REMOVAL OF AMMONIA AND ORGANIC MATTER FROM LANDFILL LEACHATE ON CLAY POWDER AND SLUDGE FROM A WATER TREATMENT PLANT

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ABSTRACT

The Sustainable Development Goals (SDGs) address the interconnectedness of social, economic, and environmental dimensions of development. Landfill disposal of urban solid waste poses significant environmental challenges, including groundwater pollution and leachate generation rich in ammonia and nitrogen. This study evaluates the adsorptive capacity of clay and water treatment plant (WTP) sludge in removal of ammonia and organic matter in simulated laboratory sample for later use at real treating landfill leachate. The research focuses on achieving SDGs related to water, sanitation, and sustainable cities by mitigating environmental impacts. Both clay and WTP sludge show potential in adsorbing ammonia from liquid media, with notable reductions observed over time. Activated carbon was used as a standard adsorbent in order to verify the feasibility of using the other materials studied. Additionally, the study assesses the reduction of organic matter (COD) using these adsorbents in both standard solution and landfill leachate. The results indicate the potential of clay and WTP sludge as sustainable adsorbents for landfill leachate treatment, the latter having obtained up to 49.42 and 50.62% of ammonia and COD removal, respectively.

Keywords: Sustainable Development Goals 1. Landfill leachate 2. Adsorption 3. Clay 4. Water treatment plant sludge 5.

1 INTRODUCTION

The Sustainable Development Goals (SDGs) are a UN (United Nations) initiative established in 2015, consisting of 17 universal goals that recognize the interconnection between the social, economic and environmental dimensions of development. The SDGs related to drinking water, sanitation and sustainable cities stand out, with targets to be achieved by 2030, including improving water quality and reducing the negative environmental impact of cities.[1]

The environmental impact caused by urban solid waste management (USWM), especially landfill disposal, is significant, contributing to groundwater pollution and the lack of incentives for recycling. Although landfills are a low-cost alternative, they contain a variety of chemical substances, such as organic matter, ammonia, inorganic salts and heavy metals in different concentrations.[2,3] Because of that the leachate biodegradability decreases over time, making biological treatment ineffective in long-lived landfills. The polluting potential of leachate is influenced by several factors, including landfill characteristics and hydrogeological conditions in the area[3]. The percolation of rainwater that occurs in landfills can eventually penetrate local groundwater systems, making it possible for pollution plumes to spread hundreds of meters below the disposal site[2]. Thus, the polluting potential of a landfill can be minimized through the collection and treatment of leachate, as well as the proper operation of the landfill[4].

For mitigation of the environmental impact, leachate treatment techniques have been proposed. Among them, adsorption has receiving attention due to its efficiency and sustainability. Adsorbent materials, such as biomasses and clays, have been studied for their ability to remove chemical components in aqueous solutions.[4,5] Residual sludge from water treatment plants (WTPs) is also an effective adsorbent for the treatment of various wastewaters. Ceramic membranes made from WTP residual sludge completely removed turbidity and reduced significantly the chemical oxygen demand (COD) and color from industrial textile effluents.[6] The flocculation/coagulation method is frequently used to treat drinking water. Nevertheless, over ten thousand tons of residual sludge is daily produced worldwide[7]. Waste management perspectives indicate that the valuation of residual sludge contributes for a sustainable development[6]. In addition, clays are also effective in removing pollutants through adsorption, have low solubility in water, ease in cation exchange and high stability when exposed to oxidizing and reducing conditions.[8]

Therefore, this study aims to evaluate the adsorptive capacity of clay and WTP sludge in the treatment of landfill leachate, contributing to a more sustainable management of urban solid waste.

2 MATERIAL & METHODS

The reagents ammonium chloride (NH_4Cl) and sucrose were of analytical grade. The clay (past form) and the activated carbon were purchased in the city of Uberaba/MG. The WTP sludge was donated by a sanitation company from the region of Triângulo Mineiro/Minas Gerais/Brazil. The landfill leachate was collected from the company Soma Ambiental (Uberaba/MG). The adsorbent materials were prepared beforehand to obtain the powder for each one.

Both WTP sludge and the clay were dried until the mass remains constant at oven (100 ºC). Then, both materials and the activated carbon grains were ground and sieved, resulting in fine particles. In the sequence, only the clay powder was heated at 400 ºC in a muffle furnace for 2 hours to remove any internal residual moisture.

The adsorption tests were carried out using both the standard solution and the landfill leachate at 25 ± 2º C, with triplicate sampling. Initially, 0.25g of each adsorbent was placed in a beaker containing 50 mL of standard solution or landfill leachate at pH 6,5. The initial concentrations of COD (267.00 and 434.20 mg/L) and ammonia (509.44 and 1567.64 mg/L) were determined for the standard solution and the leachate landfill, respectively. From then on, stirring began in 40 rpm for a total of 60 minutes. During this time interval, in addition to the final sample, an aliquot was also taken in 30 minutes to verify whether a shorter time would be sufficient for the complete adsorption process of the desired components. In the sequence, the solution in each beaker was filtered to remove the biomass, leaving only the supernatant. This supernatant was then taken for analysis. The ammonia content in the samples was quantified using the Nessler method [9], with the preparation of a calibration curve and spectrophotometric analysis. Based on the remaining concentration of this compound in the liquid fraction, the percentage of ammonia removal was calculated using equation (1). In addition, COD analysis followed the method described in Standard Methods for the Examination of Water and Wastewater.[10]

$$\text{Ammonia removal } (\%) = \frac{\textit{Standard solution concentration}\left(\mathrm{mg}\frac{\mathrm{N}}{\mathrm{L}}\right) - \textit{Treated solution concentration } \left(\mathrm{mg}\frac{\mathrm{N}}{\mathrm{L}}\right)}{\textit{Standard solution concentration}\left(\mathrm{mg}\frac{\mathrm{N}}{\mathrm{L}}\right)} \cdot 100 \qquad (1)$$

3 RESULTS & DISCUSSION

The standard solution of ammonium chloride and the landfill leachate prepared to the adsorption tests with water treatment plant sludge, clay and activated carbon powder were carried out by 60 minutes. Aliquots of the liquid fraction in 30 and 60 minutes were removed and sent for analysis of ammonia removal and the values obtained can be seen in Table 1.

Table 1 Ammonia removal (%) after 30 and 60 minutes in the standard solution and landfill leachate.

	Time (minutes)	WTP sludge (%)	Clay (%)	Activated carbon (%)
Standard solution	30	9.87	17.45	74.45
	60	26.86	33.75	98.21
Landfill leachate	30	24.71	16.47	36.04
	60	49.42	56.63	97.81

The results indicate that both WTP sludge and clay have the capacity to adsorb ammonia in liquid media, with a reduction in the ion over the agitation time. In addition, activated carbon showed significant removal of ammonia, around 98%, from the solution, which confirms its known adsorption capacity.

In landfill leachate, both the WTP sludge and the clay showed good adsorption capacity for ammonia. These adsorbents improved their adsorption capacity in the final process time (60 minutes), having an increase of approximately 84 and 68% for WTP sludge and clay, respectively. For activated carbon, an insignificant variation of 0.4% was noticed. A very different situation was found in samples taken within 30 minutes. Only the WTP sludge increased by approximately 60% between the standard solution and landfill leachate. The other materials, clay and activated carbon, had losses of approximately 6 and 106%, respectively. This fact may be related to the presence of more components in landfill leachate, which ends up interfering with the adsorption of the compound of interest.

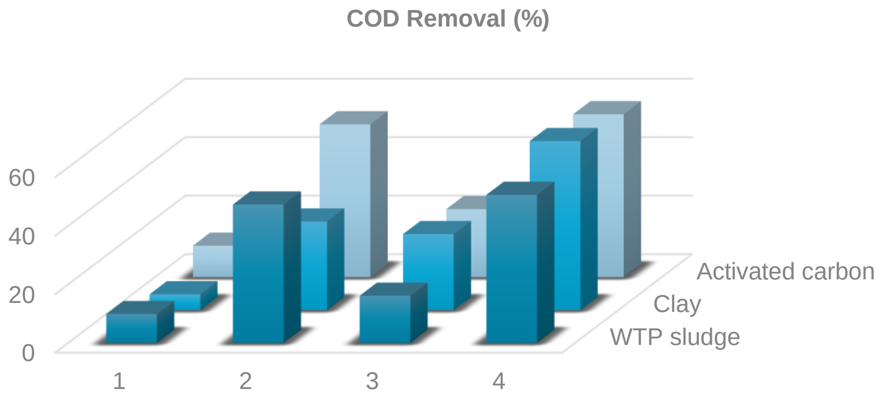

Figure 1 COD reduction tests. 1) 30 minutes and standard solution. 2) 30 minutes and landfill leachate. 3) 60 minutes and standard solution. 4) 60 minutes and landfill leachate.

A sugar solution with a concentration of 1000 mg/L was prepared to be used as a standard solution for the COD reduction analysis through the adsorptive process. After 30 and 60 minutes of agitation between the solution and the adsorbent, aliquots were removed, filtered and sent for residual COD analysis, according to Figure 1.

As shown in Figure 1, it is evident that all adsorbents removed greater amounts of COD at the tests with landfill leachate (groups 2 e 4). The COD removal values at 60 minutes increased 214.21, 122.62 and 138.91% for WTP sludge, clay and activated carbon, respectively, compared with values in standard solution. In other words, in this case, WTP sludge had a more representative improvement than the other materials when moving from the standard solution to landfill leachate, making WTP sludge evident once again as a viable material for adsorption processes.

These COD removal values at 60 minutes, ranging from 50.62 to 57.77%, are in accordance with those found in similar work that used ceramic membrane and obtained removal values of 50 - 68%.

4 CONCLUSION

The results demonstrated that both clay and WTP sludge have the potential to adsorb ammonia from liquid media. Activated carbon, known for its adsorption capacity, showed remarkable efficiency in ammonia removal.

Furthermore, the study evaluated the reduction of chemical oxygen demand (COD) using the same adsorbents in standard sucrose and NH_4Cl solutions and landfill leachate. The results indicated that all adsorbents have the potential to remove organic matter, as evidenced by the reduction in COD levels.

These findings underscore the potential of clay and WTP sludge as sustainable adsorbents for treating landfill leachate, contributing to more environmentally friendly waste management practices. By aligning with the sustainable development goals (SDGs), particularly Goal 6 (Clean Water and Sanitation) and Goal 11 (Sustainable Cities and Communities), this research emphasizes the importance of innovative approaches in addressing environmental challenges and advancing towards a more sustainable future.

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