of the sludge leachability column test study are given in Table 8.

From the results of adsorption batch-test study, both soils were found to be able to adsorb the metals. Peat soil has better adsorption capacity as compared to acid sulphate soil. After 48 hours of mixing, more than 95% of the Cu and Pb were adsorbed by the peat soil. On average, about 76% of Cu and 93% of Pb were adsorbed by acid sulphate soil. Adsorption of Al by the peat was about 60%. As for acid sulphate soil, higher concentration of Al than the added amount was found in the water. This is expected to be due to the leaching of Al that is already present in the soil.

Table 8. Results of sludge leachability column test study

Retention time (day)	Leachate concentration (mg/L)					
	Cu			Al		
	Peat	Acid Sulphate Soil	Sludge	Peat	Acid Sulphate Soil	Sludge
1	0.19	0.53	-	4.0	18.5	-
3	0.27	0.63	-	4.3	23.2	-
7	0.28	0.72	0.01	3.8	17.4	0.03

Similar findings are found in the adsorption-column test. However, less metals were adsorbed by the soil despite of longer water retention time in the column, i.e up to 72 hours. It is anticipated that despite the longer water retention time in the column, the contact between the water and the soil was not as good as in the batch-test study as mixing was not provided in the former. Hence, less metal was adsorbed by the soil.

In leachability column test, the sludge alone appears not to leach out significant concentration of Cu and Al. However, higher concentration of Cu and particularly Al was found when the sludge is buried underneath the peat and acid sulphate soils.

While very high concentration of Al found in the leachate of acid sulphate soil can be caused by the natural content of Al in the soil, high concentration of Al was also found in the leachate of peat soil. It is anticipated that the acidic nature of the peat soil leachate contributes to the leaching of the metals.

5.0 Conclusions

A study involving adsorption batch tests and leachability column tests were performed to determine the effects of soil acidity on potential of leachability of metal contaminants. Two different types of soil were utilized in this study, namely acid sulphate soil and peat soil. In addition to chemical tests, basic engineering tests to determine the engineering properties were also undertaken. Several conclusions that can be derived from the study are as follows:

- Both acid sulphate and peat soils have low permeability, 6×10^{-6} m/s and 2×10^{-6} m/s, respectively.
- In situ vane shear tests yielded different values than that obtained from laboratory unconfined compressive strength tests for both soils due to disturbances during sampling.
- Acid sulphate and peat soils have certain adsorption capacity towards Cu, Al and Pb.
- The adsorption capacity of peat soil is higher than that of acid sulphate soil.
- Acidity from acid sulphate and peat soils contribute to the leaching of the metals and the effect of the acidity is higher for Al as compared to Cu.
- Acid sulphate soil generates higher acidity as compared to peat soil, hence, causing higher concentration of metals being leached out.

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