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Biological treatment of leachate wastewater mixture

Fatima Benradi [1,*], Ayoub Doughmi [1], Mohamed Khamar [1], Essediya Cherkaoui [1], Abdelaziz Laghzizil [2], Abderrahman Nounah [1]

[1]Civil Engineering and Environment Laboratory (LGCE), High School of Technology sale, Mohammed V University in Rabat, Rabat, Morocco
[2]Laboratory of Applied Chemistry of Materials, Faculty of Sciences, Mohammed V University in Rabat, Rabat, Morocco

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ABSTRACT

Leachates and domestic wastewater constitute a real problem for the environment, given their risks to surface water, groundwater, and the surrounding soil. Their management becomes delicate because of the demographic growth, and the standard of living of the population. Due to the reduction of water resources in the world, their treatment is very essential. In this study, samples of young raw leachate were collected and mixed with domestic wastewater. After a physicochemical and bacteriological characterization of leachate, domestic wastewater, and the mixture M1 (leachate ratios of 5%), an aerated biological treatment was carried out without adding activated sludge. Over a residence time period of six weeks, the chemical oxygen demand reduction rate reached 94.8% for the wastewater, 93.8% for the M1 mixture, and only 31.9% for the leachate. The addition of 5% young leachate to domestic wastewater does not affect the aerated biological treatment system, in addition, it is an inexpensive system.

1. Introduction

In some regions of the world, Sub-Saharan Africa, South Asia, and the Middle East, by 2050 waste generation will drastically outpace population growth by more than double (Cheng et al., 2021). In Morocco, the production of household and similar waste in urban areas is estimated at 5.9 MT in 2015, and 7.82 MT/year in 2019, or an average of 0.78 kg/inhabitant/day. This production will reach 9.4 MT in 2030. Waste production has been a problem of many environmental impacts and pollution, it is usually related to changing demographic, fast urbanization, and the improvement of living standards (Zulkipli et al., 2017). The household waste in Morocco is rich in organic matter (60–70% of weight), high humidity (60–70% of water), High density (0.4–0.5), plastic and paper (5–10%), and Calorific power (P.C.I.) estimated to 900–1000 kcal/kg. For sustainable household waste management, the orientation to landfilling mode, recycling remains the best solution. Indeed, landfilling consumes space, sometimes at the expense of productive land, and is not without environmental risks (leachate management, risk of contamination of water resources and soil, greenhouse gas emissions, etc.) (Dahchour and Hajjaji, 2020; Ouigmane et al., 2018).

Leachates are high-strength wastewaters formed as a result of the percolation of rainwater and moisture through waste in landfills. They contain a mixture of organic and inorganic contaminants including humic and fulvic acids, ammonia nitrogen, heavy metals, xenobiotics, and inorganic salts, its composition depends upon the landfill age, the quality and quantity of waste, and the climate (Tałałaj et al., 2019; Campos et al., 2019; Tawakkoly et al., 2019). Given the pollutants load contained in leachates, they are sources of contamination of surface water, and by infiltrating into the subsoil, they a strong degradation of groundwater (Chtioui et al., 2008; Khattabi et al., 2001; Tawakkoly et al., 2019; Cheng et al., 2021; Dereli et al., 2021). Leachate treatments are necessary before direct discharge into natural waters and vary from one site to another, they can be classified into three major groups:

- Leachate transfer: Recycling and combined treatment with domestic sewage (Renou et al., 2008).

* Corresponding Author.
Email Address: fatimabenradi@hotmail.com (F. Benradi)
https://doi.org/10.21833/ijaas.2023.02.004
Corresponding author's ORCID profile:
https://orcid.org/0000-0002-2610-0857

- Biodegradation: Aerobic and anaerobic processes, can be applied to younger leachates containing volatile fatty acids and has a pH of less than 6.5 (Tawakkoly et al., 2019; Cheng et al., 2021; Renou et al., 2008). Aerobic processes are cheap and effective to degrade organic pollutants contained in young leachates with BOD/ COD ratios > 0.5 (Bove et al., 2015). Via combined anaerobic-aerobic treatment process, the efficiency to remove the pollutants from leachate can be improved as compared to a sole anaerobic or aerobic process (Er et al., 2018; El-Gohary and Kamel, 2016).
- Chemical and physical methods: Chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, sedimentation/flotation, and air stripping have been used to treat the old landfill leachates (Renou et al., 2008; Tałałaj et al., 2019; Tawakkoly et al., 2019; Torretta et al., 2016).

Generally, the treatment of leachates presents technical problems because of the high chemical oxygen demand (COD) (6000–15,000 mg/l), and in ammonium ions (500–3000 mg/l) (El-Gohary and Kamel, 2016). Thus, recourse to the combination of techniques, such as the combination of biological pretreatments followed by physico-chemical processes has been shown to be very efficient (Renou et al., 2008; Tałałaj et al., 2019; Tawakkoly et al., 2019; Torretta et al., 2016). Other technologies are applicable for the treatment of leachate, and membrane bioreactor (MBR) technology has been operating successfully within Germany and other European countries (Robinson, 2005). The combination of sonication (US), ozonation (O3), and electrocoagulation (EC) process is highly successful in the treatment of leachate in terms of % color removal (100 %) and % COD removal (97.50 %) with low electrical energy consumption (8kWhr/m3) (Asaithambi et al., 2020).

Combinations of biological pretreatment followed by reverse osmosis are effective in removing COD, BOD, and $N{-}NH_4^+$ from landfill leachate (Renou et al., 2008; Tałałaj et al., 2019; Kurniawan et al., 2010). Unfortunately, in Moroccan landfills, biological treatment in combination with reverse osmosis is usually applied, the delegated society all have difficulties in managing the overproduction of leachate and concentrates resulting from reverse osmosis treatment. Large volumes are stored in basins to undergo treatment by natural evaporation. However, these techniques are not satisfactory in some regions. With the strong sunshine of certain regions, the technique of forced solar evaporation was considered potentially interesting (Benyoucef et al., 2021). Therefore, the selection of the process of leachate treatment is often difficult and essential due to the variable quantity and quality of leachates. The age of a landfill is usually shown by the composition and concentration of pollutants (Tawakkoly et al., 2019; Cheng et al., 2021). Determination of adequate treatment processes not only depends on leachate characteristics but also on economics, the complexity of the process, and the availability of technology. Co-treatment of leachate and domestic wastewater in publicly owned WWTPs by Activated Sludge is one of the most commonly applied methods for leachate management. It requires less investment by using preexisting wastewater collection and treatment systems, also, trained personnel are available in WWTPs. For mixing ratio, several studies published, authors tried to optimize the volumetric ratio of leachate in the total wastewater (Dereli et al., 2021; Hernández-García et al., 2019; El-Gohary and Kamel, 2016; Del Borghi et al., 2003). In this context, our study consists in carrying out laboratory treatment tests by aerated agitation of young raw leachate, raw wastewater, and a mixture (M1) of leachate (5%) and domestic wastewater (95%), it is a simple, efficient and low-cost method.

2. Materials and methods

2.1. Sampling

The leachate used in this study was taken from the trucks transporting household waste from the city of Salé, Morocco (Urban Commune of Laâyayda), while the domestic wastewater was taken from the Wastewater Pretreatment Station of Salé (Morocco), which receives between 70000 and 80000 m^3/day of wastewater. Before applying the aerated biological treatment process to the mentioned samples, bacteriological and physicochemical analyses were conducted.

2.2. Bacteriological and physicochemical analyzes

For the bacteriological analysis, in addition to the total germs, the indicators of pollution were determined: fecal coliforms and fecal Streptococci. The analysis method used is the most probable number (NPP method) for the pollution indicators and direct counting on agar. The pH and temperature were determined by a Lutron type 206 pH meter equipped with a temperature probe. The electrical conductivity was measured by a WTW LF90-type conductivity meter. The turbidity was determined by the HACH 21009 method. The suspended matter is determined by filtering a volume of sample on cellulose filters (Rodier et al., 2016) previously dried and weighed, then placed in the oven at 105°C for 2 hours and reweighed. The total solids are constituted by the dissolved and suspended matter contained in liquid samples, they are determined by evaporation at 105°C, after cooling and weighing the ceramic crucibles, they are placed in an oven at 550°C for at least 3 hours (Rodier et al., 2016). The COD is determined by oxidation, in an acid medium with an excess of potassium dichromate at a temperature of 150°C, of oxidizable material under the conditions of the assay in the presence of silver sulfate as an oxidation catalyst and mercury sulfate as complexing agent (Rodier et al., 2016). BOD_5 is determined by the respirometric (manometric) method using a BOD WTW OxiTop (Rodier et al., 2016). For the determination of sulfates, the method used is the nephelometric method (Rodier et al., 2016). The Orthophosphates are determined by molecular absorption spectrometry in an acidic medium and in the presence of ammonium molybdate, to form phosphomolybdic acid (Rodier et al., 2016). The Nitrates are determined by molecular absorption spectrometry, in the presence of sodium salicylate, nitrates give sodium paranitrosalicylate (Rodier et al., 2016). The heavy metals are determined by ICP-AES analysis at the National Center for Scientific and Technical Research (CNRST) in Rabat.

2.3. Aerated biological treatment processes

After the bacteriological and physicochemical characteristics of the two types of liquid discharges (raw leachate and wastewater) as well as for the mixture of 5% leachate and 95% pretreated wastewater (M1), the three samples will undergo aerated agitation at 500 revolutions per minute (RPM) under the effect of sunlight (ambient condition).

3. Results and discussion

3.1. Bacteriological characteristics

The bacteriological load reveals a fairly high concentration of fecal coliforms ($2,3.10^9$/100ml) in the wastewater compared to the leachate ($9,2.10^4$/100ml). These concentrations are lower than those in the wastewater of Tiflet (11.10^{11}FC/100ml) and the direct discharge of wastewater from the city of Salé (2.10^{10}/100ml) (Qoutbane et al., 2020). However, fecal Streptococci are more frequent in the leachate than in the wastewater (Fig. 1). The concentration of FS remains lower than that found in the wastewater of Tiflet (16.10^6 FS/100ml) and the direct discharges of the city of Salé (15.10^6 FC/100ml) (Qoutbane et al., 2020). However, the wastewater and leachate remain less loaded with FS than the slaughterhouse water (20.10^8 FS/100ml) (Boughou et al., 2006).

According to the FC/FS ratio of the wastewater, the origin of the fecal pollution of the wastewater of the city of Salé is strictly human; this is in line with the same result of the three discharges of the city of Salé and the waters of Tiflet (Hussain et al., 2019; Qoutbane et al., 2020). However, the FC/FS ratio is lower than 0.7, which confirms that the source of the fecal pollution is the animal origin (R<0.7). This agrees with the result of the slaughterhouse water of Rabat (Boughou et al., 2006). The concentration of fecal pollution indicators (FC, FS) in all three samples exceeded by far the standard set by the World Health Organization at 1000 FC/100 ml.

3.2. Physicochemical characteristics

The physicochemical characteristics of the two discharges (leachate and wastewater) and the M1 mixture (5% leachate and 95% wastewater) show that the pH is acidic (4.24) for the leachate, which qualifies it as young leachate with pH<6,5 (Cheng et al., 2021). However, the pH is relatively neutral (7.58) for the wastewater of the pretreatment station which remains close to the pH of direct discharges from the city of Salé (7.5 and 7.94) (Hussain et al., 2019) and the pH of wastewater discharges from Tiflet which varies between (7.13 and 7.93) (Qoutbane et al., 2020). The measured pH values of the wastewater from the city of Salé are acceptable according to the Moroccan standards of wastewater for irrigation (6.5–8.51).

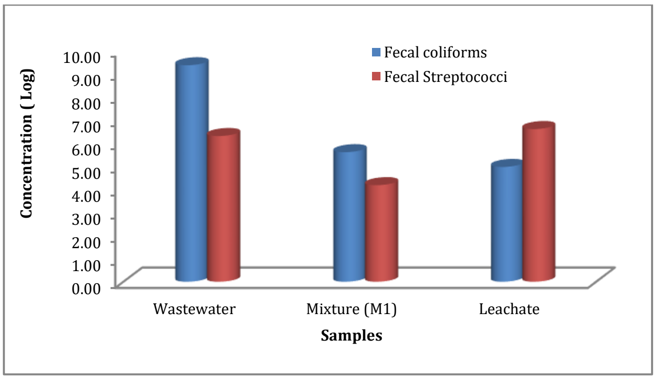

Fig. 1: Concentration log of FC and FS

The electrical conductivity of the leachate (15 ms/cm) is higher than that of the wastewater (2.2 ms/cm) which confirms the existence of considerable mineralization. These values are higher than that of the slaughterhouse water (1178 µs/cm) (Boughou et al., 2006). The comparison of the electrical conductivity values of the wastewater and leachate with the standards for irrigation water allows us to deduce that this wastewater is acceptable for crop irrigation. Similarly, these values remain below the limit value (2700 µs/cm) for direct discharge into the receiving environment (Boughou et al., 2006). The concentrations of organic matter (0.5g/l) and total solids (1.3g/l) in the wastewater are low compared to those of the leachate OM (33.1 g/l) and ST (45.3 g/l). The leachate is rich in sulfates

(244 mg/l) which are almost 8 times the concentration in the wastewater (31 mg/l), and the concentration of nitrates remains quite high in the leachate (3.1 mg/l) than in the wastewater (0.1 mg/l). The orthophosphate concentration remains higher in the leachate (0.427 mg/l) than in the wastewater (0.120 mg/l). The concentration of the latter is similar to that found in the slaughterhouse water (0.10 mg/l), but it is lower than that of the wastewater of the direct discharges of the city of Salé (2.93 mg/l) (Boughou et al., 2006). The orthophosphate concentration in the leachate is lower than that of the leachate of the Agadir landfill (172.3 mg/l) (Mherzi et al., 2020). The nitrate concentration remains higher in the leachate (3.1 mg/l) than in the wastewater (0.1 mg/l) and in the M1 mixture (0.2 mg/l). For the wastewater, the nitrate concentration remains lower than that of the slaughterhouse water (2.65 mg/l) and that of the Agadir landfill leachate (62 mg/l) (Mherzi et al., 2020; Boughou et al., 2006). The pretreated wastewater has a lower suspended matter load (0,049g/l) than the leachate (1.771 g/l) and the M1 mixture (0.256 g/l), this result is lower than that found for Tiflet city wastewater (0.282 g/l) and Rabat slaughterhouse wastewater (1.068 g/l) (Qoutbane et al., 2020; Boughou et al., 2006). The value found in the suspended matter for the wastewater (49 mg/l) respects Moroccan standards for indirect discharge (600 mg/l) and direct discharge (50 mg/l). On the other hand, for the mixture, M1 (256 mg/l) respects only the Moroccan standards of indirect discharge (600 mg/l) (Boughou et al., 2006). The heavy metals Cd and Pb are not found in all three samples (wastewater, leachate, and M1 mixture). Similarly, Cr is not found in wastewater and M1 mixture and exists only in low concentration (0.628mg/l) in leachate. Regarding Fe, Na, and Zn (Table 1), their concentrations are shown to be very high in the leachate compared to the wastewater.

The concentration of Zn in wastewater is higher than that found in the direct discharge of wastewater from the city of Salé (0.3 mg/l). However, the Fe concentration is higher than that of the slaughterhouse water (0.005 mg/l) (Boughou et al., 2006). Turbidity shows an increasing gradient from wastewater (213 NTU) to leachate (989 NTU) with a value of 326 NTU for the M1 mixture. Thus, the turbidity of the wastewater is slightly lower than that found in the Tiflet wastewater (292 NTU) and higher than that of the slaughterhouse water (853 NTU) (Qoutbane et al., 2020; Boughou et al., 2006).

Table 1: Concentration in mg/l of heavy metals

Sample	Zn	Fe	Na
Wastewater	1.33	0.61	7.62
Leachate	24.56	570.17	28.36
M1	6.96	28.73	12.28

3.3. Biological treatment by aeration

In order to characterize the performance and determine the efficiency of the aerated biological treatment process, the physicochemical parameters (pH, conductivity, turbidity, COD, and BOD_5) as well as the bacteriological parameters CF and GT were monitored.

3.3.1. Physicochemical analyzes

After six weeks of biological treatment, with the exception of the leachate, the wastewater, and the M1 mixture turned green in color. This color change is the result of algae growth. These play a promising role in biological purification. Similarly, the electrical conductivity decreased from 67.2% for the wastewater to 69.7% for the M1 mixture, however, the conductivity of the leachate showed an increase (20%)(Fig. 2), which can be explained by the aerobic degradation of the organic matter into the mineral matter. The turbidity abatement rate is 82.6% for the wastewater, 90% for the leachate, and 70.4% for the M1 mixture (Fig. 3), these percentages are higher than the one recorded for the wastewater in Tiflet (47%) after aerobic treatment (Qoutbane et al., 2020).

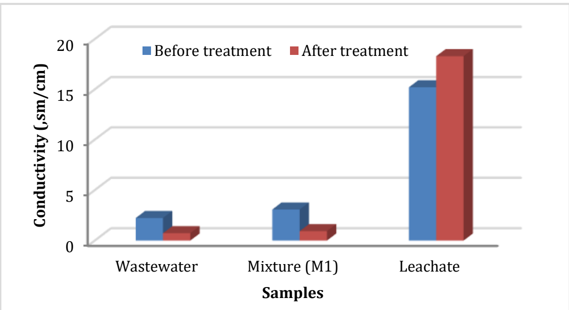

Fig. 2: Variation in conductivity (ms/cm)

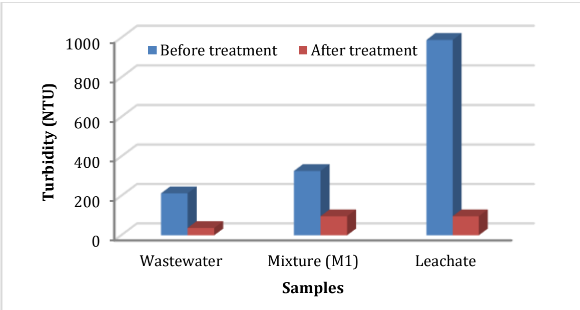

Fig. 3: Turbidity variation (NTU)

After treatment, Fig. 4 gives an abstract of pH, it increases for both samples (leachate and mixture M1). The M1 mixture changes from an acidic to a basic medium (8.26), while the leachate remains acidic. As for the wastewater, a slight decrease in pH is recorded, generally neutral. The suspended matter concentration increased significantly in all three samples (Fig. 5), ranging from 98.5% for wastewater, 92.1% for M1 mixture, and 80.4% for leachate.

Fig. 6 shows the change in total solids concentration after the biological treatment, wastewater showed no change, but we registered a 35% decrease for the M1 mixture and 15% for the leachate.

The organic matter has an abatement rate of 58% for the M1 mixture and 30% for the leachate, while an increase of organic matter of 34.4% is observed in the wastewater (Fig. 7). This increase in organic matter after treatment can be explained by the rather large amount of algae that have developed.

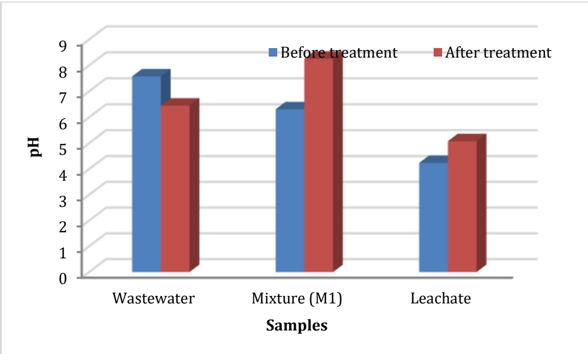

Fig. 4: Variation in pH

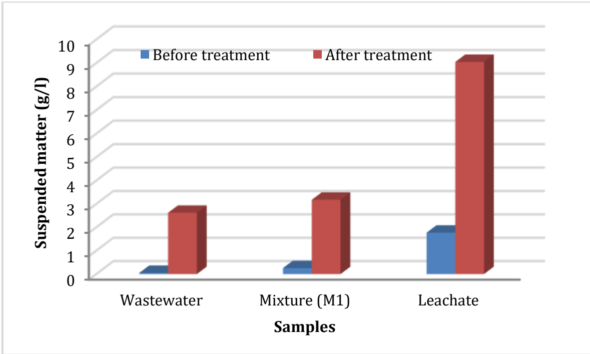

Fig. 5: Suspended matter variation in g/l

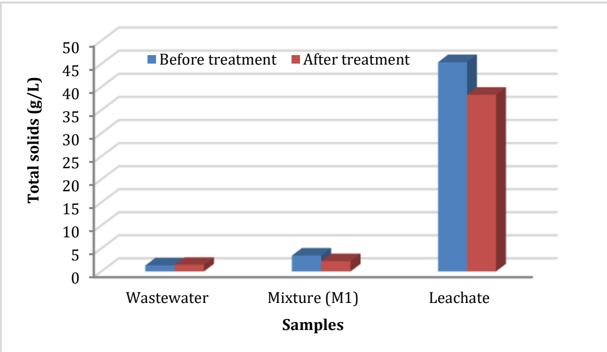

Fig. 6: Variation in the concentration of total solids

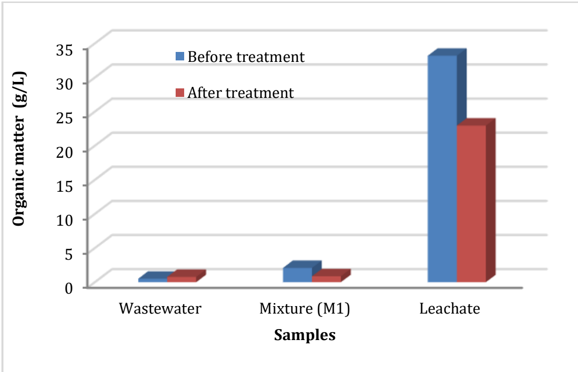

Fig. 7: Variation in OM concentration

The COD removal rate (mg O_2/l) reaches 94.8% (wastewater), 93.8% (M1 mixture), and 31.9% (Leachate).

For BOD_5 (mg O_2/l), the abatement rate amounts to 91.3% (mixture M1) and 71.4 (wastewater). On the other hand, the leachate abatement rate is low to inexistent.

The yield of COD and BOD of the wastewater and of the M1 mixture remains higher than that of Rabat slaughterhouse water (79.28% for BOD_5 and 59.49% for COD) and that of Tiflet wastewater (61.5% BOD_5) (Qoutbane et al., 2020; Boughou et al., 2006).

Monitoring of the biological treatment under sunlight showed a color shift of both samples (wastewater and M1) towards green; this coloration is due to the proliferation of algae. However, for the leachate, despite the significant degradation of the organic matter into the mineral matter which went from 33.1g/l to 22.96 g/l with an increase in conductivity and sulfates. The concentration of sulfates (Fig. 8) went from 234.9 mg/l to 447.47 mg/l, leachate did not change its coloration and remained dark.

3.3.2. Bacteriological analyzes

Bacteriological analysis (fecal coliforms and total germs) after treatment and decantation, shows that the total germs elimination efficiency for wastewater is 99.98%, 99.89% for the M1 mixture, and 74.28% for the leachate.

On the other hand, the removal efficiency for fecal coliforms is 90.86% for wastewater, 84.75% for the M1 mixture, and 61.95% for leachate.

Therefore, the removal efficiency of total germs and fecal coliforms is more important for the wastewater and M1 mixture than for the leachate.

This study showed that the use of an aerated biological treatment process for a leachate wastewater mixture (M1 mixture) gives a similar performance to that of water alone for the same residence time.

4. Conclusion

The analysis of the physicochemical and bacteriological parameters of the three samples before treatment shows high levels of BOD_5, COD, bacteriological load, turbidity, and organic matter: these waters cannot, therefore, be discharged into the environment without any treatment.

After the application of the aerated biological treatment process over a period of six weeks, the wastewater and the M1 mixture changed color and became green as a result of the algae proliferation. Thus COD, BOD_5, turbidity, and organic matter, in addition to the bacteriological load were significantly reduced. The COD abatement rate (mg O_2/l) reached 94.8% (wastewater), 93.8% for the M1 mixture, and only 31.9% for leachate. On the other hand, the BOD_5 (mg O_2/l) reached 91.3% for M1 and 71.4 for wastewater and remained significantly low to absent for leachate. These values obtained after the treatment are coherent with the Moroccan standards of indirect discharge.

These results show that the addition of leachate (5%) to wastewater does not affect the biological treatment system applied to wastewater. Also, this inexpensive process of treating the wastewater/leachate mixture can solve the leachate problem and prevent its negative impact on the environment.

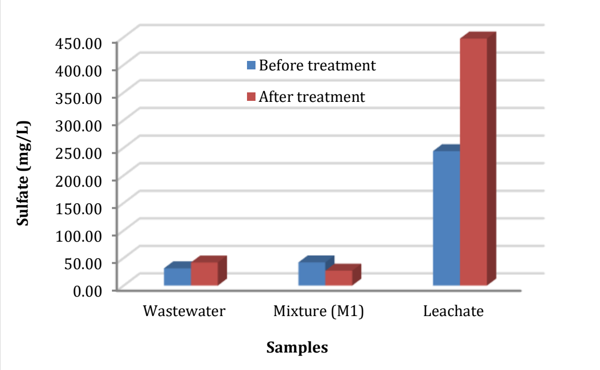

Fig. 8: Variation in sulfate concentration

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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