Landfill leachate treatment by chemical precipitation, carbonation, and phytoremediation fine-tuning

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The deposition of solid waste, domestic or industrial, in sanitary landfills has, as one of the main problems, the formation of a brownish liquid, called leachate. The high organic and inorganic loads of this leachate pose a huge challenge in the search for efficient solutions for its treatment. The main objective of this work was to study the efficacy of an integrated solution of several treatment technologies - chemical precipitation (CP), carbonation (CB) and phytoremediation (Phyt) – to treat a sanitary landfill leachate.

The leachate samples, after being characterized (Table 1), according to standard procedures (Eaton *et al*, 2005), were submitted to CP, with addition of calcium oxide. The influence of the precipitating agent concentration and stirring time and speed on the sludge sedimentability and organic and inorganic loads removal was studied. It was found that, for the leachate under study, the best results were obtained by adding 160 mL of a CaO 200 g/L aqueous solution to 1 L of leachate, being the stirring speed and time 300 rpm and 40 min, respectively. The characterization of the treated sample, under the referred experimental conditions, is presented in Table 1. It can be observed that the addition of calcium oxide lead to an increase in pH and conductivity and a decrease in the redox potential. Removals of 65 and 67% were also observed for COD and Abs (410 nm), respectively. However, the biodegradability index was drastically reduced, being the CBO_5 of the treated leachate almost zero. The sludge collected after sedimentation was also analysed (Table 2).

Table 1. Characterization of the raw leachate and the samples collected after the different treatments.

Parameter	Raw leachate	After CP	After CP+CB
pH	8.13±0.03	12.5±0.02	11.53±0.09
Conductivity (mS/cm)	19.7±0.3	23.1±0.2	15.0±0.3
Redox Potential (mV)	19±4	-188±19	16±9
Abs_254 nm	>3	0.413±0.06	0.16±0.01
Abs_410 nm	1.111±0.002	0.372±0.009	0.141±0.002
COD (g O_2/L)	1.33±0.07	0.46±0.01	0.474±0.04
BOD_5 (g O_2/L)	1.0±0.4	<0.002	0.15±0.03
Phosphorous (mg P/L)	15±5	<0.1	<0.1
Total hardness (g $CaCO_3$/L)	0.9±0.2	0.53±0.05	<0.0001
Hardness Ca (g $CaCO_3$/L)	0.69±0.01	049±0.05	<0.0001
Hardness Mg (g $CaCO_3$/L)	0.2±0.1	0.03±0.01	<0.0001
Alkalinity metil orange (g $CaCO_3$/L)	8.4±0.8	7.53±0.07	4.48±0.07
Alkalinity phenolphthal. (g $CaCO_3$/L)	<0.0001	6.6±0.3	2.35±0.05
Fluoride (mg F^-/L)	<0.1	<0.1	<0.1
Chloride (g Cl^-/L)	2.617±0.002	2.44±0.06	2.986±0.006
Sulfate (mg SO_4^{2-}/L)	138±9	45±6	23±7
Nitrite (mg NO_2^-/L)	<5	<1	<1
Nitrate (mg NO_3^-/L)	<10	<1	<1
Ammonium nitrogen (mg N-NH_4^+/L)	1060±8	889±9	<0.1
Kjeldhal nitrogen (mg N-Kj/L)	1201±9	938±6	46±3
Organic nitrogen (mg N/L)	142±7	48±5	46.0±0.4
Zinc (mg Zn/L)	0.33	0.02	0.04
Iron (mg Fe/L)	16.46	0.25	0.02
Manganese (mg Mn/L)	0.75	0.02	0.02
Chromium (mg Cr/L)	0.45	0.05	0.06
Copper (mg Cu/L)	0.14	0.04	0.05
Lead (mg Pb/L)	0.05	0.01	0.02

The sample obtained in the supernatant, after sedimentation of the CP assay, was submitted to carbonation by the atmospheric CO_2. For that, a sample volume between 3 and 4 L was left in contact with the atmosphere (surface area of 0.02 m^2), in the outside at ambient temperature, without stirring, for 32 days, to allow precipitation and sedimentation. Samples were extracted over time to follow the variation of characterization parameters, and their values at the 16th day, when ammonium nitrogen was eliminated, are presented in Table 1 (column CP+CB). pH and conductivity decreased, and hardness was drastically reduced. BOD_5 increased, leading to an increase in the biodegradability index of the treated effluent. Concentrations in COD, chloride and metals suffered a slight increase due to natural evaporation. Sludge collected after carbonation was also analysed (Table 2).

The supernatant samples collected after CP and CP+CB treatments were utilized in phytoremediation tests, in artificial wetlands, with two vertical flow beds in series, composed of *Vetiveria zizanioides* (Fig. 1). Initial samples were diluted with tap water (1:4) to reduce electrical conductivity, placed in a 100 L reservoir (R) and distributed on the surface of bed A (inlet), where it was flowing downwards. Sample was pumped back to the top of bed B, where it also flowed downwards until it left the rejection valve (outlet). Beds have 0.24 m^2 area, 0.70 m height and leca® as a filling medium. In both tests, the applied hydraulic load was similar, 90 L m^{-2} d^{-1}. The results obtained in the phytoremediation tests are presented in Table 3. The COD removal was higher in the sample first submitted to CP+CB. Data obtained for nitrites and nitrates, together with the ammoniacal nitrogen data, points to the existence of nitrification, which is the main mechanism for decreasing the ammonium nitrogen content.

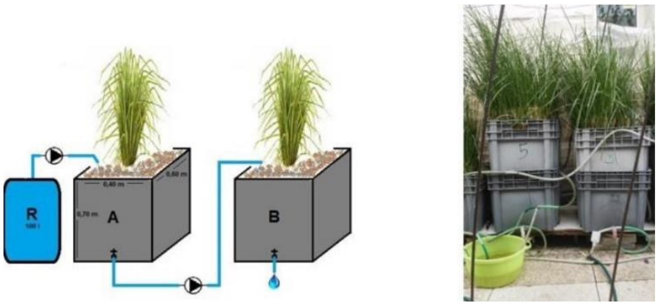

Figure 1. Scheme and pilot of the phytoremediation beds in vertical flow in series.

Table 2. Characterization of the sludges.

Parameter	CP	CP+CB
Quantity (g/L)	27.8	1.09
pH	12.4	10.0
Conductivity (mS/cm)	28.5	61.53
Dry solids (%)	97.9	96.5
Humidity (%)	2.1	3.5
Organic matter (%)	10.9	14.9
Urea (%)	0.04	0.12
Kjeldhal N (g N/kg)	1.96	1.85
Organic N (mg N/kg)	0.15	0.79

Table 3. Results of the Phytoremediation tests.

Parameter	CP+Phyt	CP+CB+Phyt
pH	4.3	6.8
Conductivity (mS/cm)	7.3	7.4
Redox Potential (mV)	290	180
Dissolved Oxygen (mg O_2/L)	4.6	4.6
COD removal (g O_2 m^{-2} d^{-1})	4.9	6.2
N-NH_4^+ removal (g m^{-2} d^{-1})	5.0	- 0.6
Kjeldhal N removal (N m^{-2} d^{-1})	6.8	0.2
Nitrite removal (g m^{-2} d^{-1})	0.25	0.19
Nitrate removal (g m^{-2} d^{-1})	-0.42	-0.09

The application of CP for the treatment of leachate, with lime as a low-cost reagent, with disinfectant properties and without harmful effects to the environment, allows the pretreatment of a highly contaminated wastewater. This same reagent is responsible for capturing atmospheric CO_2 and its transformation in carbonates, contributing to lower greenhouse gases and CO_2 mitigation. In addition, it fully recovers the utilized reagent, making it a marketable product. It generates stable sludge with very low levels of humidity, with potential recovery in the landfill itself, which would eliminate the need for transport and dehydration, also contributing to the lowering of the carbon footprint associated to its transport. It totally removes the ammonia in the leachate, with the potential to be captured and become a marketable product, preventing it from reaching the receiving waters, eliminating the environmental impact associated to ammonia. The use of a phytoremediation step in the leachate tuning is a very important step, as it allows the use of the green economy concept, since the biomass can still be reusable.

References

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