CO-DISPOSITION OF SLUDGE GENERATED DURING LEACHATE LANDFILL TREATMENT WITH HOUSEHOLD SOLID WASTE

M.L.ELIAS*, L.S.M.S.LIMA*, V. R. AMORIM**, M. A. G. HINOJOSA**, A.L.F.M. CONDE**, B. R. QUINTAES** AND J. C. CAMPOS*[1]

**UFRJ, Federal University of Rio de Janeiro, Technology Center, School of Chemistry149 Av. Athos da Silveira Ramos, E206, 21941-909, Rio de Janeiro, Brazil.*
***COMLURB, Municipal Company of Urban Cleaning. 647 Rua Américo de Souza Braga, 22783-385, Rio de Janeiro, Brazil.*

SUMMARY: The final environmental disposal of household solid waste is one of the determinations of the National Solid Waste Policy in Brazil, established by Law 12.305/ 2010. Despite this, the organic fraction of household solid waste is still deposited in landfills, generating heavily contaminated leachate. There are several wastewater treatment techniques applied to the leachate, and many of them, such as coagulation/flocculation and evaporation, generate solid waste. The objective of this work is to evaluate the impact of co-disposition of solid waste from leachate treatment plant with household solid waste (HSW). The solid wastes from leachate treatment that were evaluated in present work were generated in a forced evaporation treatment system (ESW) and a lime treatment step (LSW). These processes are part of the leachate treatment station of the Seropedica landfill, Rio de Janeiro State, Brazil. Nine cells simulating landfill were set up to evaluate the impact of sludge co-disposition with HSW. After 225 days of monitoring, the results showed the cells were in acid phase of waste degradation and for all parameters except COD and TOC, the cells showed similar behavior with the control cells. The higher content of organic matter may have influenced waste degradation inside the cell with evaporator sludge.

Keywords: evaporation, coagulation/flocculation, sludge, codisposition

1. INTRODUCTION

Landfill is the most widely used technology worldwide, although it is not considered the most appropriate solution in some countries disposal in sanitary landfills is still practically the only technique applied to deal with MSW [1]. One of the great consequences of this type of final waste disposal is the generation of the leachate, the name given to the liquid effluent derived from the decomposition of the organic matter of the residual mass, with a series of natural compounds, dissolved and suspended [2]. In order to solve this issue, over the years, effluent treatment technologies have been developed in order to minimize environmental damage. The technologies used for the landfill leachate treatment can be (i) biological processes (ii) chemical and physical processes [3]. However, to meet stringent quality standards for the direct discharge of leachate into surface water, it is necessary to develop integrated treatment methods, i.e., a combination of chemical, physical and biological steps [3].

Biological processes can be omitted from treatment system. Renou et al. [4] used lime as a coagulant agent to precipitate with lime as a pre-treatment of leachate to improve the efficiency of the treatment by reverse osmosis. The treatment with lime is traditionally used to temporarily eliminate the hardness of water by decarbonation, but several studies have been done to focus on the removal of organic molecules with high molecular weight molecular weight as humic and fulvic substances [2].

The leachate treatment and landfill gas recovery should be managed integrally in order to minimize risk posed by waste disposal [5]. Evaporation, using energetic power from landfill gas, can be used to separate humic suspensions from leachate, concentrate leachate into a small volume at or close to crystallization point, thus to reduce its contained toxicity and non-biodegradability [6].

The Seropedica landfill, which is located in the city of Rio de Janeiro, began operations in April 2011 in a land with more than 2 million square meters and the Leachate Landfill Treatment plant has the capacity to treat 1000 m^3 of leachate per day [7]. The collected leachate receives pre-treatment with lime, which 800 m^3 of leachate per day, before going to the ammonia entrainment unit with air [7]. Leachate from the equalization pond is pumped into

[1] Address for correspondence: Juacyara C. Campos, School of Chemistry, Federal University of Rio de Janeiro, UFRJ, Rio de Janeiro, Brazil; Phone and Fax: +55 21 3938-7640. e-mail: juacyara@eq.ufrj.br

the CO_2 withdrawal tank to reduce acidity. The lime slurry is then added. The insoluble compounds precipitate in alkaline medium and sediment forming the sludge at the bottom of the reactor. Then, the sludge is withdrawn through pumps and directed to geobag where the sludge will dry and will be returned to the landfill. After the treatment with lime, the leachate goes to the biological treatment (anoxic tank) and on leaving the biological treatment goes to nanofiltration. The sludge generated with the precipitation with lime is recirculated to the landfill

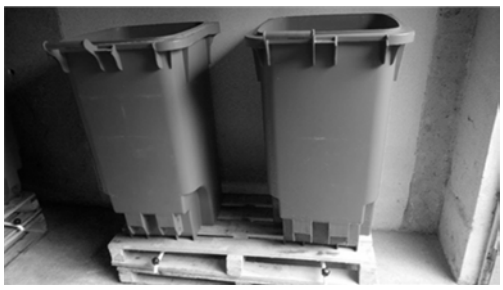
The leachate is also treated by the process of forced evaporation inside the landfill where methane gas and solar energy are used as the energy source. The sludge from lime treatment and the leachate concentrate from evaporation are recirculated to the landfill.

There are few data on the consequences of recirculation of sludge and concentrates in the landfill in the literature. Bilgili et al. [8] that evaluated the recirculation of the reverse osmosis concentrate asserts that the recycle of the concentrate presents advantages such as distribution of nutrients and enzymes, dilution of the compounds that inhibit the microorganisms that degrade the solid waste. In addition, landfill stabilization time can be reduced [9]. On the other hand, maintaining concentrate recirculation may lead to inhibition of the methanogenic degradation phase due to the high concentration of organic acids that are toxic to methanogenic microorganisms [10]. According to Ledakowicz et al. [10], the recycling of the concentrate can alter the quality of the leachate produced, increasing the concentration of inorganic and organic compounds.

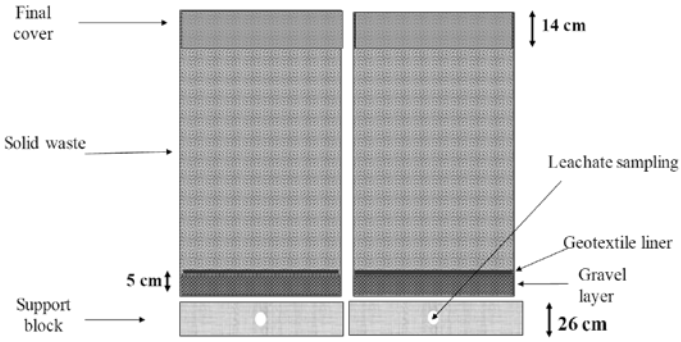
The objective of this study was to evaluate the polluting impact in the leachate generated from the solid household waste co-disposition with waste from the leachate treatment process, lime treatment and evaporation.

2. MATERIALS AND METHODS

The experimental work was carried out in a controlled system using as 9 cells which are high density polyethylene containers of 50 kg waste capacity (dimensions of 57.5 cm x 51.5 cm x 100 cm), as show in Fig. 1a. The experimental cells were designed as Fig. 1 b. In order to simulate a real landfill, precipitation was simulated using watering can according to the precipitation conditions of the Seropedica. The artificial precipitation was based on the rainfall data of the climatological station of the National Institute of Meteorology, INMET, Seropedica Station (A601) during the second half of 2016. This period was chosen due to the experiment occurring in the second half of 2017 (May to November). Therefore, a daily precipitation of 1.91 mm was applied to the cells. Figure 1 c shows the drainage of leachate.



(a)



(b)

(c)

Figure 1. Experimental cells. (a) photo of the cells; (b) schematic project of experimental cells; (c) leachate drainage

Three types of cells were evaluated, performing each model in triplicate: the control cell (only solid household waste – SHW; cells C); SHW plus evaporator sludge (cells E) and SHW plus lime treatment sludge (cells L). The proportion of sludge used in each cell was according to the proportion of sludge generation per volume of leachate in the landfill. In turn, the volume of leachate produced in the landfill was associated with the mass of waste deposited. Thus, the following ratios, 4.80×10^{-6} kg evaporator sludge per kg of deposited waste and 0.005 kg lime treatment sludge per kg of deposited waste, were calculated and reproduced in the cells [11]. Leachate monitoring was performed by measuring the physical-chemical parameters pH, COD (Chemical Oxygen Demand), TOC (Total Organic Carbon), alkalinity, turbidity, conductivity, absorbance at 254 nm, ammonia nitrogen and chloride [12].

The HSW used in the experiment were collected in the Recreio dos Bandeirantes neighborhood, in the city of Rio de Janeiro. Samples from the COMLURB (Municipal Company of Urban Cleaning) truck were used and the HSW were characterized to be arranged in the experimental cells. For avoiding vector proliferation and reducing odors, a 14 cm layer of clay was placed above the SHW layer and compacted with a cylindrical specimen measuring 10 cm in diameter and 19.5 cm tall. The sludge from evaporator (Fig. 2a) was collected in the equipment installed in the Seropedica Landfill. The lime treatment sludge was collected in geobags arranged in the Seropedica Landfill, next to the Leachate Treatment Station, used to store the deposits resulting from the primary treatment with lime.

The HSW gravimetric evaluation was performed on the following eleven components: Paper; Cardboard; Plastic (polyethylene, polypropylene, polystyrene); Glass (colorless/colored); Metal (ferrous/non-ferrous); Textile; Putrescible Organic Matter; Wood; Electro-electronic materials; Inert materials and Others. Total nitrogen, total carbon, total fixed solids and total organic matter were evaluated in both of sludges based on methodology of Kiehl [13] and adapted by COMLURB (Municipal Company of Urban Cleaning of Rio de Janeiro City) [11].

(a) (b)

Figure 2. (a) sludge from evaporator and (b) sludge from lime treatment in a geobag

In order to analyze the impact of the sludges on leachate quality, Mann-Whitney (non-parametric) test was used, adopting 95% of confidence interval.

3. RESULTS AND DISCUSSION

Figure 3 shows the physical composition of household solid waste that was used to compose the cells. The putrescible organic matter represented the highest percentage in the composition (50%), which presents in the composition remains of fruits, vegetables and foods. Plastic (22%) was the second largest composition; the third largest composition was paper (11%). These results are in agreement with the HSW generated in Rio de Janeiro city in 2016: 53.2% of putrescible organic matter; 14.8% of paper/cardboard and 20.2% of plastic [11].

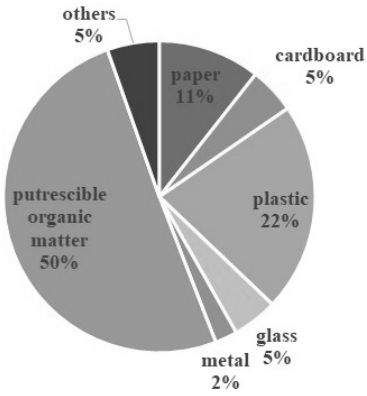


Figure 3. Gravimetric composition of HSW used in the experimental cells.

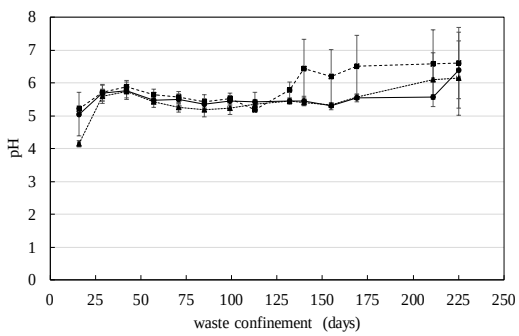
Table 1 presents the characteristics of the sludges used in the experiments. The sludges presented high inorganic composition, being the primary reject with the largest composition. Although in the evaporation process the loss of the volatile organic compounds, contributing to the decay of the organic matter, this reject still presented higher content of organic matter than the reject of the primary treatment. It should be noted that the total carbon content of the primary waste is higher due to the $CaCO_3$ formed during the treatment with lime, since the leachate has a high content of carbonates and bicarbonates (high alkalinity).

Table 1. Results of sludges composition

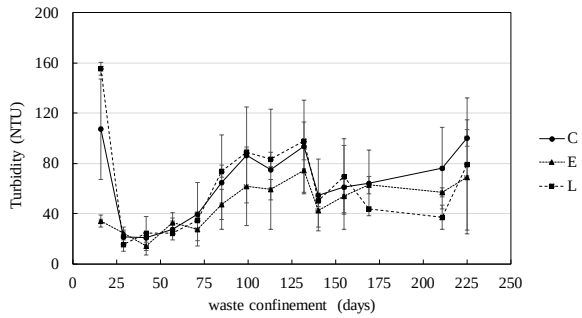
Parameter	Lime treatment sludge ("L")	Evaporator sludge ("E")
Total nitrogen (%)	0.70	0.88
Total organic matter (%)	12.41	35.80
Total carbon (%)	19.90	6.89
Total fixed solids (%)	87.59	64.19

The sludges presented high inorganic composition. Although in the evaporation process the loss of the volatile organic compounds, contributing to the decay of the organic matter, this sludge still presented greater content of organic matter than the one from lime treatment. It should be noted that the total carbon content of the lime treatment sludge is greater than evaporation sludge due to the $CaCO_3$ formed during the treatment with lime, since the leachate has a high content of carbonates and bicarbonates, i.e., high alkalinity [14].

Figures 4 (a-i) shows the results of monitoring leachate characteristics over time of waste confinement. The triplicate data of the cells were non-parametric using the Ryan-Joiner normality test. Although the results showed, at times, values with high dispersion, the Shapiro-Wilk normality comparison test showed that the results from all 3 cells of each type were similar to each other (using confidence limit of 95%).



(a)



(b)

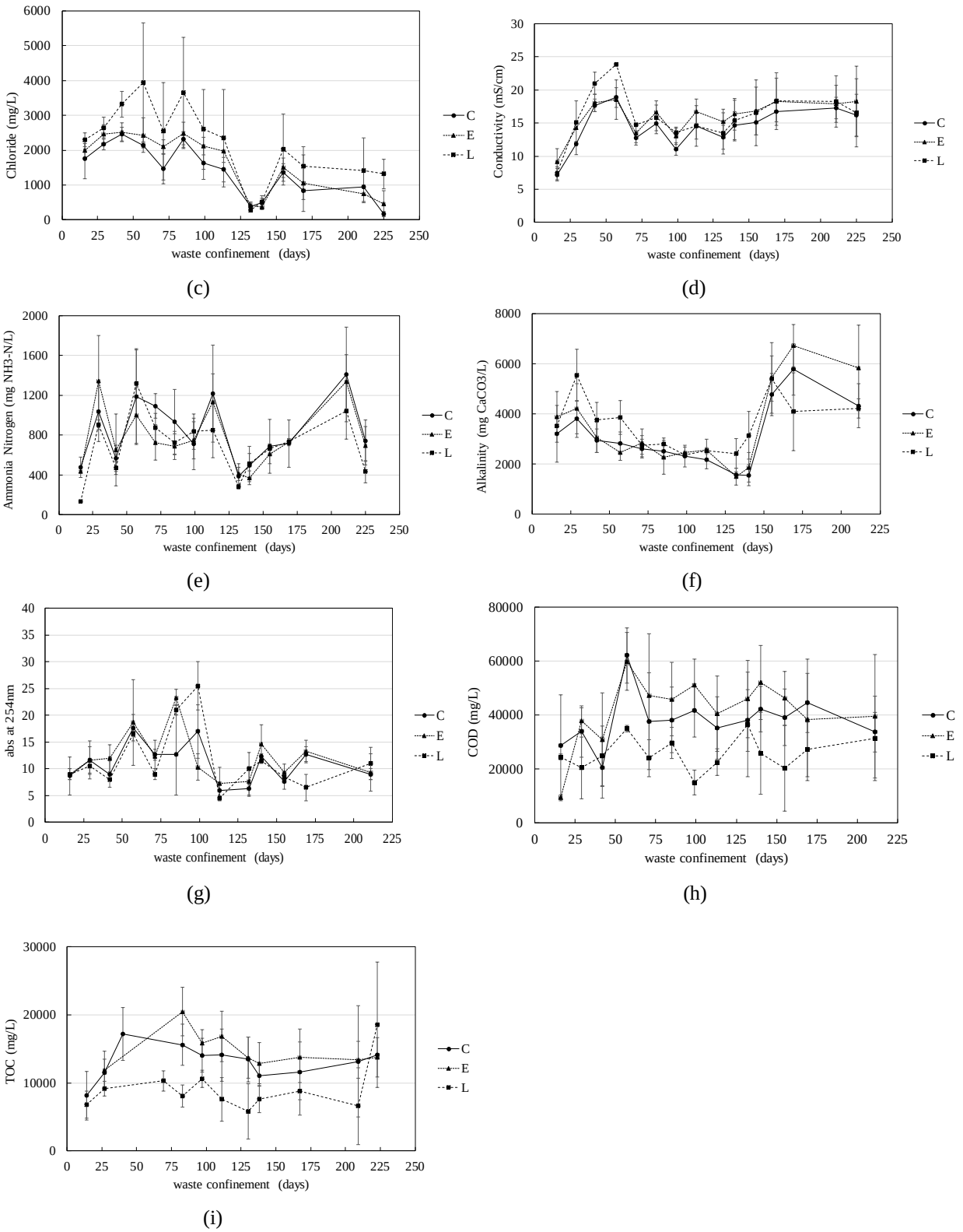
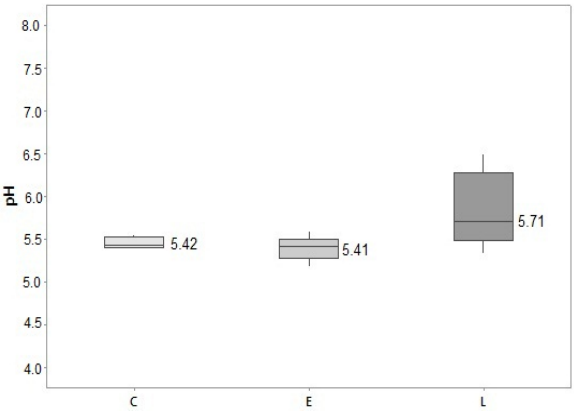
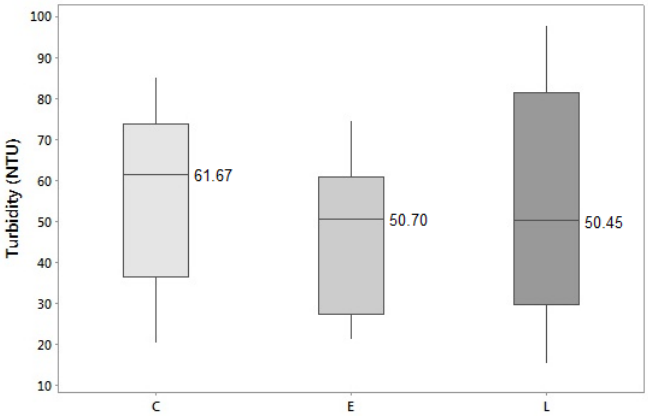


Figure 4. Results of monitoring of physical-chemical parameters: (a) pH; (b) turbidity; (c) chloride; (d) conductivity; (e) ammonia nitrogen; (f) alkalinity; (g) absorbance at 254 nm; (h) COD and (i) TOC

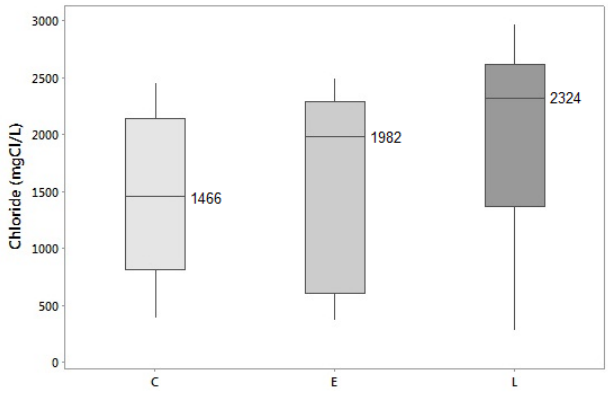
The data showed the parameters varied according to the acidic phase of waste degradation [15]. For a better understanding of the results, Figure 5 (a-i) presents the values in box plot graph, showing the medians of each parameter.


pH
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
5.42
5.41
5.71
C
E
L

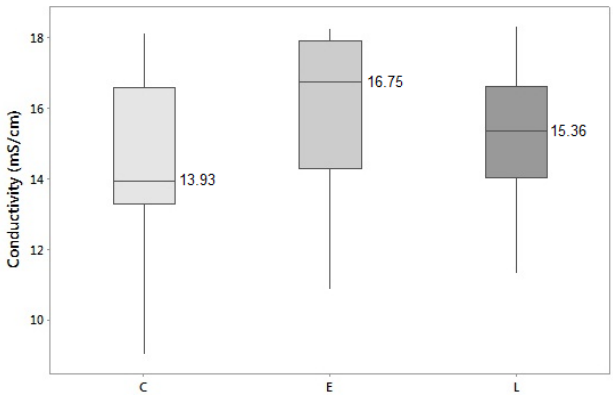
(a)


Turbidity (NTU)
100
90
80
70
60
50
40
30
20
10
61.67
50.70
50.45
C
E
L

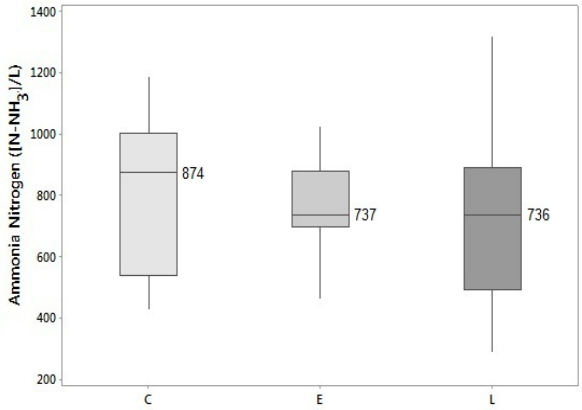
(b)


Chloride (mgCl/L)
3000
2500
2000
1500
1000
500
0
1466
1982
2324
C
E
L

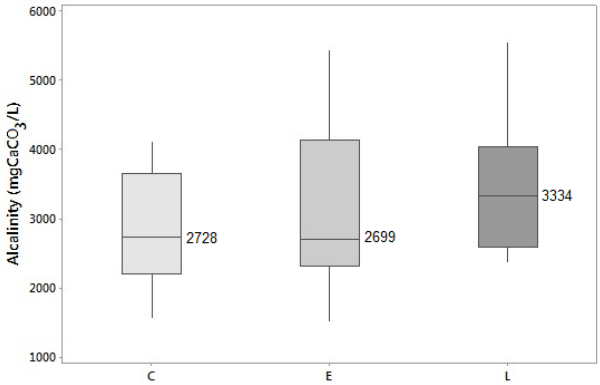
(c)


Conductivity (mS/cm)
18
16
14
12
10
13.93
16.75
15.36
C
E
L

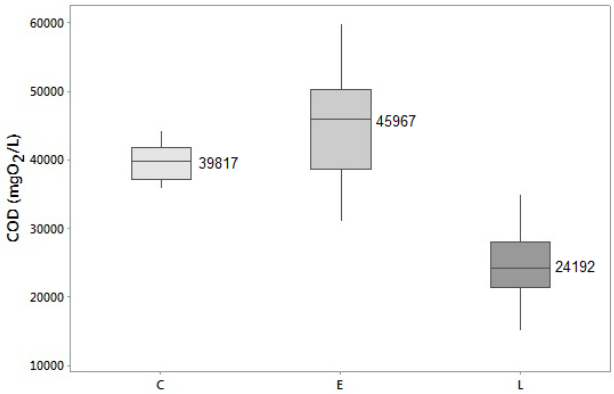
(d)


Ammonia Nitrogen ([N-NH3]/L)
1400
1200
1000
800
600
400
200
874
737
736
C
E
L

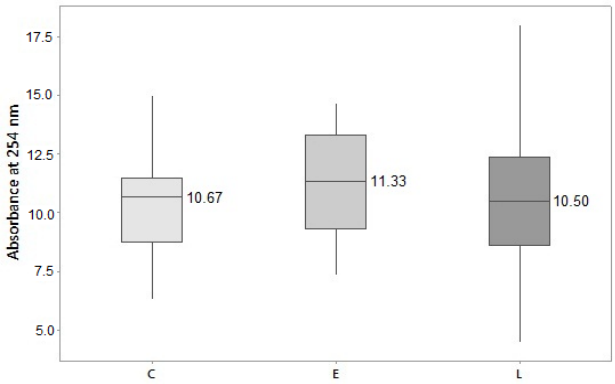
(e)


Alcalinity (mgCaCO3/L)
6000
5000
4000
3000
2000
1000
2728
2699
3334
C
E
L

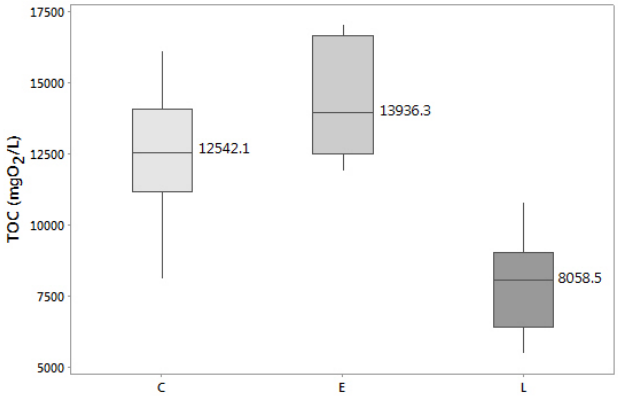
(f)


COD (mgO2/L)
60000
50000
40000
30000
20000
10000
39817
45967
24192
C
E
L

(g)


Absorbance at 254 nm
17.5
15.0
12.5
10.0
7.5
5.0
10.67
11.33
10.50
C
E
L

(h)



(i)

Figure 5. Results physical-chemical parameter box-plot graphs: (a) pH; (b) turbidity; (c) chloride; (d) conductivity; (e) ammonia nitrogen; (f) alkalinity; (g) absorbance at 254 nm; (h) COD and (i) TOC

Mann-Whitney test was performed for comparing the results the cells with codisposition with the control cell. The values of p obtained did not present significance (p greater than 0.5) for most parameters when comparing the cells, except for TOC and COD. The leachate from cell with lime treatment sludge presented values lower than leachate from control cells. Unlike this, the leachate from cell with evaporator sludge presented values greater than leachate from control cells. The evaporator sludge contained high organic content and this fact could influenced in the results in waste acid phase degradation.

4. CONCLUSION

In general, all the cells presented values that are within the expected and correspond to the data reported for the acid phase of degradation. For all parameters except COD and TOC, the cells showed similar behavior with the control cells. The higher content of organic matter may have influenced waste degradation inside the cell with evaporator sludge.

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