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INFLUENCE OF PRINTED CIRCUIT BOARDS' COMPONENTS ON *ACIDITHIOBACILLUS FERROOXIDANS*-LR GROWTH

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ABSTRACT: Bioleaching is a recycling process used to leach metals through microorganisms' metabolism. It has been studied to metals recovery from WEEE, mainly printed circuit boards (PCB). Besides its environmental advantages, a longer process time is a decisive aspect to commercial application. It has been suggested that reaction time could be influenced by the toxicity of some PCB components to the bacterium. Thus, the main purpose of this research was to determine if PCB components from tablets influence on *Acidithiobacillus ferrooxidans*-LR growth. The characterization of tablets' PCB was carried through aqua regia digestion, resulting in 33% ceramic, 32% polymeric and 35% metallic portion. After bioleaching' parameters analysis (pH, ferrous ions and copper concentration), the pulp density of 15g/L was chosen to carry out the last stage. Lastly, the PCB components influence were determined: epoxy resin presented microbiostatic effect, and the metallic synthetic solution microbiocide effect on the bacterium growth. Individually, the metals Ag and Sn presented microbiocide, and Cu microbiostatic effect on the bacterial growth. Using the pulp density of 30 g/L capacitors presented microbiocide effect on *A. ferrooxidans* - LR growth. Therefore, alternatives to the use of epoxy resin in WEEE, or on process to avoid/reduce silver, tin and copper contact with the microorganism, are essential to the bioleaching process improvement.

Keywords: Acidithiobacillus ferrooxidans. Bioleaching. Printed circuit boards. Tablets. Waste of electrical and electronic equipment

1. INTRODUCTION

Tablets share market with smartphones and notebooks, reaching the worldwide sales mark of 248 million units in 2015. Due its lifetime, in about five years it becomes waste electrical and electronic equipment (WEEE) (FRAMINGHAM, 2016; BALDÉ et al., 2017; KUMAR, HOLUSZKO, ESPINOSA, 2017). Annualy is gerenated more than 40 million tons of WEEE, and its growth rate is three times faster than others solid wastes (GUAN et al., 2012; HONDA, KHETRIAL, KUEHR, 2016).

The bioleaching is a recycling process used to leach metals through microorganisms' metabolism, being *Acidithiobacillus ferrooxidans* one of the main bacteria used. It has been studied for metals' recovery from WEEE, mainly printed circuit boards (PCB) (KARWOWSKA et al., 2014).

Its advantages are related to cost and toxic gases emission, comparing to hydrometallurgy and pyrometallurgy techniques (PRADHAN; KUMAR, 2012). However, the disadvantage is the time spent in the process (up to 15 days), longer than in others (few hours), which is a decisive aspect to industrial application (JOWKAR et al., 2018).

Authors suggest time could be a result of the toxicity of some PCB components to the bacterium, influencing on its metabolism (BRANDL, BOSSHARD, WENGMANN, 2001; ILYAS et al., 2007; XIANG et al., 2010; KARWOWSKA et al., 2014; LAMBERT et al., 2015; SYED, 2016). Therefore, the components have a microbiostatic effect, reversibly inhibiting essential process to the cellular growth, or microbiocide, irreversibly leading the cell to death (MADIGAN et al., 2016).

Among PCB componets, fiberglass, epoxy resin, capacitors and metals are the main componentes indicated as influencers on the bacterium growth. Fiberglass and epoxy resing are suggested because of its alkalinity, and the presence of polymers and fiberglass are suggested to contribute to a slower kinetics of the reactions, as they increase the diffusion time of the substances, acting as an obstacle (ILYAS et al., 2007; RODRIGUES et al., 2015; VALIX, 2017).

Capacitors are related to alkalinity increase on the medium, but also to toxicity, as substances as Ta and polychlorinated bipheyl may be present on its composition (GARLAPATI, 2016; VALIX, 2017).

The toxicity of some metals has also been studied, such as Ag (0.001 g/L), Hg (0.0201 g/L) and Mo (0.096 g/L), and has been shown the potential of bacteria adaptation (GARCIA JÚNIOR, 1989; BRANDL, BOSSHARD E WANGMANN, 2001; ILYAS et al., 2007; POURHOSSEIN, MOUSAVI, 2018; JOWKAR et al., 2018). Other substances may be tolerated, arsenite (4.16 g/L) and arsenate (8.891 g/L), Zn and Mn (XIN et al., 2012, YAN, 2017).

The alkalinity of the material influences microrganisms' metabolism by altering the pH to values above the optimum for its' growth, also, although the microorganisms may show resistance to high concentrations of metals, the WEEE presents some toxicity to them when the bacterium is not adapted (BRANDL, BOSSHARD AND WANGMANN, 2001).

Nonmetallic components also contribute to the increase of the pH during the process, despite that, the metallic fraction is the main responsible for inhibiting the bacterial growth (ILYAS et al., 2007). The acidity consume is also related to polymers presence, it may limit and even inhibit the bioleaching of copper by *A. ferrooxidans* (LAMBERT, 2015).

Thus, the main purpose of this research was to determine if PCB components individually influence on *Acidithiobacillus ferrooxidans*-LR growth and which influence was observed.

2. METHODOLOGY

2.1 Stage 1 - Printed circuit boards' characterization

The printed circuit boards were cut in 1 cm² fractions and shredded in a vibratory plate mill. The material was divided, quartering in samples of 4 g approximately.

This samples were digested in aqua regia (1:20 solid/liquid ratio; 24 h) and filtered. The solid fraction, preserved on the filter, was oven dried (70°C, 48 h). The weight was measured, and the samples were submitted to 800°C for 2 hours to determine the polymeric (volatile) and ceramic (non volatile) fractions by mass balance. The metals leached in the liquid fraction were characterized in ICP MS (Nexlon 300D, Perkin Elmer).

2.2 Stage 2 - Bioleaching parameters test

During the second stage, copper bioleaching parameters were tested, monitoring the pH, ferrous ions and copper concentration. The bacterium (A. ferrooxidans – LR) was previously adapted to 30 g/L of computer PCB, a different WEEE. Therefore, the pulp densities of 30, 15 and 5 g/L were tested in triplicates to check the feasibility of bioleaching metals from tablets PCB . The parameters used are related in Table 1.

Table 1. Caption caption caption caption caption caption.

Parameter	Value
Initial pH	1.8
Initial Fe^{2+}	6.75 g/L
Temperature	30°C
Rotation	180 rpm
Bacterial inoculum	10% v/v

Source: Yamane, 2012.

The experiment was performed for five days. The parameters pH, Fe^{2+} and Cu concentration were monitored daily, and the pH adjusted to 1.8.

It was utilized T&K medium. Abiotic controls were also prepared in triplicates, using T&K medium and the pulp density tested, to compare the results.

Aliquots were taken daily to determine copper concentration, replenished with H_2SO_4 solution to maintain the mass transfer rates (pH 1.8). These aliquots were centrifugued (30 min; 35000 rpm) to separate the supernatant.

From the supernatant, 5 mL was preserved with HNO_3 and stored (4°C), lately analized by flame atomic absorption spectroscopy (F AAS). The other amount (10 mL) was used to verify Fe^{2+} concentration.

2.3 Stage 3 - Components' influence

At the last stage, the influence of fiberglass, epoxy resin, metals and capacitors individually were determined in shaken flasks tests (180 rpm, 30°C). The flasks contained T&K medium, bacterial inoculum (10% v/v) and the analyzed component.

Fiberglass, epoxy resin and capacitors were comminuted using the same methodology of the first stage. Metals were tested in a synthetic solution of metallic salts, one solution with all metals and solutions per metal, considering the metallic concentration observed in stage 1. The components concentration was determined in the second stage, as the higher pulp density to allow bacterial growth.

After the solutions preparation, flasks were allocated on the shaker and monitored daily, through the solution color and pH. The solution color showed the ferrous ions consumption, which generates ferric ions and changes the colour of the solution from green to red (exponential growth phase), as Figure 1. A biotic control was prepared at the same time, containing T&K medium and bacterial inoculum.

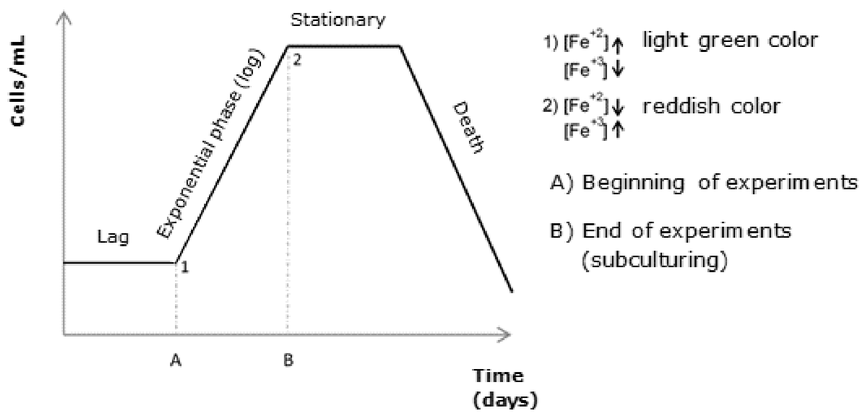

Figure 1. Bacteria growth stages and monitoring parameters behavior.

When the biotic control colour change was observed, representing the microorganism growth, it was compared to the samples. If the event happened in a different timming, the component was considered as influentional. From this, a new solution was prepared in triplicate, using the previous sample as the bacterial inoculum, in order to evaluate the type of influence (microbiocide or microbiostatic), as described in Figure 2.

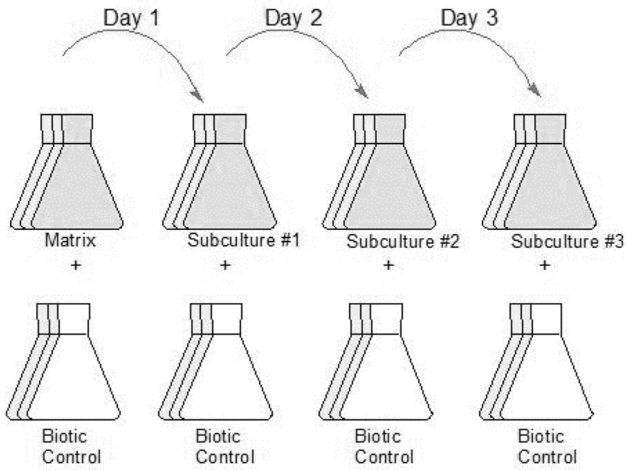

Figure 2. Bacterial subculturing from a sample with component influence detected.

3. RESULTS AND DISCUSSION

3.1 Stage 1 - Printed circuit boards' characterization

The results show the PCB' composition as: 33% ceramic, 32% polymeric and 35% metallic (Cu, Ni, Sn, Pb, Zn, Ag, Au, Pt, Mn, Sr, among others). The results are similar to other researchs, as tablets' PCB– 36% metalic, 33% ceramic and 31% pollimeric, computers – 35% metallic (Veit, 2001; Park and Fray, 2009; Motta, 2018).

Others found the composition as 40% metalic 30% polimeric and 30% ceramic, but it was characterized other kinds of WEEE (HE et al., 2006; GHOSH et al., 2015; KUMAR, HOLUSZKO, ESPINOSA, 2017).

Figure 3 shows the metallic fraction composition, totalizing 35%.

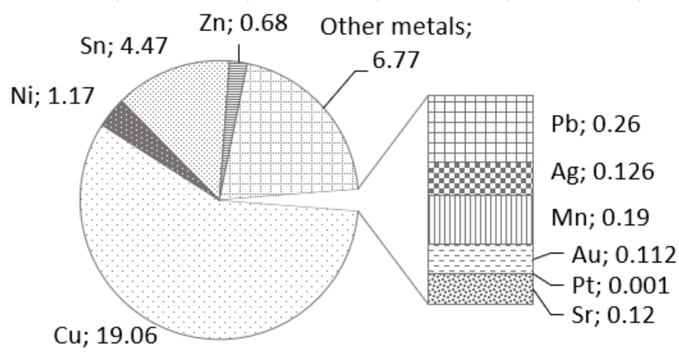

Figure 3. Metalic composition (%w/w).

Fe an Al could not be characterized because of other metals interferece. Comparing to other researches, the composition is consistent. Tablets composition may vary due diferente models, manufactorers, year, among others (MOTTA, 2018). It emphasizes the importance of WEEE characterization. This is crucial to define if it is viable to recicle and the best recycling route to apply (MARTINHO *et al*., 2017).

Pb concentration (0.26% w/w) is lower than in other EEE (0.4-4.19%) this is a positive fator, since it is a toxic metal (ROCHA, 2009). The precious metals are found in lower rates than other metals, however, it representes a superior value. It is a decisive point to adopt metallic recovery industrialy

(CUCCHIELLA *et al*, 2015).

Iron, aluminum, cobalto, barium and tantalum were not identified, yet, they are likely to be present on the samples, as non identified metals represent 6.85% w/w of the metallic fraction (OGUCHI *et al.,* 2011; CUCCHIELLA *et al*., 2015; ISILDAR *et al.,* 2016).

3.2 Stage 2 - Bioleaching parameters test

The bioleaching parameters were tested to ascertain which pulp density was copper extraction is presented in Figure 4.

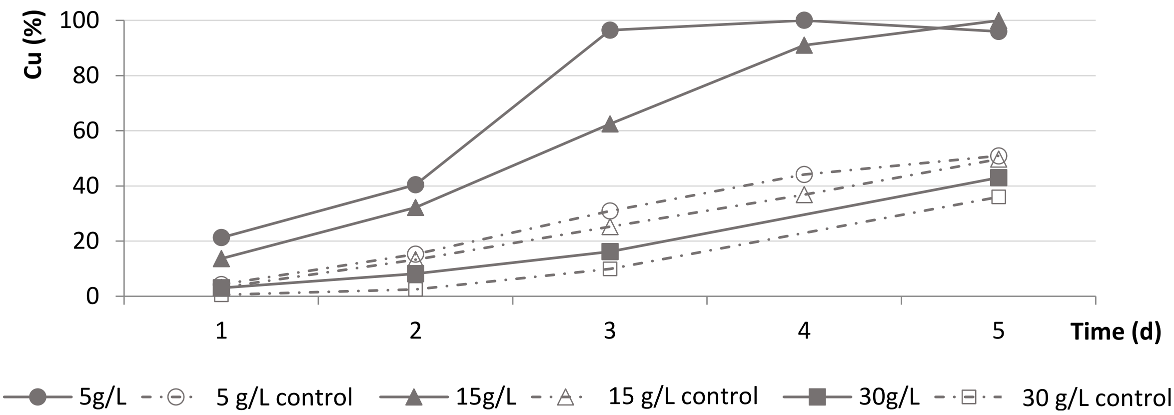

Figure 4. Cu extraction versus time (%).

Copper extraction on 30 g/L samples occured simmilarly to abiotic control samples after the 5 days. It indicates an inhibition of the bacterial activity by the pulp density. The result is 7% higher than the control, pointing out a chemical leaching process (YANG et al., 2009; HONG, VALIX, 2014).

Comparing the copper extraction on the other samples, 99.9% were obtained on both (5 and 15 g/L) with the time difference of one day. However, the 15g/L used 3 times the pulp density, being selected as a better result since ir bioleached a higher amount of copper.

It was possible to affirm the baterial activity in the 15 g/L pulp density sample by comparing the resuls with the abiotic controls. It was the higher pulp density A. ferrooxidans – LR resisted and is the optimum value considered in other researches (YAMANE, 2012; YANG et al., 2014).

The decrease observed on the 5 g/L sample after the peak (day 4) may be explained by jarosite precipitation (combination of ferrous hidroxide and soluble ions of the solution -– NH_4^+, Na^+ or K^+) (BRANDL, 2001; SILVAS, 2014) (Figure 5).

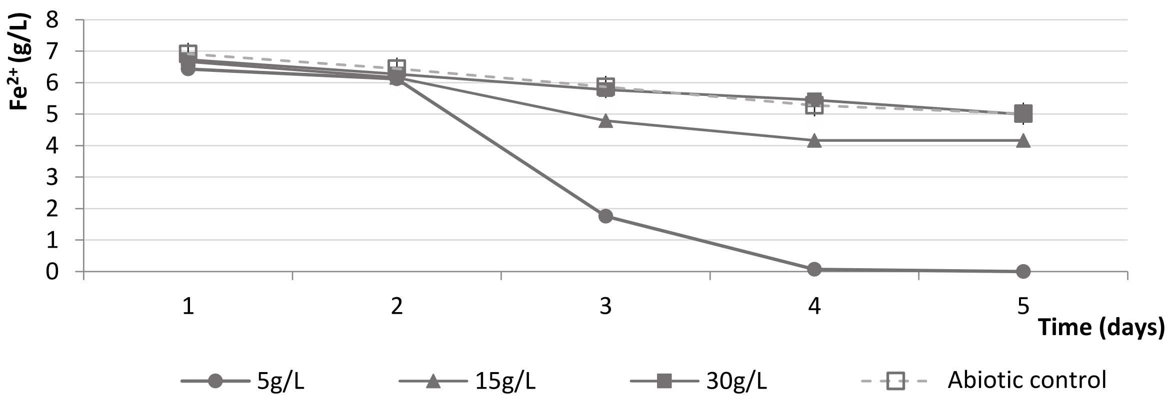

Figure 5. Ferrous ions consumption (g/L)

The Fe^{2+} consumption on 5 g/L samples was total on day 4, evidencing the bioleaching peak. On 15 g/L samples, the consumption was faster from day 1 to 2. After that the consumption rate decreased, relative to the increase of solubilized metal on solution, and may represent a negative effect of metal concentration to bacterial population (BRANDL, BOSSHARD, WEGMANN, 2001; ILYAS et al., 2007). Fe^{2+} consumption is related to A. ferrooxidans growth (NIE et al., 2014).

On 30 g/L samples, the Fe^{2+} consumption rate was similar to the abiotic control samples. The concentration decrease on these samples can be related to chemical leaching, endorsed by the pH increase from day 3 to 5, even considering the daily pH adjustment (YANG et al., 2014).

Pulp densities above 30 g/L may turn the ferrous ions oxidation slower, reaching levels of 2g/L, similar to the observed (YAMANE, 2012).

Analyzing the consumption of Fe^{2+} would not be possible to conclude the inhibition of microbial activity by WEEE presence (30 g/L), since it could indicate the renovation of the ferroous ion cycle due *A. ferrooxidans* metabolism. However, the evolution of copper extraction, similar to the abiotic control, demonstrated the inhibition of bacterial growth in the presence of 30 g/L tablets PCB.

The pulp density of 15 g/L was chosen to carry out the tests.

3.3 Stage 3 - Components' influence

3.3.1 Observation of influences

The results obtained during the tests of components influence are summarized on Table 1.

Table 1. Components' influence on microbial growth

	Type of Influence		
Components	**No influence**	**Microbiostatic**	**Microbiocide**
Fiberglass	x		
Epoxy resin		x	
Capacitors	x		x (30 g/L)
Syntethic metallic solution			x
Fe	x		
Ni	x		
Mn	x		
Sr	x		
Zn	x		
Pb	x		
Al	x		
Cu		x	
Ag			x
Sn			x

On the biotic control solution, the exponential growth phase occured after 1 day. The presence of fiberglass and capacitors did not influence the bacterial activity, as its samples had a similar behavior.

The presence of these componentes were suggested by other authors as inhibitors due an increase on substances diffusion time, acting as barriers, and also the possible toxicicity of those materials to the microorganism (RODRIGUES et al., 2015; LAMBERT, 2015; VALIX, 2017). Despite that, this study showed the opposite, the pulp density used did not influence *A. ferrooxidans* – LR growth (TORMA, ITZKOVITCH,1976; GARLAPATI, 2016).

As literature indicates an influence, it was tested those two components for 30 g/L pulp density. Fiberglass did not influence bacterial growth, as prior results.And so forth, it is not necessary to remove this component to proceed to a bioleaching process, in the densities tested. This pre treatment could represent a tecnical issue, since the PCB componentes are attached to a fiberglass base.

The pH stood in the optimum range (1.5-3.5), however it was possible to observe a slightly increase. This observation leads to conclude that greater pulp densities could influence on the bacterial metabolism, even inhibiting *A. ferrooxidans* – LR growth (NEMATI et al., 1998; BRANDL, BOSSHARD, WANGMANN, 2001; ILYAS et al., 2007; DIAO et al., 2014; LAMBERT, 2015).

The samples containing capacitors (30 g/L), epoxy resin and synthetic metals solution presented influence, as suggested by literature (BRANDL, BOSSHARD, WENGMANN, 2001; ILYAS et al., 2007; RODRIGUES ET AL., 2015).

3.3.2. Capacitors

As the literature reinforces capacitors influence on microbial growth, the pulp density of 30 g/L was tested. It showed microbiocide effect on *A. ferrooxidans* – LR growth, considering the solution colour and pH evolution, compared to the control samples. Authors suggest its possible toxicicity to the microorganism due Ta and polychlorinated bipheyl presence (RODRIGUES et al., 2015; LAMBERT, 2015; VALIX, 2017).

3.3.3. Epoxy resin

In the presence of epoxy resin (in a fiberglass base), the growth peak is reached 1 day after the control, with pH increase, demonstrating a growth inhibition. As suggested by literature, other factors associated to the presence of epoxy resin are the salinity and organic substances as bisphenol A, toxic to *A. ferrooxidans* – LR (BRYAN et al., 2015; DIAO et al.,2015).

Besides that, it is used to grant resistance to PCB's fiberglass base. In this base are applied brominated flame retardants, also reported as toxic to microorganisms (VALIX, 2017). And so, is possible to infer epoxy resin (15 g/L of PCB) is microbiostatic to *A. ferrooxidans* – LR.

3.3.4. Synthetic solution

Considering the presence of the synthetic metal solution, the pH and solution colour shows no microbial activity, even after 4 days. The pH increase associated to the dissolution of metals is not observed due the previous solubilization of metalic salts.

The synthetic solution was prepared considering the dissolution of all PCB metals, characterized previously, a hypotetic scenario where the bacteria have contact with the whole metallic cargo since day 1 and not gradually as would happen in a bioleaching case. This happened because the main goal was to observe if this microorganism could handle the presence of this component. And so, it was possible to imply that solubilized metals (15 g/L of PCB) are microbiocide to *A. ferrooxidans* – LR.

The solution color indicates no Fe^{2+} oxidation, inherent to this bacteria growth in this culture medium, opposite to what is observed in controls samples. This result may be a response to the presence of one metal or the set of metals. Thus, the metals were separetad

Literature emphasizes the toxicity metals can offer to micrmisorganisms, it is discussed on the specific topic (SUGIO et al., 1984; GARCIA JÚNIOR, 1989; BOSECKER, 1997; BRANDL, BOSSHARD e WANGMANN, 2001; ILYAS et al., 2007).

No influence was observed on the solution containing Fe. It is essential to *A. ferrooxidans* growth, however, its presence in great concentrations may inhibit bacterial growth. Studies show a maximum concentration of 6-9 g/L, depending on the bacterial adaptation to higher concentrations (NEMATI et al.,1998; XIANG et al., 2010; YAMANE, 2012).

This study utilized 6.94 g/L, considering the medium and the PCB concentrations, in this case indicated by the tablet's characterization performed by Motta (2018), since it was not possible to quantify this element in this research. Since it is an optimum value to the growth of this species, it's consistent to affirm it did not influence *A. ferrooxidans*-LR growth.

No influence was observed on the solution Ni. Its presence was reported to be influentional above 3 g/L, due to a fast protons and ferric ions consumption on the solution, inhibiting indirectly the bacterial growth (BRYAN et al., 2015). Other studies present a tolerance to 30-50 g/L of this metal (BOSECKER, 1997; CABRERA, GÓMES, CANTERO, 2005).

Cosidering the second stage PCB characterization, it was utilized 0.175 g/L of Ni^{2+}. As the metal was previously solubilized, and the concentration was below the reported in literature to be influentional, it was not observed a growth influence on *A. ferrooxidans*-LR activity (BOSECKER, 1997; CABRERA, GÓMEZ, CANTERO, 2005; BRYAN et al., 2015).

No influence was observed on the solution containing Mn. This metal is also reported to be influentional after a greater concentration than the used. It is known a resistance to values below 9.89 g/L, it was used 28.5 mg/L. REF?

The presence of strontioum (18 mg/L) did not present toxicity to *A ferrooxidans* – LR, the amount previously reported on literature (1 g/L) does not contemplate its toxicity to *A. ferrooxidans (*JOWKAR et al., 2018).

Zinc is not influentional to *A. ferrooxidans* – LR growth, considering the tested conditions. (102 mg/L). Sugio et al. (1984) reported an *A. ferrooxidans* tolerance of 0.33 g/L of zinc. Other values are reported in leterature, ranging from 9.8 to 30 g/L of metal concetration (GARCIA JÚNIOR, 1989; CABRERA, GÓMEZ, CANTERO, 2005; YANG et al., 2014).

Lead is also not influentional to A. ferrooxidans – LR on the tested conditions (39 mg/L). In literature, its presence is supported by bacterium until 2.07 g/L (SUGIO et al., 1984)

Aluminum (10.4 mg/L) is tolerated by the bacterium, considering the tested conditions. Literature did not report Al influence o bacterial growth in concentrations higher than 0.95 g/L (YANG et al., 2014).

3.3.5. Cu

Bacterial growth was observed after with 1 day of delay, in comparison to the control samples, representing a microbiostatic effect on *A. ferrooxidans* – LR growth, considering the tested conditions (2.86 g/L). After subculturing, bacterial growth retook its normal rates, comparing to control samples.

Literature reports a possible adaptation of bacterial cells to higher copper concentrations (9.53 -13 g/L) (TUOVINEN, NIMELA, GYLLENBERG, 1971; DAS, MODAK, NATARAJAN, 1997; CABRERA, GÓMEZ, CANTERO, 2005; MYLYTCZUK et al., 2011).

This is an essential metal to *A. ferrooxidans* growth, as a rusticianine component, a protein part of respiratory chain (LILOVA et al. 2007; MADIGAN et al, 2016).

3.3.6. Ag

Silver (19.5 mg/L) presented a microbiocide effect to bacterial population. Literature shows toxicity in concentrations above 0.10 mg/L (HOFFMAN, HENDRIX, 1976; SUGIO, et al., 1984; DE et al., 1997).

Ions are acumulated on celular walls and bacterial membrane, which can promove celular lyses (TUOVINEN et al., 1985).

Silver is applied as weld and electrical conductive stickers, also as a thin layer overlapped to copper layers, in order to avoid its oxidation (MARQUES; CABRERA; MALFATTI, 2013).

This precious metal is not usually bioleached, gathered on the solid fraction and posteriorly recovered in other process, such as HNO_3 (8 mol/L) chemical leaching (VOGEL, 1981; YAMANE, 2012). Thus, silver toxicity to *A. ferrooxidans*-LR is not a barrier to PCB recycling through bioleaching process.

3.3.7. Sn

Tin, as silver, is microbiocide to A. ferrooxidans – LR, in the tested conditions (0.67 g/L). Literature reports toxicity in a 1 g/L solution, but no influence in 0.01 g/L solutions (DE, OLIVER, PESIC, 1997; BRYAN et al., 2015).

Considering its low fusion temperature, easy welding and mechanical capacities, it is used in welds and metallic connections, whitch fix componentes to the PCB base. Tin can be used in metallic alloys with copper, silver and lead. However Pb has been avoided due its toxicity (JHA et al., 2012; HOCHENG, CHAKANKAR, JADHAV, 2017).

This metal is concentrated on the PCB surface (welds and bonding) and can be partially bioleached (20%-59.5%). Thus, an alternative to avoid contact with the bacterium is the components and welds separation, as a pretreatment (YAMANE, 2012; BLAZEK, et al., 2018).

This separation can be performed by immersion in solvents, avoiding toxic gases emission from pyrometallurgical techniques. Hydrochloric acid is pointed as ideal, in comparation to surfuric and nitric acids (VOGEL, 1981; JHA et al., 2012).

Tin can combine to oxigen molecules and precipitate as SnO, a white precipitate which may increase particles and bacterium collision, interfering on the bioleahing process (BRANDL, BOSHARD, WEGMANN, 2001; BRYAN et al., 2015).

3.3.8 Other discussions

It is importante to considerate metals combination toxicity to bacterium, which can be cumulative (DAS, MODAK, NATARAJAN, 1997). *A. ferrooxidans* has a mechanism to expel toxic metalic ions from cell, causing a longer lag phase and a consequente delay on bacterial growth, justifing the observed on Cu presence (TAKAMATSU, 1995; MYLYTCZUK et al., 2011).

Different response mechanisms are utilized by bacteria to adapt to unusal media, reducing negative effects related to toxic metals on solution. However, those mechanisms are nos completely elucidated yet (POURHOSSEIN; MOUSAVI, 2018).

The stress caused by toxic metals presence increases citoplasmic membrane permeability, as the cytoplasm fluidity, in order to adapt to metals concetration on media. In cases of great distubances, bacteria can loose the capacity to expel toxic ions, reducing survival feasibility of bacterial population (MYLYTCZUK et al., 2011).

To permit WEEE bioleaching, bacterial adaptation is applied, allowing greater pulp densities use. Literature shows bacterial adaptation to different metals (ILYAS et al., 2007; YAMANE, 2012; YANG et al., 2014; ARSHADI, MOUSAVI, 2014; POURHOSSEIN, MOUSAVI, 2018).

As the main mechanism acting in bioleaching process is the indirect one, a two step bioleaching would avoid bacteria and metals contact (Nie et al. (2014).

On the first step the bacterial growth occurs, generating Fe^{3+} from Fe^{2+} inputs. On the second stage, the leaching agent (Fe^{3+}) promotes metals solubilization from WEEE (BRANDL, BOSSHARD, WEGMANN, 2001; HOCHENG, CHANG, JADHAV, 2012; BRYAN et al., 2015).

It is recomended the study of other WEEE components influence on *A. ferrooxidans* growth, as resistors and other nonidentified metals. Besides that, the understanding of microbiocides and microbiostatic componentes action on *A. ferrooxidans* metabolism is of great importance.

Another topic is the study of alternative materials to substitute silver and tin on PCB, allowing bioleaching on industrial scale to recover metals from WEEE.

4. CONCLUSIONS

Printed circuit boards have similar composition to other electric and electronic equipments, being 33% ceramic, 32% polymeric and 35% metallic. Its metallic fraction is composed of Cu, Ni, Sn, Pb, Zn, Ag, Mn and Sr, among other nonidentified metals.

Copper bioleaching from tablets' PCB is technically viable, and *A. ferrooxidans* adaptation to the WEEE is indispensable to the process success. PCB showed variable metallic composition, and besides the previous bacterial adaptation to 30 g/L PCB, when in contact to another WEEE it did not allowed bacterial growth.

Fiberglass and capacitors (15 g/L) did not present influence on *A. ferrooxidans* – LR growth, and so are not barriers to bioleaching process. When in greater concentration (30 g/L), capacitors presented a microbiocide effect to bacterial growth. This material removement is essential to bioleaching process in industrial scale, considering greater pulp densities.

Epoxy resin presented microbiostatic effect, as copper in concentrations above 285.91 mg/L. Silver (1.89 mg/L) and tin (67.03 mg/L) presented microbiocide effect on *A. ferrooxidans* - LR growth.

Therefore, it is possible to conclude that studies on alternatives to the usage of epoxy resin, silver, tin and copper in WEEE, or on process to avoid contact of these components and the bacterium are essential to enhance the bioleaching process.

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