Journal of Materials and Environmental Science
ISSN : 2028-2508
CODEN : JMESCN

Copyright © 2021,
University of Mohammed Premier
Oujda Morocco

J. Mater. Environ. Sci., 2021, Volume 12, Issue 05, Page 631-644

http://www.jmaterenvironsci.com

Innovative process for treatment of leachates from controlled public discharge of Fes city in Morocco

Hanane EL FADEL [1]*, Mohammed MERZOUKI [1], Mohamed BENLEMLIH [1]
1. Biotechnology, Environment, Agrifood and Health Laboratory, Faculty of Sciences Dhar El Mahraz, University Mohamed Ben Abdellah, Fez, Morocco

**Corresponding author, Email address: elfadelha@gmail.com*

Received 02 Jan 2021,
Revised 05 April 2021,
Accepted 08 April 2021

Keywords
- ✓ *Leachate*
- ✓ Coagulation-floculation,
- ✓ Biological treatment by SBR
- ✓ Effluents norms.

Email address:
elfadelha@gmail.com
Phone: +212690970671;

Abstract

The objective of this work is to treat the leachate from the controlled public landfill in the city of Fez by a biological treatment by Sequencing Batch Reactor (SBR) combined with a chemical treatment by coagulation-flocculation. The Biological treatment by SBR allowed a reduction of 87% for COD_T and 96,77% for BOD_5. The chemical treatment by coagulation-flocculation, using lime, ferric chloride ($FeCl_3$ 6H2O) and alumina sulfate [$Al_2(SO_4)_3$14H2O], respectively reduced the COD_T by 36,6%; 81,67% and 85%. The coagulation-flocculation with 200 mg/L of $FeCl_3$ $6H_2O$ showed a reduction of faecal germs of more than 85%. The treatment of the leachate by combined system allowed to obtain satisfactory results in terms of removal of the mineral elements contained in the leachate and a reduction of COD_T, BOD_5 and polyphenols, respectively by 98%; 99,16% and 94,53% thus meeting the discharge standards in force.

1. Introduction

The landfilling of solid waste is still a significant problem in the soilid waste management systems of all countries worldwide [1,2]. However, landfill leachate is a complex liquid generated from rainwater penetration through landfills that often includes high-strength contaminant resistance, such as humic acids, ammonia nitrogen, heavy metals, xenobiotics, and inorganic salts, which are important to avoid due to their adverse effects on the environment. The factors that affect the composition of landfill leachate include the composition of waste, the level of compaction, the absorptive capacity of solid waste and age of solid waste, weather variations, precipitation, landfilling temperature, size of landfilling, hydrogeological conditions, factors of landfill operation, pH, and chemical and biological activities in the process of landfilling [3]. In general, young leachate produced from landfills (10 years old) has high organic content of relatively high-molecular-weight materials, for instance, humic and fulvic substances that are refractory and not rapidly degradable. Generally, old leachate has a lower concentration of COD, BOD_5, and BOD_5/COD. Leachate is stabilized and has low biodegradability since most landfills are old [4-7]. As a landfill gets older, a change from a relatively shorter initial aerobic to a longer anaerobic decomposition period takes place. Due to the biological breakdown of organic compounds and precipitation of soluble components, such as heavy metals, the strength of leachate generally lowers over time. Because of its biodegradable nature, organic compounds decrease faster than inorganic compounds with the increasing age of leachate production. Several treatment techniques, such as physic-chemical processes, are used to treat leachate (coagulation precipitation, activated carbon adsorption, membrane filtration, activated carbon adsorption, and/or other separation techniques), in addition to biological treatment methods, such as aerobic and anaerobic processes [3]. Landfill leachate is commonly treated offsite with municipal wastewater. This offsite leachate treatment may be limited or no longer applicable due to the increasingly stringent regulations and concerns related to toxic substances discharge into the environment, resulting in development of full-scale, onsite leachate treatment facilities [8]. The protection of the environment is nowadays a collective concern in the various sectors of activity, it is becoming a privileged necessity in the policies of developing countries [9]. The current national waste production amounts to around 17,413 tonnes per day and varies from region to region (the production rate in Morocco is 0, 75 Kg / inhabitant /d and it is approximately 750 T/d in the region of Fès-Boulemane). The goal of biological wastewater treatment is essentially to achieve the elimination of organic compounds, mostly present in soluble form, and ammoniacal nitrogen [10], biological treatment processes occupy a very important place in the treatment of wastewater [11]. The different techniques used can be classified according to the ventilation conditions and the use of the microorganisms. Thus, we distinguish:

- Aerobic processes with free cultures or activated sludge;
- Aerobic processes with fixed cultures;
- Natural lagooning;
- Anaerobic free culture processes;
- Anaerobic processes with fixed cultures.

Landfill waste during storage and under the combined action of rainwater and natural fermentation, produces a liquid fraction called "leachate" or "household waste juice" rich in organic matter, nitrogen and elements in the form of traces [12]. In contact with leachate, surface water and groundwater become polluted and degrade chemically and biologically. These leachates cannot therefore be discharged directly into the natural environment and must be carefully collected and treated.

In this context, we have offered to participate in the management of this waste by developing an optimization of the treatment of leachate from the controlled public landfill of the city of Fez by chemical and biological processes. The physico-chemical process used as primary treatment has the advantage of immediate adaptation to variations in the flow rates of the effluents to be treated and it is practically insensitive to seasonal climatic variations, to qualitative changes in wastewater and it cannot under any circumstances be disturbed by the presence of toxic substances while for the biological process, it is based on microbial metabolism, these microorganisms play an important role in purification due to:

- From their multiplication speed;
- Their richness in enzymes;
- Their great possibility of adaptation to the continual variations of pollution.

2. Material and Methods :

The controlled public landfill in the city of Fez is located in the south-east of the city of Fez, at Ouled Mhamed road to Sidi Harazem, covers an area of 120 hectares and receives more than 800 tonnes per day of waste from any nature. The public landfill in Fez has been in use since 1981, and soon reaches saturation point. This is why the garbage from the city of Fez is sent to the new controlled landfill (Sidi Harazem road). Samples are taken from the general leachate collector which records a flow rate of 15 l/min.

2.1. Biological treatment by the Sequencing Batch Reactor (SBR) process:

The SBR process is a batch sequential process whose operation is based on time . Thus, all the phases of the treatment take place in the same reactor which, depending on the stages, plays the role of the aeration basin (aerobic treatment), agitation (anaerobic treatment) and of the settling tank (separation of the solid and liquid phases) [13]. (Figure 1).

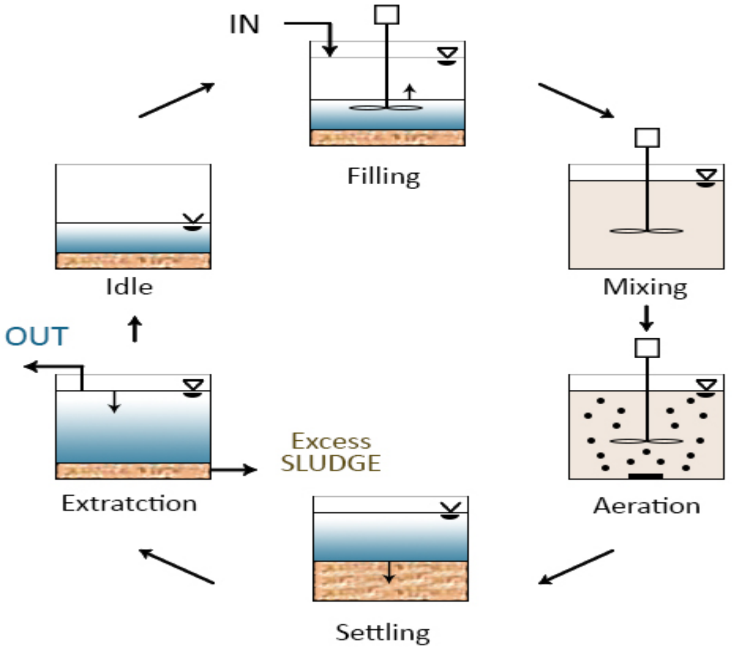

Diagram of the functional cycle of a Sequencing Batch Reactor (SBR)

Figure 1. Operating principle of the sequencing batch reactor process (SBR)

The volume treated (3 liters) during a cycle corresponds to one day of production and is stored in a first buffer tank. The reactor, which contains activated sludge, is fed with the effluent to be treated once or more times a day. The aeration is carried out for several hours during which the water is purified and then it is stopped so that the sludge settles. The supernatant is then discharged and a new volume of effluent to be treated enters the reactor. When the sludge concentration is very high in the reactor, part of the sludge is withdrawn [14].

The SBR process is based on the principle of aerobic biological treatment of effluents in cycles. The advantages of this process are as follows:

- Compact process;
- Lower installation and operating costs;
- High purification efficiency;
- No sludge recirculation;
- Elimination of nitrogen due to the fact that in the SBR process there is an aerobic phase allowing the oxidation of ammoniacal nitrogen to nitrite and then to nitrate (nitrification), possibly followed by an anaerobic phase allowing denitrification;
- Elimination of phosphorus by modifying the operating sequences, but without adding additional works;
- Good technical reliability;
- Limited labor requirement;
- Possibility of direct discharge of treated effluents into the natural environment.

2.2. Chemical treatment: Coagulation-flocculation:

The main purpose of coagulation is to destabilize the particles in suspension, that is to say to facilitate their agglomeration. This process is characterized by the injection and dispersion of chemicals (coagulants). It involves adding an electrolyte to the water to neutralize the negative charges that are responsible for keeping it in stable suspension [15]. Salts of a trivalent metal, Fe^{3+} or Al^{3+} are generally used [16]. The purpose of flocculation is to promote, by means of slow mixing, the contacts between the destabilized particles, these particles agglutinate to form a floc which can be removed by settling. This flocculation coagulation technique can also be used before biological treatment to protect the biomass from the attack of toxic elements in the discharges (in the case of activated sludge) [17].

The coagulation-flocculation tests in 500 ml beakers were carried out in order to verify the coagulation-flocculation potential of the leaching water. To do this, two series of tests were carried out to determine the effect of different variables on the efficiency of coagulation-flocculation. The first series looked at the effect of pH on the efficiency of coagulation-flocculation (constant concentration of coagulant). The second set of tests looked at the effect of the chemical nature of the coagulant and its concentration on the efficiency of coagulation-flocculation (constant pH). Two coagulants were tested during the tests: ferric chloride ($FeCl_3$) and alumina sulfate [$Al_2(SO_4)_3 14H_2O$]. During the trials, the effectiveness of coagulation-flocculation was estimated based on the COD_T measurement.

The coagulation-flocculation tests were based on the following operations:

- Coagulation speed at 150 rpm;
- Injection of the coagulant;
- Wait one minute for the coagulant to disperse and initiate the reaction;
- Flocculation speed at 45 rpm;
- 10 minute flocculation period;
- Stopping the agitation;
- 60minute settling period;
- Purging of sampling sockets;
- Sampling of supernatant water for analysis.

For comparison, a control was also prepared under the same conditions, but without the addition of chemical reagents.

2.3. Coupling of the SBR process with the coagulation-flocculation system:

In this study, we coupled the coagulation-flocculation treatment system with that of the biological treatment by SBR (Figure 2). The SBR (Sequencing Batch Reactor) system uses a microbial culture dispersed in the form of flocs within the leachate to be treated. The aeration and settling stages take place in the same reactor [18]. This free culture process generally combines carbon depollution and nitrification, then denitrification.

To ensure effective treatment of our leachate, the sludge used must be young and well ventilated. We worked with a sludge age of 15 and 20 days and with a dissolved oxygen concentration that exceeded 3 mg/L.

The raw leachate was treated by coagulation flocculation. After decanting of the coagulate, the resulting supernatant was entrained in the SBR reactor to be treated with the activated sludge. At the end of the treatment cycle, the water withdrawn must comply with the discharge standards in force. In this leachate treatment process, we performed microbiological and physico-chemical analyzes for four types of leachate:

- Raw leachate;
- Coagulated leachate;
- The entry of coagulate to the SBR;
- Exit from SBR.

Figure 2. SBR process coupled to the coagulation-flocculation system

Our bioreactor has a volume load of 0,7g COD/L per day and a volume of 3 liters distributed as follows:

- 500 ml of sludge carried out from an urban wastewater treatment plant with a solids load of 3g/L;
- 2450 ml of distilled water;
- 50 ml of the leachate to be treated per day.

To obtain a satisfactory treatment rate, it is necessary to work with young sludge. For this reason, the excess sludge was drawn off according to the following relationship:

$$\text{age of sludge} = V/Q$$

with V: Volume of the bioreactor (3000 ml) and Q: Flow rate of the sludge to be withdrawn.

We worked with a sludge age of 15 days, so the volume of sludge to be withdrawn is 200 ml per day. This batch treatment process by sequential aeration is based on the principle of treatment with activated sludge. The operation of the SBR is based on the following processing phases:

- Filling phase: the reactor is supplied with the leachate to be treated for 3 minutes;
- Aeration and stirring phase: in the presence of oxygen, the microorganisms are kept mixed with the leachate to be treated, its duration is 22h 54 min for one cycle per day;
- Settling phase: when the aeration and stirring are stopped, the reactor is put to rest to promote the separation of the sludge and the treated leachate. The settling time is set at 60 min;
- Draw-off or emptying phase: this phase lasts 3 min during which 50 ml of the treated leachate are withdrawn then replaced by the same volume of raw leachate and a new cycle begins.

3. Results and discussions:

3.1. Biological treatment of leachate by SBR:

The Table 1 shows the results of the analyzes of the chemical parameters before and after treatment with SBR. The reduction rate of BOD_5 is greater than that of COD_T, it takes the value of 96,77%. This is due to the presence of a fraction of non-biodegradable COD, also called hard COD. The high reduction rate of BOD_5 is explained by the performance of the sludge used in the SBR which degrades the biodegradable organic matter present in the leachate and also by the presence of a purifying biomass.

3.2. Chemical treatment of leachate by coagulation-flocculation:

3.2.1. Effect of pH on the efficiency of coagulation-flocculation:

The results are obtained following a change in pH from 6,0 to 7,5 of the leaching water. The concentration of $FeCl_3$ used as coagulant is 140 mg/L. The maximum pH of 7,5 was chosen so as not to generate too large an amount of SS by raising the pH, while seeking to minimize the amount of NaOH added. The optimum pH is around 7,35 with a COD_T reduction rate of 33,34%. In view of the results obtained, the coagulation-flocculation tests must be carried out at a constant pH of 7,35.

3.2.2. Effect of coagulant concentration on coagulation-flocculation efficiency:

The Figure 3 shows the results obtained following a variation in the concentration of two coagulants usually used in the field of wastewater purification, namely ferric chloride ($FeCl_3$ 6 H_2O) and alumina sulfate [$Al_2(SO_4)_3$ $14H_2O$].

Table 1. Variation in the average concentrations of the physico-chemical parameters before and after treatment with Sequencig Batch Reactor

Parameters	Entrance SBR	Exit SBR	Reduction rate (%)	Moroccan indirect discharge standards (mg/L)
Temperature (°C)	20 ,26	20,86	-	35
pH	8,89	8,95	-	6,5-8,5
Dissolved oxygen (mg / L)	5,23	1	-	-
COD_T (mg / L)	7886,6	1026,6	86,99	1000
BOD_5 (mg / L)	5166	166,6	96 ,77	500
Orthophosphates (mg / L)	3,22	2,04	36,64	-
NH_4^+(mg/L)	1,24	0,093	92,5	-
NO_3^-(mg/L)	4,84	2,28	52,89	-
NO_2^-(mg/L)	0,57	0,08	85,96	-
Polyphenols (mg / L)	428 ,57	56,71	86,76	5
SS (mg / L)	4833,33	600	87,58	600

During the tests, the concentrations of each of the two coagulating agents vary from 0 to 500 mg/L and from 0 to 600 mg/L respectively for ferric chloride and alumina sulphate, a slightly lower threshold of COD_T is reached when the concentration of alumina sulphate exceeds 300 mg/L, while better performance is observed when low concentrations of ferric chloride are used, these two coagulants offer fairly satisfactory treatment performance in terms of reducing the COD_T. The Ferric chloride offers an abatement rate of 81,67% while the opposite is observed at higher concentration where alumina sulphate is advantaged by giving an abatement rate of 85%.

Based on these results, respective concentrations of ferric chloride and alumina sulfate of 200 mg/L and 386 mg/L are recommended for the treatment of this leachate. The choice of ferric chloride and its concentration is based on the fact that this coagulating agent allows, at very low concentrations, a satisfactory reduction of the COD_T. This low concentration employed contributes to a reduction in the volume of sludge produced and the cost price of the treatment process. It would have been interesting to have the volumes of sludge produced by the various tests. Following a variation in the lime concentration ranging from 100 to 600 mg/L, it can be concluded that the addition of lime as a coagulant has a significant impact on the yields obtained. A concentration as low as 100 mg/L can already break down a good proportion of COD_T (12%). The optimum lime concentration is around 500 mg/L, giving 36,6% reduction in COD_T. The reduction rate drops from 600 mg/L.

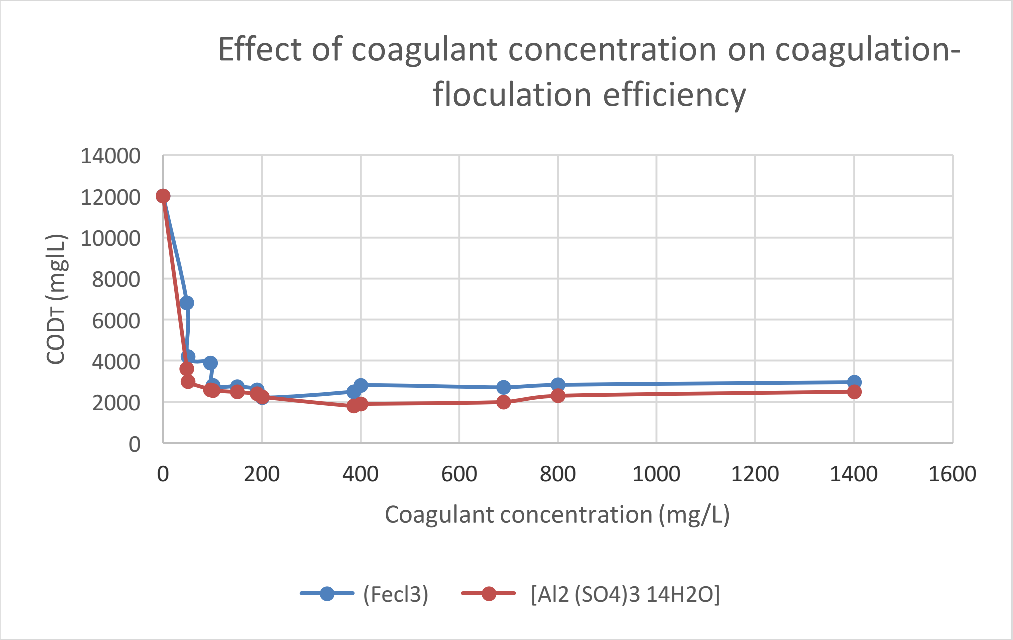

Figure 3. Effect of coagulant concentration on coagulation-flocculation efficiency

The initial COD_T of our sample is 52333 mg/L. This value does not correspond to the value indicated in figure 3 (12000 mg/L). This is another leachate sample, still from the same collection site, and used for the coagulation-flocculation tests. The COD of the leachate fluctuates during the day, for this we are interested in measuring the reduction rate to better meet the discharge standards in force.These results mean that the concentration of lime must be adjusted so as to ensure good flocculation of the micro-flocs formed following the addition of the coagulant.

The chemical treatment system that we have applied to the leachate, gives good results in terms of reduction of organic load and foul odors. However, a biological treatment in Sequencing Batch Reactor (SBR) complementary to the chemical treatment is essential to meet the discharge standards in force.

3.2.3. Results of the analyzes of the physico-chemical parameters before and after treatment of the leachate by coagulation-flocculation:

For the physico-chemical analyzes of the leachate, we analyzed their evolution before and after treatment by coagulation-flocculation with ferric chloride ($FeCl_36H_2O$) at a concentration of 200 mg/L to demonstrate the effectiveness of the treatment of the leachate by coagulation flocculation. The Table 2 shows the results of the analyzes of the chemical parameters before and after treatment by coagulation flocculation using ferric chloride.

3.2.3.1. Total Chemical Oxygen Demand (COD_T) reduction:

The elimination of organic pollution such as COD_T exceeds 81%, this is due to the phenomenon of absorption that is established between the cations of ferric chloride and the anions of organic matter [19].

Table 2. Variations in the average concentrations of the physico-chemical parameters before and after treatment by coagulation-flocculation

Parameters	Raw leachate	Coagulated leachate by Ferric chloride	Physico-chemical treatment reduction rate (%)	Moroccan indirect discharge standards (mg/L)
Temperature (°C)	19,56	20,6	-	35
pH	7,11	7,09	-	6,5-8,8
Dissolved oxygen (mg L)	0,86	0,86	-	-
COD_T (mg / L)	53199,6	9751	81,67	1000
Orthophosphates (mg /L)	16,61	14,6	12,1	-
NH_4^+(mg/L)	2,41	1,35	43,98	-
NO_3^-(mg/L)	11,3	9,8	13,27	-
NO_2^-(mg/L)	2,99	2,07	30,76	-
Polyphenols (mg / L)	1037,14	877,85	15,35	5
SS (mg / L)	5500	2866,66	47,88	600

3.2.3.2. Abatement of orthophosphates (PO_4^{3-}) :

Phosphorus can be found in the form of mineral salts but also in the form of organic compounds. These different compounds are either solubilized or fixed on the suspended matter **[20]**.

Orthophosphates react rapidly with ferric chloride through their negative charges to form amorphous precipitates. From the results of Table 3, the average value of orthophosphates in the raw leachate is 16,61 mg/L, while the coagulated leachate has a concentration of 14,6 mg/L. The reduction rate is very low since it does not exceed 12,1%. This result can be explained by the low concentration of orthophosphates in the raw leachate.

3.2.3.3. Reduction of nitrogen compounds:

The nitrogen pollution in groundwater, surface and marine waters results in tremendous economic, environmental and human health issues. The Mineral nitrogen (ammonia, nitrates, nitrites) constitutes the major part of total nitrogen **[21]**. As shown in Table 3, the raw leachate contains an average ammonium value of 2,41 mg/L. After treatment, this value became 1,35 mg/L with a reduction rate of 43,98%. The decrease in ammonium concentration after treatment with SBR can be explained by the phenomenon of nitritation. The nitrate and nitrite content in the raw leachate has values of 11,3 mg/L and 2,99 mg/L, respectively. After the treatment, the concentration takes the value of 9,8 mg/L for nitrate (NO_3^-) with a very low reduction rate which does not exceed 13,27% and 2,07 mg/L for nitrite with a rate of reduction of 30,76%.

3.2.3.4. Abatement of suspended solids (SS):

The Suspended solids is found in the leachate in various forms: mineral suspended matter, organic suspended matter and finally living suspended matter **[22]**. Due to repulsion phenomena, colloids generally form very stable suspensions. The coagulation phenomena then act in such a way as to neutralize their charges, in order to promote their agglomeration and allow their settling **[23]**. The analysis of the evolution of suspended matter in the leachate after the treatment with ferric chloride shows the effectiveness of the physicochemical treatment. The average content goes from 5500 mg/L before the treatment to 2866,66 mg/L after the leachate treatment. The average abatement rate is 48%. This shows that coagulation-flocculation is very effective for the elimination of SS.

3.2.4. Results of microbiological analyzes before and after treatment by coagulation-flocculation:

The aerobic populations of leachate have been relatively poorly studied. Due to the sampling difficulties associated with landfill waste, leachate has long been a simple solution for determining the anaerobic biomass of a landfill. However, the presence of toxic elements (heavy metals, organic micropollutants, xenobiotics, etc.) can inhibit the growth of certain populations. Nevertheless, the microorganisms found in a leachate are autochthonous to the landfill **[24].** The leachate percolation through the entire mass of waste then leads to a very large diversity of bacteria.

In anaerobic conditions, the microorganisms use elements other than oxygen for the needs of their respiratory mechanism. Nitrates and sulphates can serve as final electron acceptors **[25].** These parameters then condition the microorganisms likely to be encountered. In our work, we carried out 4 tests by working on the raw leachate and coagulated with ferric chloride ($FeCl_36H_2O$) at a concentration of 200 mg/L. The results obtained are the averages of the 4 tests performed: total germs with a reduction rate of 7,83%, total coliforms with 88,85% reduction, fecal coliforms with 82,94% reduction and faecal streptococci with 87,35% reduction.

From the results obtained by the physico-chemical treatment of the raw leachate, we can conclude that ferric chloride is able to eliminate a large part of the germs of faecal pollution by adsorbing on the negative charges of the poly-saccharide wall. bacteria. Therefore, the flocs are formed and settled during the settling phase. But despite the high reduction rate of faecal pollution germs which exceeds 85%, the rates of residual germs remain very high ($7{,}08.10^5$ for total coliforms; $2{,}37.10^4$ CFU/mL for fecal coliforms and $7{,}6.10^5$ CFU/mL for fecal streptococcus). For staphylococci, the coagulation-flocculation treatment has no effect on their level in the leachate. The number of staphylococci after the treatment is $1{,}25.10^6$ CFU/mL, on the other hand the average number of staphylococci in the raw leachate is $1{,}65.10^5$ CFU/mL. Indeed, these bacteria resist a high salinity of the leachate and are not affected by the presence of inhibitor products.

According to the results obtained, the treatment of the leachate by coagulation-flocculation leads to more or less satisfactory results in terms of reduction of the physico-chemical and microbiological parameters. It is for this reason that we have combined this physicochemical treatment with the biological treatment by SBR to better meet the discharge standards in force.

3.3. Coupling of the chemical and biological treatment of the leachate:

3.3.1. Physicochemical and microbiological characterization of the sludge used:

The results of the microbiological and physicochemical analyzes of the sludge used in our SBR process show a composition essentially of heterotrophic microorganisms which degrade organic matter: total germs with 30.10^6 CFU/mL, total coliforms with 43.10^4 CFU/mL, fecal coliforms with 72.10^3 CFU/mL, streptococci with 90.10^3 CFU/mL, staphylococci with 22.10^5 CFU/mL, yeasts with 10^7 CFU/mL and fungi with 10^5 CFU/mL and also degradation products, including ammonium (NH_4^+) with 16 mg/L is degraded into nitrites (NO_2^-) with a concentration of 54,9 mg/L. The introduction of oxygen by aeration is therefore essential for the action of these microorganisms which must be kept in an intimate mixture with the leachate to be treated and thus constantly come into contact with these organic pollutants.

3.3.2. Monitoring of the variation of dissolved oxygen in the bioreactor for 24 hours:

The variation in the dissolved oxygen concentration in our bioreactor during a 24 hour leachate treatment cycle shows that at the start of the cycle, dissolved oxygen has a concentration of 1 mg/L. At the start of aeration the value increases to 1,3 mg/L. After 2 hours of aeration, the dissolved oxygen reaches a high value of 5,4 mg/L. This value remains constant for 17 hours, then the bioreactor undergoes a slight increase in dissolved oxygen to a value of 5,7 mg/L for 2 hours. When aeration is stopped, the recorded value of dissolved oxygen in the bioreactor decreases to 5,5 mg/L then to 1,7 mg/L. Fifteen minutes before starting a new cycle, the treated leachate is drawn off with a pump. The dissolved oxygen at the outlet of the SBR takes the value of 1 mg/L. From these results, it can be concluded that our bioreactor is well ventilated and therefore the amount of oxygen in the bioreactor is sufficient for the optimal growth of bacteria.

3.3.3. Results of physicochemical and microbiological analyzes before and after treatment by the combined system:

Tables 3 and 4 respectively represent the results of the various physicochemical and microbiological analyzes of the leachate before and after treatment by the combined system: Coagulation-flocculation followed by SBR.

Table 3. Results of physicochemical analyzes before and after treatment with the combined system

Parameters	Raw leachate	coagulated leachate	reduction rate of physicochemical treatment (%)	Entrance SBR	Exit SBR	reduction rate of SBR treatment (%)	reduction rate of the combined system (%)	Moroccan indirect discharge standards (mg/L)
Dissolved oxygen (mg/L)	0.86	0.86	-	5.23	1	-	-	-
COD_T (mg/L)	53199.6	9751	81.67	7886.6	1026.6	86.99	98.07	1000
BOD_5 (mg / L)	20000	14166	29.17	5166	166.6	96.77	99.16	500
Orthophosphates	16.61	14.6	12.1	3.22	2.04	36.64	87.71	-
NH_4^+(mg/L)	2.41	1.35	43.98	1.24	0.093	92.5	96.14	-
NO_3^-(mg/L)	11.3	9.8	13.27	4.84	2.28	52.89	79.82	-
NO_2^-(mg/L)	2.99	2.07	30.76	0.57	0.08	85.96	97.32	-
Polyphenols (mg/L)	1037.14	877.85	15.35	428.57	56.71	86.76	94.53	5
SS (mg/L)	5500	2866.66	47.88	4833.33	600	87.85	89.09	600

Table 4. Results of microbiological analyzes before and after treatment by Combined System

Types of germs (CFU/mL)	Raw leachate	Coagulated leachate	Reduction rate of physicochemical treatment (%)	Entrance SBR	Exit SBR	Limit values	Reduction rate of SBR treatment (%)	Reductio rate of th combined system (%
Total germs	$6.89.10^7$	$6.35.10^7$	7.83	$6.48.10^6$	$2.87.10^4$	No standard	99.55	99.95
Total coliforms	$6.28.10^6$	$7.08.10^5$	88.85	$1.25.10^4$	0	No standard	100	100
Fecal coliforms	$1.39.10^5$	$2.37.10^4$	82.94	$2.13.10^3$	0	1000/100mL	100	100
Fecal Streptococcus	$6.01.10^6$	$7.6.10^5$	87.35	$5.38.10^4$	75	No standard	99.86	99.99
Staphylococcus	$1.65.10^5$	$1.25.10^6$	-	$2.89.10^3$	25	No standard	99.13	99.98

3.3.3.1. Total Chemical Oxygen Demand COD_T and biological oxygen demand BOD_5 reduction:

The reduction rate of BOD_5 is greater than that of COD_T, it takes the value of 99.16%. The mean SBR output value is 166.6 mg/L, this concentration is much lower than that of the standard for indirect discharges (500 mg/L). The high reduction rate of BOD_5 can be explained by the performance of the sludge used in SBR which degrades the biodegradable organic matter present in the leachate.

3.3.3.2. Abatement of orthophosphates (PO_4^{3-}):

The concentration of Orthophosphates (PO_4^{3-}) is reduced from 3.22 mg/L to 2.04 mg/L at the outlet of the SBR with a reduction rate which does not exceed the value of 36.64%. This low rate of reduction of orthophosphates can be explained by the absence of the anaerobic phase. During the aeration phase of our bioreactor, which lasted 22 hours, dephosphating bacteria accumulate orthophosphates. But to promote the accumulation of the latter, it is better to precede the aerobic phase with an anaerobic treatment phase to release the orthophosphates to facilitate their accumulation during the aerobic phase. The alternation of the two anaerobic and aerobic phases promotes the growth and selective enrichment of phosphate accumulating bacteria.

3.3.3.3. Reduction of nitrogen compounds:

The Nitrogen pollution, mainly in soluble form, is found in the form of organic nitrogen and ammoniacal nitrogen **[26]**. These two forms of nitrogen are involved in the phenomenon of eutrophication. From the results presented in Table 5, the ammonium concentration at the inlet of the SBR of 1,24 mg/L decreases to the concentration of 0.093 mg/L. The reduction rate takes the value of 92.5%. The decrease in ammonium concentration after treatment with SBR can be explained by the phenomenon of nitritation. The monitoring of the nitrite concentration shows a treatment rate in the bioreactor of 85.96%. The value found at the outlet of the bioreactor is 0.08 mg/L. the decrease in the concentration of nitrites is explained by the oxidation of nitrites to nitrates using bacteria of the genus Nitrobacter, Nitrocystis, Nitrospira, Nitrococcus **[27]**. The average nitrate concentration present in the leachate entering the SBR is 4.84 mg/L, after treatment, this concentration drops to 2.28 mg/L. The reduction rate is 52.89%.

3.3.3.4. Abatement of suspended solids (SS):

The suspended solids (SS) concentration of the bioreactor was recorded at the threshold of 5 g/L because of the sludge present in the bioreactor. On leaving the SBR, the suspended solids concentration became 0.6 g/L. this decrease can be explained by the good separation between the solid phase (sludge) and the liquid phase (leachate withdrawn) in the bioreactor during settling.

3.3.3.5. Results of microbiological analyzes before and after treatment by combined system:

According to the results obtained after treatment with the combined system (Table 4), the germs of faecal contamination are completely eliminated with 100% reduction. This could be due to the presence of toxic substances such as organic micropollutants, and also to biological phenomena such as: predation, parasitism, antagonism and competition. The low presence of fecal streptococcus (75 CFU/mL) at the outlet of the SBR is due to its chain shape which gives it a slight resistance compared to total coliforms and fecal coliforms.

Conclusion

From the studies carried out and the results obtained, it can be concluded that:

- The raw leachate contains a high organic load in terms of COD_T and BOD_5. Other chemical parameters are recorded in excessive levels such as suspended solids (average value 5500 mg/L).
- The microbial load found in the raw leachate is very high, especially for faecal pollution germs.
- The biological treatment of the leachate by SBR gives very satisfactory results in terms of reduction of COD_T up to 86,99% and BOD_5 to 96,77%.
- The chemical treatment of the leachate by coagulation-flocculation gives a reduction rate of the chemical parameters around 81% for the COD_T, hardly exceeds 15% for the orthophosphates, the nitrates and the polyphenols and takes a value close to 50% for ammonium and suspended solids (SS).
- The coupling of the chemical and biological treatment of the leachate gives relevant results whether it is for the physico-chemical parameters or the germs, with reduction rates of COD_T of 98% and of BOD_5 of 99%. For faecal pollution germs, the reduction rate reaches 100%.
- The chemical and microbiological parameters at the output of the combined system largely meet Moroccan standards for indirect discharges. Based on these results, we can apply our combined system to treat the leachate from the landfill on a large scale.

References

1. Z. Gu, W. Chen, Q. Li, A. Zhang-Treatment of semi-aerobic aged-refuse biofilter effluent from treating landfill leachate with the Fenton method, Process. Saf. Environ. Prot, 133 (2020) 32–40. https://www.sciencedirect.com/science/article/pii/S0957582019305452.
2. S.Y. Guvenc-Optimization of COD removal from leachate nanofiltration concentrate using H_2O_2 /Fe^{2+} /heat-activated persulfate oxidation process, Process. Saf. Environ. Prot, 126 (2019) 7–17. https://www.researchgate.net/publication/332095336_Optimization_of_COD_removal_from_Leachate_Nanofiltration_Concentrate_Using_H2O2Fe2Heat_-_Activated_Persulfate_Oxidation_Processes.
3. M.J. Abdulhasan, M.M. Hanafiah, M.S. Satchet, H.S. Abdulaali, M.E. Toriman, A.A. AlRaad-Combining GIS, fuzzy logic and AHP models for solid waste disposal site selection in Nasiriyah, *Iraq. Appl. Ecol. Environ. Res, 17* (2019) 6701–6722. https://www.epa.hu/02500/02583/00059/pdf/EPA02583_applied_ecology_2019_3_67016722.pdf
4. T.J. Banch, M.M. Hanafiah, A.F. Alkarkhi, A.M. Salem-Factorial design and optimization of landfill leachate treatment using tannin-based natural coagulant, Polymers 11 (2019) 1349. https://www.sciencedirect.com/science/article/pii/S2213343720313567.
5. T.J. Banch, M.M. Hanafiah, A.F. Alkarkhi, A.M. Salem-Statistical evaluation of landfill leachate system and its impact on groundwater and surface water in Malaysia. Sains Malays, 48 (2019) 2391–2403. http://journalarticle.ukm.my/14422/1/10%20Tawfiq%20J.H.%20Banch.pdf.
6. T.J. Banch, M.M. Hanafiah, A.F. Alkarkhi, A.M. Salem, N.U. Nizam-Evaluation of different treatment processes for landfill leachate using low-cost agro-industrial materials, Processes 8 (2020) 111. https://www.mdpi.com/2227-9717/8/1/111.
7. R.A. Maslahati , S. Chelliapan, W.W. Mohtar, H. Kamyab-Prediction and optimization of the fenton process for the treatment of landfill leachate using an artificial neural network, Water 10 (2018) 595. https://www.mdpi.com/2073-4441/10/5/595.

8. D. Feng, C. Song, W. Mo-Environmental, human health and economic implications of landfill leachate treatment for per-and polyfluoroalkyl substance removal, Journal of Environmental Managment, 289 (2021). https://www.sciencedirect.com/science/article/pii/S0301479721006204.
9. M. Erostate, F. Huneau, E. Garel, S. Ghiotti, Y. Vystvana, M. Garrido, V. Pasqualini- Groundwater dependent ecosystems in coastal Mediterranean regions : Characterization, challenges and management for their protection, Water Research, 172 (2020). https://www.sciencedirect.com/science/article/pii/S0043135419312382.
10. J.T. Hernandez, A.G. H. Ramirez, E.M. Ramirez-Impacts on water quality by in situ induced ozone-oxygen oxidation in a polluted urban reservoir, Science of the Total Environnement, 735 (2020). https://www.sciencedirect.com/science/article/pii/S0048969720328813.
11. P. Pal, R. Kumar-Chapter 2- Recent advances in biological treatment processes for wastewater and water treatment, Current Trends and future developments on (Bio-) Membranes, (2020) 41-66. https://www.sciencedirect.com/science/article/pii/B9780128173787000021.
12. A.D. Thomson, T. Worlev, M. Sandra, U.J. Contreras, S.H.A. Brawley, K. Karcher- Determining the effects of Class I landfill leachate on biological nutrient removal in wastewater treatment, Journal of Environmental Management, 275 (2020). https://www.sciencedirect.com/science/article/pii/S0301479720311233.
13. M. Hang, Q. Teng , D. Zhang, G. Jilani, W.M. Ken, Z.P. Yang, T. Alam, M. Ikram, Z. Iqbal-Performance and microbial community dynamics in anaerobic continuously stirred tank reactor and sequencing batch reactor (CSTR-SBR) coupled with magnesium-ammonium-phosphate (MAP)-precipitation for treating swine wastewater, Bioresource Technology, 320 (2021). https://www.sciencedirect.com/science/article/abs/pii/S0960852420316102.
14. F.D. Caprio, L.T. Nguemna, F. Pagnaneli-Microalgae cultivation by uncoupled nutrient supply in sequencing batch reactor (SBR) integrated with olive mill wastewater treatment, Chemical Engineering Journal, 410 (2021). https://www.sciencedirect.com/science/article/abs/pii/S1385894721000164.
15. A.R. Lshak, F.S. Hamid, S. Mohamad, K.S. Tay-Stabilized landfill leachate treatment by coagulation-flocculation coupled with UV-based sulfate radical oxidation process sulfate radical oxidation process,Waste Management, 76 (2018) 575-581. https://www.sciencedirect.com/science/article/pii/S0956053X18301363.
16. K. Djeffal, S. Bouranene, P. Fievet, S. Déon, A. Gheid-Treatment of controlled discharge leachate by coagulation-floculation: influence of operational conditions, Separation Science and Technology, 56 (2019). https://www.tandfonline.com/doi/full/10.1080/01496395.2019.1708114.
17. B. K. Tripathy, M. Kumar-Sequential coagulation/floculation and microwave-persulfate processes for landfill leachate treatment : Assessment of bio-toxicity, effect of pretreatment and cost-analysis, Waste Management, 85 (2019) 18-29. https://www.sciencedirect.com/science/article/pii/S0956053X18307578.
18. Z.Youcai.-Biological Treatment Processes for Leachate, Pollution Control Technology for Leachate from Municipal Solid Waste, (2018). http://scholar.google.com.eg/scholar?q=Biological+Treatment+Processes+for+Leachate,+Pollution+Control+Technology+for+Leachate+from+Municipal+Solid+Waste&hl=ar&as_sdt=0&as_vis=1&oi=scholart.
19. J. A. Gyamfi, B. Ouddane, L. Rietveld, J.P. Cornard, J. Criquet-Natural organic matter-cations complexation and its impacts on water treatment : A critical review. Water Research, 160 (2019) 130-147. https://www.sciencedirect.com/science/article/pii/S004313541930452X.

20. A. S. Sanchez-Technical and economic feasibility of phosphorus recovery from wastewater in Sao Paulo's Metropolitan Region. Journal of water Process Engineering, 38 (2020). https://www.sciencedirect.com/science/article/pii/S2214714420304153.
21. K.M. N'Goran, K.M. Yao, N.L.B. Kouassi, A. Trokourey-Phosphorus and nitrogen speciation in waters and sediments highly contaminated by an illicit urban landfill: The Akouedo landfill, Côte d'Ivoire, Regional Studies in Marine Science, 31 (2019). https://www.sciencedirect.com/science/article/pii/S2352485518303499.
22. J. Umamaheswari, T. Bharathkumar, S. Shanthakumar, K.M. Gothandam-A feasibility study on optimization of combined advanced oxidation processes for municipal solid waste leachate treatment, Process Safety and Environmental Protection, 143 (2020) 212-221. https://www.sciencedirect.com/science/article/pii/S095758202031586X.
23. K. Djeffal, S. Bouranene, P. Fievet, S. Déon, A. Gheid-Treatment of controlled discharge leachate by coagulation-flocculation: influence of operational conditions, Separation Science and Technology, 56 (2021). https://www.tandfonline.com/doi/full/10.1080/01496395.2019.1708114.
24. S.F. Corsino, M. Capodici, D.D. Trapani, M. Torregrossa, G. Viviani-Assessment of landfill leachate biodegradability and treatability by means of allochthonous and autochthonous biomasses. New Biotechnology, (2020) 91-97. http://scholar.google.com.eg/scholar?q=Assessment+of+landfill+leachate+biodegradability+and+treatability+by+means+of+allochthonous+and+autochthonous+biomasses&hl=ar&as_sdt=0&as_vis=1&oi=scholart.
25. Z. Jin, M. Ci, W. Yang, D. Shen, L. Hu, C. Fang, Y. Long-Sulfate reduction behavior in the leachate saturated zone of landfill sites, Science of The Total Environment, 730 (2020) 138946. http://scholar.google.com.eg/scholar?q=Sulfate+reduction+behavior+in+the+leachate+saturated+zone+of+landfill+sites&hl=ar&as_sdt=0&as_vis=1&oi=scholart.
26. L. Miao, G. Yang, T. Tao, Y. Peng-Recent advances in nitrogen removal from landfill leachate using biological treatments- A review, Journal of Environmental Management, (2019) 178-185. https://www.sciencedirect.com/science/article/pii/S030147971930060X.
27. X. Huang, W. Mi, H. Ito, Y. Kawagoshi-Unclassified Anammox bacterium responds to robust nitrogen removal in a sequencing batch reactor fed with landfill leachate, Bioresource Technology, 316 (2020). https://www.sciencedirect.com/science/article/abs/pii/S0960852420312311.

(2021) ; http://www.jmaterenvironsci.com