Journal of Urban and Environmental Engineering
E-ISSN: 1982-3932
celso@ct.ufpb.br
Universidade Federal da Paraíba
Brasil

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Journal of Urban and Environmental Engineering, vol. 10, núm. 2, 2016, pp. 155-161
Universidade Federal da Paraíba
Paraíba, Brasil

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Journal of Urban and Environmental Engineering, v.10, n.2, p.155-161

ISSN 1982-3932
doi: 10.4090/juee.2016.v10n2.155161

Journal of Urban and Environmental Engineering

www.journal-uee.org

# CONJUGATE TREATMENT OF LEACHATE FROM LANDFILL AND SEWAGE IN DOMESTIC STABILIZATION PONDS

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Received 22 June 2016; received in revised form 21 September 2016; accepted 21 September 2016

**Abstract:** In Brazil, the per capita generation of municipal solid waste is approximately 0.80 kg hab$^{-1}$ day$^{-1}$, which implies daily production of 156 tons, whereas on average 50% of this quantity of waste is composed mainly of putrescible organic material that will contribute to the leachate generation process directly influencing the qualitative and quantitative aspects. Landfill leachate basically originates from the percolation process of different types of water and is considered a wastewater to cause in significant environmental impact on the environment, given in possession of high concentration of ammonia nitrogen, organic matter difficult to biodegradation, metals heavy and xenobiotics. The objective of this study was to evaluate the performance of a series of stabilization ponds, the treatment process conjugate of landfill leachate fresh more domestic sewage in the proportion of 1 plus 99% (volume percent), respectively. The experimental system consisted of four stabilization ponds in series, being a facultative pond, followed by three maturation ponds. . The applied surface charge (λs) the series of stabilization ponds was 320 kg $DBO_5$ ha$^{-1}$ day$^{-1}$ with hydraulic retention time (HRT) of 17 days for the series. The average removal efficiency of $BOD_5$ and ammonia was 69 and 86% respectively, while removing coliform efficiency always in the 99.9% threshold during the monitoring period was 220 days. Overall it can be concluded that treatment conjugate landfill leachate and sewage in stabilization ponds, in northeastern Brazil, is emerging as a promising technological alternative, given the comfortable area availability in northeastern Brazil, conditions climate favorable and the ponds system present low ratio cost / benefit when compared to other waste treatment systems of this nature.

**Keywords:** Wastewater; leachate; biological treatment conjugate; waste biodegradability

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## INTRODUCTION

Landfill leachate is basically originated from infiltrated rainwater fraction in the cell of the landfill and water present in the mass grounded waste. Qualitative and quantitative characteristics of the leachate generated in the landfill depend directly on the physical and chemical composition of the waste going to landfills, the mass of the compaction of waste in landfill cells, climatic factors and certain operating parameters (Leite *et al.*, 2011).

In the percolation process of the liquid mass through the layers of waste grounded, there will solubilization of certain types of organic and inorganic compounds, arising from biodegradation. the putrescible organic fraction of municipal solid waste, as well as the drag of microorganisms and other biological materials, generating by-products such as biogas and leachate with variable composition and high pollution potential (Mannarino *et al.*, 2011). According Abbas *et al.* (2009), the amount of in a landfill leachate generated depends on the percolation of the rain water through the cells of the grounded residues of the biochemical processes occurring in the mass of putrescible organic waste, waste percentage of humidity, but also the degree compaction of waste on the site (Di Laconi *et al.*, 2011). The generation and leached the chemical composition are related to the physical characteristics of municipal solid waste were disposed in landfill and even after landfill closure, these continue to be degraded, generating leachate for several decades (Hazar *et al.*, 2009).

New landfills, under the age of five years are in the acidogenic phase and as a result presents great amount of biodegradable organic matter, which is fermented easily, resulting in the production of volatile fatty acids (Gou et al, 2010). When the landfill exceeds five, the methanogenic phase begins, degrading the volatile fraction of the fatty acids, generating methane ($CH_4$) and carbon dioxide ($CO_2$), resulting in reduced biodegradability of the organic fraction leachate (Ifeanyichukwu, 2008). Ahmed and Lan (2012) found that the landfill leachate when new, has high concentrations of biodegradable organic matter, it will provide high ratio of biochemical oxygen demand for chemical oxygen demand ($BOD_5$/COD). This reason will decay with time, resulting from the stabilization process of the biodegradable organic matter, leaving only the organic matter are difficult to degrade, which hinder the treatment of the leachate because new display characteristic (Pasqualine, 2010). Li *et al.* (2009), highlights the potential danger of the leachate produced in landfills implies the need to treat it, in order to meet the disposal requirements in water bodies, but its features make it disturbing environment as much as economically, given the costs involved in the treatment.

According to Mara (2004), stabilization ponds are large shallow basins bounded by earth embankments, which should be designed to treat raw sewage by entirely natural processes, involving algae and bacteria. It is noteworthy that the application of stabilization ponds for the treatment of sewage, in tropical countries, it is feasible due to weather conditions with high temperatures, high intensity sunlight and the availability of low cost land.

Stabilization ponds can be considered as an important technology which has the advantages of economy and efficiency in sewage treatment in small communities and can be applied in hot climates (Shanthala *et al.*, 2009). According Mozaheb *et al.* (2010), the stabilization ponds represent the most simple process, low cost and maintenance, used as alternatives for wastewater treatment in stabilization ponds, the mutual activity between algae and bacteria is important for sewage treatment. The photosynthesis by algae provides oxygen ($O_2$) to the aquatic environment, providing conditions aerobic and is used by the bacteria in the process of decomposition of organic matter (Von Sperling & Oliveira, 2010).

According to Mannarino *et al.* (2011), treatment conjugate leachate more sewage landfill, can become a viable alternative for the treatment of leachate, in order to reduce their striking effects on the environment, but must consider certain requirements for their application, as the viability of the leachate transportation to the ETE, the station's ability to assimilate it, the process is compatible with the leachate characteristics and the possibility of handling the sludge produced. Ghazy *et al.* (2008) reported that the number of series of treatment ponds used in the system is related to the applied organic loading and the desired quality of the final effluent. Yu *et al.* (2010) designed an experimental system consisting of anaerobic/anoxic/aerobic ($A_2$/O) on ETE Datansha in Guangzhou, southern China for the treatment conjugate landfill leachate and sewage. The proportions of the mixtures used were 1: 250; 1: 350; 1: 500 and 1: 700, and the authors concluded that the best ratio used was 1: 500, with an average removal efficiencies of N-$NH4^+$, COD and total nitrogen of 96.5%, 61.0% and 81,7%, respectively, with 11 hours HRT.

Among the technologies being studied to properly treat landfill leachate, the combined treatment is an alternative that has been implemented in some ETE in Brazil, whose goal is to add the landfill leachate to sewage treatment in conventional units existing ones, thus minimizing the costs of the landfill in relation to the treatment of leachate.

## MATERIAL AND METHODS

The experimental system was designed, built and monitored the physical facilities of the Experimental Biological Station of Sewage Treatment (EXTRABES), the State University of Paraiba and being geographically located in the city of Campina Grande (PB), in northeastern Brazil (7°13′11″ S, 35°52′31″ W and 550 m above sea level) and consists of 04 stabilization ponds in series, as schematic shown in **Fig. 1**.

- In point 1: Deposit pair storage substrate
- In point 2: Local Pond effluent collection 1.
- In point 3: Local Pond effluent collection 2.
- In Point 4: Local Pond effluent collection 3.
- In Item 5: Local collection of effluents series of ponds.

The ponds were built in concrete masonry, cement and iron and interconnected through rigid PVC pipes, and in the first pond was installed record for substrate flow control. **Table 1** shows the main physical parameters of the stabilization ponds used to carry out the experimental part of the work.

In this paper substrate denomination is the liquid waste fed to the series of stabilization ponds and consisted of 99% of sewage plus 1% landfill leachate (percentage by volume). The sewage used for preparation of the substrate was collected daily in a manhole constructed with permission of Water and Sewage Company of the State of Paraíba (CAGEPA) in eastern interceptor sewage system of the city of Campina Grande (PB) which crosses along the EXTRABES. The leachate used for preparation of the substrate was collected in the landfill in the metropolitan area of the city of João Pessoa (PB) and was transported in truck tank with volume capacity of 7 $m^3$ to the EXTRABES with semimonthly frequency, and then properly stored and subjected to the characterization chemistry.

The load applied on the first surface stabilization pond series was 320 kg $DBO_5$ $ha^{-1}$ $day^{-1}$, the hydraulic retention time in the series of ponds was 17 days and the monitoring period was 220 days. For the definition of the applied surface charge, it was taken into account the depth of the ponds, the region of room temperature and relative $BOD_5/COD_{total}$. The chemical characterization of domestic wastewater, leachate from the landfill, the substrate and samples of liquid waste always collected at 8 am with a weekly frequency in the series of stabilization ponds throughout the monitoring period, was conducted in line with what advocates APHA (2012).

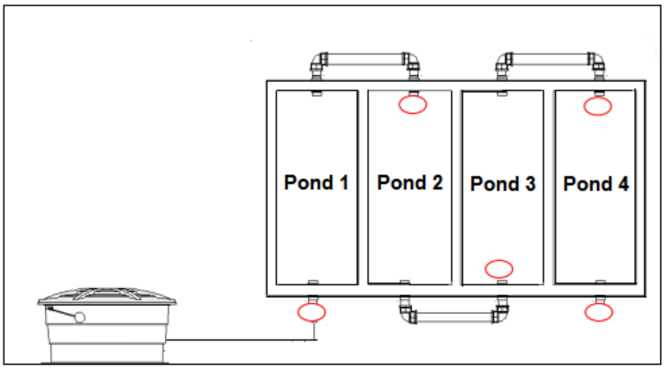


**Fig. 1** Schematic diagram of experimental system.

**Table 1.** Physical characteristics of stabilization ponds

| Ponds | C (m) | L (m) | H (m) | A ($m^2$) | V ($m^3$) |
|---|---|---|---|---|---|
| *LF | 2.05 | 1.00 | 0.56 | 2.05 | 1.14 |
| **LM1 | 2.05 | 1.00 | 0.55 | 2.05 | 1.12 |
| LM2 | 2.05 | 1.00 | 0.54 | 2.05 | 1.,10 |
| LM3 | 2.05 | 1.00 | 0.53 | 2.05 | 1.08 |

**Facultative Pond; ** Maturation pond.*
*C: lenght; L: width: H: height; A: area; V: volume.*

## RESULTS AND DISCUSSION

**Table 2** presents the data coming from the chemical characterization of the leachate *in natura* collected at the landfill Joao Pessoa City (PB) and used for substrate preparation. The leachate was collected in a leachate reception pit landfill drainage system and was originated from three different cells of the landfill, aged 2-10 years.

When analyzing the data presented in **Table 2** it can be seen that the leachate used for preparation of the substrate was low compared $BOD_5/COD_{total}$ (0.35), high concentration of total nitrogen and this concentration corresponds on average 91.3% the concentration of

**Table 2.** Data arising from the chemical characterization of the leachate *in natura*, expressed in mg $L^{-1}$, except for pH

| Parameters | X | Y | Z |
|---|---|---|---|
| pH | 7.9 | 7.8 | 8.0 |
| Total alkalinity | 9054 | 7187 | 1082 |
| Volatile Fatty Acids | 3318 | 2340 | 4284 |
| Total Solids | 21794 | 20004 | 23179 |
| Total Volatile Solids | 6261 | 5204 | 7578 |
| Total Suspended Solids | 952 | 899 | 1000 |
| Volatile Suspended Solids | 469 | 431 | 543 |
| Total COD | 19672 | 18370 | 21733 |
| COD Filtered | 11448 | 13293 | 10647 |
| $BOO_5$ | 7021 | 6328 | 7439 |
| Total Kjeldahl Nitrogen | 2383 | 1791 | 2756 |
| Ammonia nitrogen | 2177 | 1586 | 2550 |
| Total phosphorus | 11.2 | 9.1 | 12.8 |
| Orthophosphate | 6.0 | 5.1 | 6.6 |

M: average magnitude; Y: minimum magnitude: Z: maximum magnitude.

ammonia nitrogen. Therefore, taking into account only these two parameters, it is perceivable that there is difficulty or even impossibility of applying the biological treatment process for this type of waste. As favorable factors application of the biological treatment can be highlighted the magnitude of the pH and concentration of total alkalinity, comprising 74.3% of bicarbonate alkalinity.

**Table 3** presents the data coming from the chemical characterization of the substrate, which is the result of the mixture of landfill leachate (1%), more sewage (99%). In the substrate, the average concentration of total COD and $BOD_5$ was 241 and 637 $mgO_2/L$, $BOD_5$ providing respect/COD of 0.37, which demonstrates that the addition of domestic sewage at the ratio of 99% (volume percent) not contributed significantly to increase the biodegradability of the organic material present in the substrate. In the case of ammonia, in which the concentration in the sewage of the city of Campina Grande (PB), revolves around 50 mgN/L, the average concentration in the substrate was to 77mgN/L, standing still in the range recommended for application in biological processes. One of the great advantages of conjugate treatment of landfill leachate and sewage is the marked reduction of ammonia nitrogen concentration of landfill leachate, economically enabling the costs of applying any type of biological treatment, considering not be necessary for the implementation physico-chemical treatment to suit the concentration of ammonia nitrogen to the acceptable level of biological processes. Please note that with the exception of carbonaceous material, expressed in terms of $BOD_5$ and $COD_{total}$ which consists of material difficult biodegradation, the other parameters fit in the sewage classification, ranging in medium and heavy range.

**Table 3.** Data arising from chemical characterization of substrate, expressed in mg $L^{-1}$. except for pH

| Parameters | M | X | Z |
|---|---|---|---|
| pH | 7.4 | 7.1 | 7.7 |
| Total alkalinity | 418 | 369 | 479 |
| Volatile Fatty Acids | 116 | 78 | 182 |
| Total Solids | 1129 | 937 | 1746 |
| Total Volatile Solids | 553 | 384 | 766 |
| Fixed Total Solids | 662 | 600 | 781 |
| Total Suspended Solids | 194 | 140 | 271 |
| Volatile Suspended Solids | 175 | 133 | 251 |
| Fixed Suspended Solids | 43 | 32 | 84 |
| Total COD | 637 | 585 | 715 |
| COD Filtered | 223 | 214 | 232 |
| $BOO_5$ | 241 | 203 | 286 |
| Total Kjeldahl Nitrogen | 98 | 76 | 121 |
| Ammonia nitrogen | 77 | 61 | 92 |
| Total phosphorus | 7.5 | 4.2 | 9.9 |
| Orthophosphate | 4.5 | 3.2 | 5.8 |

M: average magnitude; Y: minimum magnitude; Z: maximum magnitude.

**Figure 2** shows the behavior of the temporal variation of room temperature quantified throughout the monitoring period of the series of stabilization ponds. It can be seen that there were significant variations in temperature throughout the monitoring being achieved higher ambient temperatures during the first 100 days, considering to be the hottest season of the year in what is the summer, with maximum temperature of 32°C. After 100 days of monitoring, begins to fall season and the temperature is decreased while the attenuation of oscillation, with minimum temperature 23.6ºC environment. The average ambient temperature during the entire monitoring period of the series of stabilization ponds was 27.9°C. In the liquid mass series of stabilization ponds, the average temperature was 24.9°C for the LF LM1 and LM2 and 25.1 °C for the LM3.

The behavior of the temporal variation of the concentration of dissolved oxygen in the liquid mass of the series of stabilization ponds is shown in **Fig. 3**. The presence of dissolved oxygen (DO) in significant concentrations in facultative lagoons and maturation is extremely important, considering being one of the good performance indicator parameters of the same in relation to removal of nutrients and pathogens.

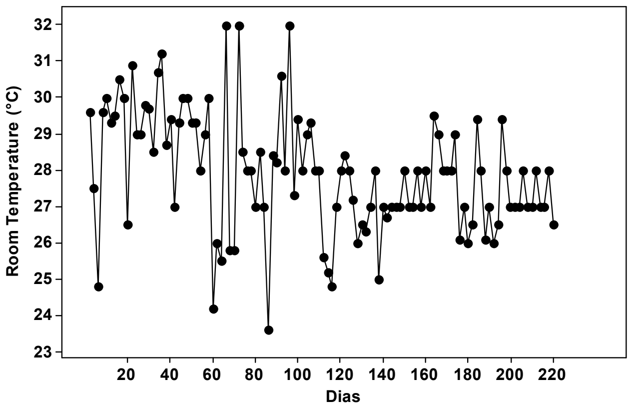


**Fig. 2** Performance of temporal variation in ambient temperature.

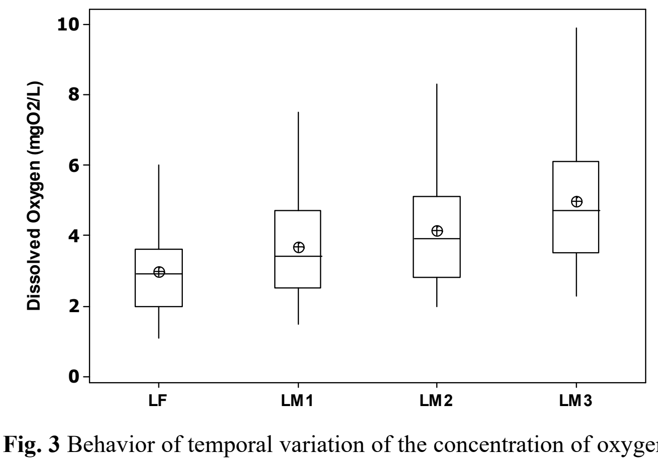


**Fig. 3** Behavior of temporal variation of the concentration of oxygen dissolved in the liquid mass of stabilization ponds.

Analyzing the behavior of **Fig. 3**, it is observed that the average concentrations of dissolved oxygen, ranged 3-5 $mgO_2.L^{-1}$ respectively in sequential order of the number of ponds. In facultative pond was quantified the lowest concentration of dissolved oxygen which can be justified by the presence of a larger quantity of organic material capable of biodegradation and also by the difficulty of penetration of solar radiation across the net mass of the pond, contributing to the reduction of algal mass generation and dissolved oxygen generation, even in the case of considered shallow lagoon. The mechanism of the interactions established between the generation of organic matter and dissolved oxygen can be represented by the equation: $CO_2 + H_2O + O_2 \rightarrow$ COD. It is observed that the mass of oxygen formed by the photosynthetic process is sufficient to oxidize the organic matter produced, but this mass of oxygen is not used for oxidation of cellular material from algae. In the process of aerobic bacterial oxidation behavior can be represented by the equation: COD + $O_2 \rightarrow CO_2 + H_2O$, denoting that the photosynthesis processes and bacterial oxidation are complementary, in view of the photosynthetic products to be used as reactants in bacterial oxidation.

Regarding the lagoons of maturation, it can be seen that there was a higher production of dissolved oxygen, which is directly associated with increased production of algae and found itself distributed throughout net mass of the lagoons which led to the most massive production of oxygen dissolved as it can be reached by the basic equation of photosynthesis.

**Figure 4** shows the behavior of the temporal variation of pH and ammonium nitrogen concentration of the influent and effluent liquid waste from the series of stabilization ponds during the monitoring period.

The magnitude of the increase in pH in the liquid mass of serial stabilization ponds during the monitoring period are associated with the activity of algae through photosynthesis consume $CO_2$ present in the liquid medium using it for growth and releasing $OH^-$ radicals, making the pH of the liquid medium increases progressively from an initial magnitude level of 7.4 to 8.9 pH units. In the case of ammonia, wherein the concentration of the substrate was 77 mg N $L^{-1}$, has been reduced along the series of ponds, coming to produce effluent with an average concentration of 11 mg N $L^{-1}$ and 86.7% removal efficiency and that this ammonia concentration is below the legal limit recommended by CONAMA 430/2011, to release water body. The ammonia nitrogen removal efficiency is associated with the desorption process, which in this lagoon system was favored by the depth of the ponds and the increase in pH of the liquid mass, compared to the significant flowering of mass algae.

**Figure 5** shows the behavior of the temporal variation of $BOD_5$ concentration of affluent liquid wastes and effluents will series of stabilization ponds monitored.

The average concentration of $BOD_5$ of the substrate fed to the first stabilization pond was 241 mg $O_2$ $L^{-1}$ and has been reduced gradually, reaching 74 mg $O_2$ $L^{-1}$ in the final effluent, providing average efficiency of 69% reduction and which falls within the legal standards for release in water body that is 120 mg $O_2$ $L^{-1}$ (CONAMA 430/2011).

In stabilization ponds, the biostabilization process of organic matter is a function of the applied surface charge and the relationship established between $BOD_5/COD_{total}$. In the specific case of this work, wherein the $BOD_5$/substrate ratio was $COD_{total}$ the level of 0.37 and that can be considered low, 69% $BOD_5$ reduction efficiency is quite significant, considering percentage of this magnitude have been achieved for stabilization ponds with this setting, treating domestic wastewater.

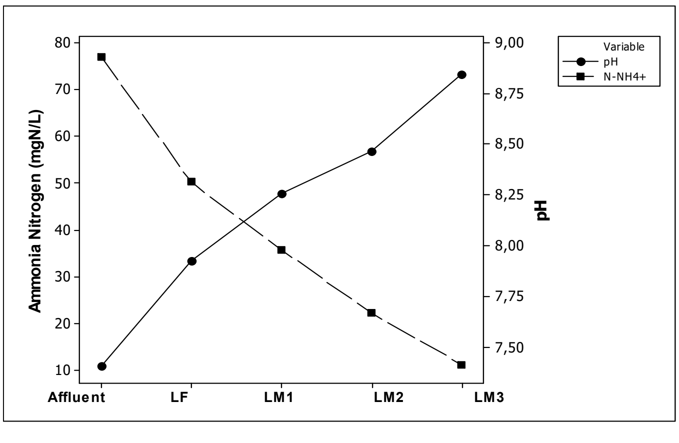


**Fig. 4** Behavior of temporal variation of pH and ammonia nitrogen concentration in the liquid mass of the series of stabilization ponds.

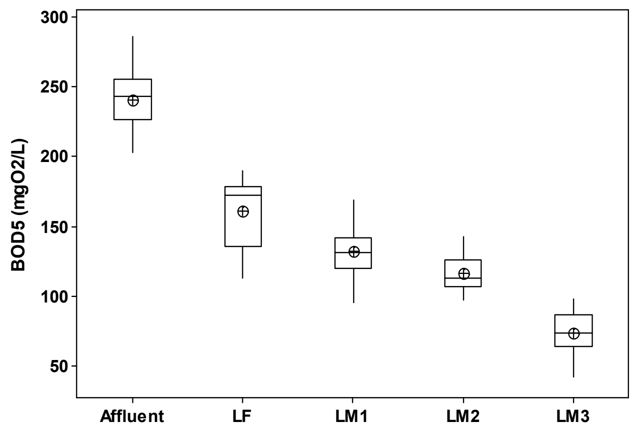


**Fig. 5** Behavior of temporal variation in $BOD_5$ concentration of affluent liquid waste and effluent from the series of stabilization ponds.

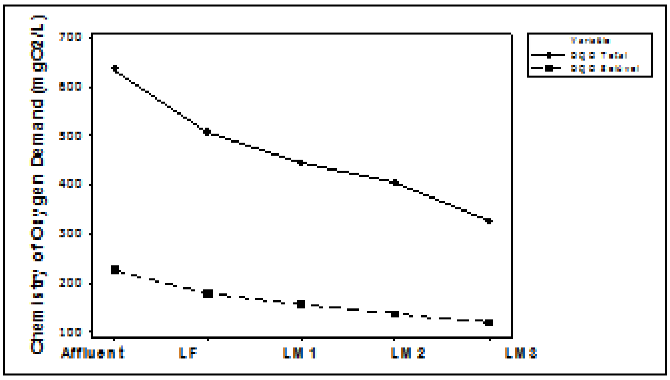


**Fig. 6** Behavior of the temporal variations of the total COD concentrations and filtered COD.

The behavior of temporal variations of the total COD concentrations and COD filtered throughout the series of stabilization ponds are shown in **Fig. 6**.

The quantification of the concentration of chemical oxygen demand in biological treatment process liquid waste throughout the monitoring period is of critical importance, given express indirectly the amount of organic matter likely to biostabilization. Analyzing the behavior of **Fig. 4**, it is observed that the data of the average concentration of COD Total tributary was 636 mg $O_2$ $L^{-1}$, passing the 326 mg $O_2$ $L^{-1}$ in LM3, providing removal efficiency of 49% with surface application rate applied 320 kg $DBO_5$ $ha^{-1}$ $day^{-1}$ and hydraulic retention time of 17 days. With respect to soluble COD data, it is noted that the average magnitude of influent was 226 mg $O_2$ $L^{-1}$ and produced the final effluent concentration was 118mg $O_2$ $L^{-1}$ in LM3, and removal efficiency of 48% indicating that there was no significant difference from the total COD removal efficiencies and filtered in the series of stabilization ponds fed with substrate consisting of 1% of landfill leachate over 99% of domestic sewage (percentage by volume).

In this work, the substrate used (made up of 99% domestic sewage and 1% landfill leachate) to feed serie stabilization ponds, concentrations of fecal coliforms ranged from $5 \times 10^5$ CFU/100 mL to $4 \times 10^7$ CFU/100 mL. In the final effluent produced by stabilization pond system, the concentrations of fecal coliforms ranged from 1 $10^2$ CFU/100 mL to 4 $10^5$ CFU /100 mL, with an average concentration of 2.35 $10^4$ CFU/100 mL. The minimum concentrations, high, average and standard deviation for the influent and effluent of each stabilization pond (LF, LM1, LM2, LM3) are presented in **Table 4**.

**Table 4.** Concentrations minimum (X), maximum (Z), mean (M) and standard deviation (SD) of concentrations of fecal coliforms

| | Substratum | LF | LM1 | LM2 | LM3 |
|---|---|---|---|---|---|
| Y (UFC/100mL) | 5.0 $10^5$ | 3.7 $10^4$ | 1.0 $10^4$ | 1.0 $10^3$ | 1.0 $10^2$ |
| Z (UFC/100mL) | 4.0 $10^7$ | 7.0 $10^6$ | 3.0 $10^6$ | 1.0 $10^6$ | 4.0 $10^5$ |
| M (UFC/100mL) | 9.3 $10^6$ | 1.3 $10^6$ | 4.4 $10^5$ | 1.1 $10^5$ | 2.3 $10^4$ |
| SD | 9.7 $10^6$ | 1.1 $10^5$ | 7.5 $10^5$ | 2.3 $10^5$ | 6.3 $10^4$ |

The concentration of fecal coliform in the substrate used in this study was similar in quantitative terms the sewage concentrations *in natura*, indicating that the addition of landfill leachate did not change the concentration of these bacteriological indicators. The average removal efficiency coliform was 99.76% and yet on the season in which the room temperature was milder the effluent produced showed coliform concentrations up to $10^5$ UFC/100 mL in some samples examined during the monitoring period.

## CONCLUSION

Treatment conjugate landfill leachate and sewage in a 1% plus 99% (percentage by volume) four stabilization ponds in series with surface charge applied 320 kg $DBO_5$/ha day and HRT of 17 days, produced effluent with average concentration of $BOD_5$ of 74 mg $O_2$ $L^{-1}$, average concentration of ammonia nitrogen 11 mg N $L^{-1}$ and fecal coliforms at a level of 104 CFU/100 mL. So it was not identified impact on the performance of the stabilization ponds treating this type of substrate, compared to the treatment of domestic sewage, which happens to emerge as a promising technological alternative for treatment of landfill leachate, mainly in northeastern Brazil. Among regulated chemical parameters, the highest efficiency was identified in ammonia nitrogen concentration, considering having achieved average removal efficiency equal to 87.6%. It is noteworthy that in the case of experimental system on a pilot scale, with substrate consisting of 99% of sewage plus 1% of landfill leachate, which is a ratio that fits in quantitative terms with a regional reality, becoming viable technological alternative, given the area availability, favorable climate conditions and its low cost/benefit ratio when compared with other technological alternatives available for treating these waste streams.

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