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Characterization and treatment of leachate from the controlled discharge of large Agadir by coagulation-flocculation

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Abstract

Leachate from urban waste is one of the major constraints for the management of public landfills. Indeed, given their pollutant load, they represent a threat to the environment and human health. Their composition varies from one landfill to another, depending on the nature and age of the waste, climatic conditions and the topography of the site. The controlled landfill in Greater Agadir is among the sites that suffer from the problem of leachate management. It generates a significant quantity of these liquid effluents. In 2016, quantities in the order of 671,965.93 Tonne. A recirculation and sprinkling system has been set up to reduce leachates, but performance remains very low. Diagnosis of the leachate water showed a high level of organic pollution. The low values of the BOD_5/ COD ratio (0.27) indicate that the leachates are rich in non-biodegradable organic matter (intermediate leachate). The purpose of this study is to characterize the leachates from different districts of Greater Agadir and to evaluate the performance of the treatment by coagulation-flocculation. FeCl3 allows a COD removal of 74% at pH=6.55, in the case of $Al_2(SO_4)_3$ the treatment gave a COD removal of about 64% at pH=5.6. They allowed us to show that the mixture of coagulant/flocculants gives an improvement in treatment. However, the mixture of $FeCl_3$ /polyacrylamide allows a high COD removal and Turbidity compared to the results obtained.

1. Introduction

The siting of landfills in sites that are not suitable or not specifically developed for this purpose increases the risk of contamination of surface and ground water, and consequently human health [1-3]. As a result of the bio-physico-chemical evolution of the waste thus piled up and the action of rainfall, a juice called leachate is generated. This juice constitutes a source of pollution for the environment. Indeed, in addition to the odors that it emits, it leads to an alteration in the quality of surface and underground water due to its high pollution load (organic and mineral matter and bacteriological pollution marked by the development of bacteria, viruses and algae). More generally, the problem of waste management is daily and global and the situation is dramatic in developing countries [4-6] and particularly in Morocco [7-9].

Leachate composition varies from landfill to landfill depending on the nature and age of the waste, weather conditions and site topography [10]. It is therefore difficult to determine the precise properties of the leachate since it changes in time and space and becomes richer in non-biodegradable compounds over time [11-13].

The controlled landfill in Greater Agadir is among the sites that suffer from the problem of leachate management. It generates a significant amount of these liquid effluents.
In 2016, quantities in the order of 671,965.93 Tonne were stocked. A recirculation and sprinkler system has been set up to reduce leachate, but performance remains very low [14]. The physicochemical analyses of these leachates have enabled us to distinguish three types of effluents (fresh, intermediate and stabilized leachate) according to their age and chemical composition.

Coagulation-flocculation is a process that has been shown to be highly effective in eliminating pollution in effluent treatment [15-16]. This process can be applied directly to leachates to remove organic matter along with suspended solids [17]. In recent years, a wide range of laboratory and pilot scale experiments have been conducted to evaluate the effect of several coagulants [18-20].

2. Materials and Methods

2.1. Presentation of the studied site

The leachate samples were taken from the controlled public landfill of the city of Agadir, covering an area of 41 ha, located in the locality of Tamellast (Figure 1), which will receive a volume of more than 200,000 tons of waste per year. In fact, a population of nearly 800,000 inhabitants is concerned by the operation.

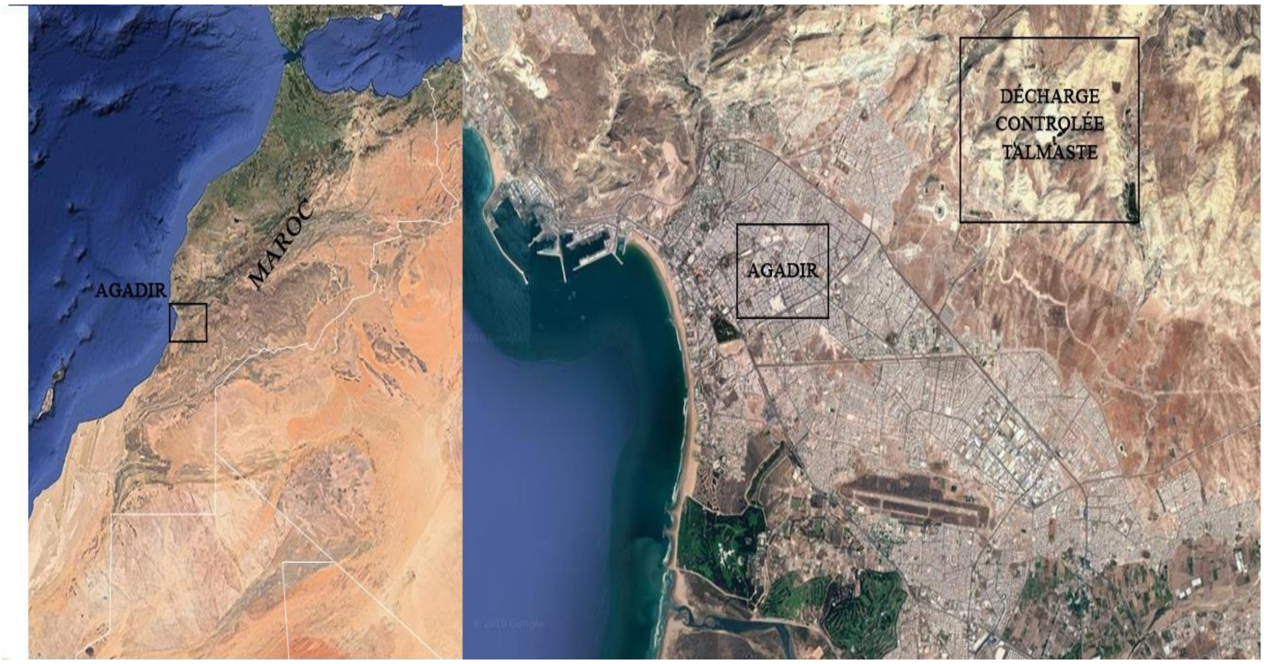

Figure 1. Location of the controlled landfill in Greater Agadir

2.2. Sampling

The samples to be treated were taken carefully and in sterile vials from the different ponds where the leachate is stored (depending on the age of the leachate). They were then transported to the laboratory and stored in cold storage (4°C) (Figure 2),

2.3. Analytical techniques

The various physico-chemical parameters (COD, BOD_5, pH, $N0_3^-$, ...) are determined by standard methods [21]. The metallic elements in the leachate and well water were analyzed by AA-7000 atomic absorption spectrophotometry after mineralization.

Figure 2. Effluent collected from the Agadir controlled landfill

Jar Test Procedure

The coagulation-flocculation tests were carried out using a propeller flocculator (jar test). The test equipment consisted of a flocculator with four stirrers (Fisher 1198 Flocculator) with an individual rotation speed varying between 0 and 200 rpm [22]. This apparatus allows simultaneous agitation of the liquid contained in a series of beakers each filled with 500 ml of leachate. Different concentrations of selected coagulants and flocculants were added to the leachate. The mixture is stirred rapidly at 200 rpm for 10 min. The speed is then reduced to 60 rpm for 30 min. After 60 minutes of settling, the supernatant is recovered to analyze the parameters (Figure 3).

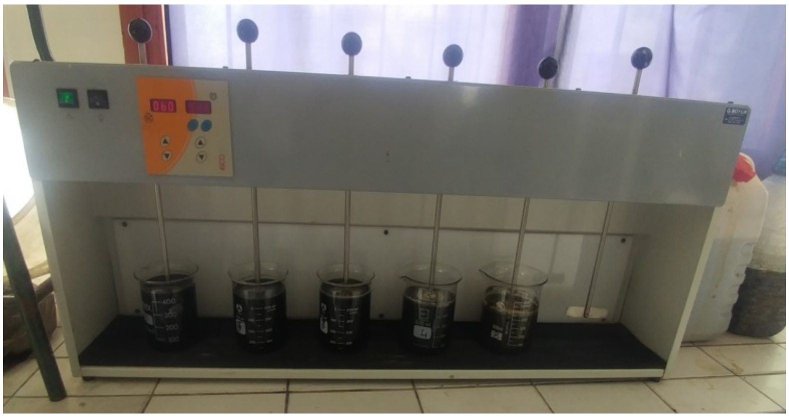

Figure 3. JAR TEST device

3. Results and Discussion

3.1. Characterization of urban waste

Household waste is a heterogeneous mixture of materials with very different physical and chemical properties. This composition is largely determined by the nature of the waste and its packaging as well as consumption practices, which vary according to the standard of living and cultural habits. With its large population, Greater Agadir produces annually more than 220,000 tons of household and similar waste [10]. Table 1 presents the different fractions of urban waste in Greater Agadir. Household and similar waste in Greater Agadir is characterized by the predominance of organic matter (77%). Their composition is almost similar to all household waste in Morocco.

Table 1: Average composition of urban waste in Greater Agadir

Materials	%
Glass	2
Plastic	10
Cardboard papers	6
Metals	1
Organic matter	77
Others	4

3.2. Characterization of leachate discharge from the great Agadir River

The chemical composition of the leachate is specific to each landfill. Indeed, it varies closely with the nature and age of the landfill, the type of waste and its degree of decomposition, the method of disposal, the nature of the landfill site and climatic conditions [23-29]. The results of the physicochemical analyses of the leachates are presented in tables 2, 3 and 4.

Table 2. Physico-chemical characteristics of leachates from fresh household waste in Greater Agadir

sampling	pH	Turbidity NTU	Conductance mS/cm	COD mg O2/l	BOD_5 mg O2/l	BOD_5/ COD	SO_4^{2-} mg/l	NO_3^- mg/l	Cd mg/l	Pb mg/l
E1	5.7	2320	106.76	38135	18062	0.47	242	45	ND	1.673
E2	6.2	2104	115.37	27800	12100	0.43	202.5	55	ND	1.56
E3	6.1	1920	114.7	32.000	17.000	0.53	323	63	ND	1.75
Moroccan NORMS	5.5-8.5	250.00	2.70	600.00	300.00	-	500	5	0.2	1.0

Table 3. Physico-chemical characteristics of leachates from intermediate household waste in Greater Agadir

sampling	pH	Turbidity NTU	Conductance ms/cm	COD mg O2/l	BOD_5 mg O2/l	BOD_5/ COD	SO_4^{2-} mg/l	NO_3^- mg/l	Cd mg/l	Pb mg/l
E4	6.95	1279	79	12656	2645	0.20	132.40	27.47	ND	1.262
E5	7.21	986	92.6	14560.7	5300.15	0.36	128	26.17	ND	1.12
E6	7.22	1120	91.2	15256	4357	0.28	156	43.24	ND	1.34
Moroccan NORMS	5.5-8.5	250.00	2.70	600.00	300.00	-	500	5	0.2	1.0

Table 4. Physico-chemical characteristics of leachates from stabilized household waste in Greater Agadir

sampling	pH	Turbidity NTU	Conductance ms/cm	COD mg O2/l	BOD_5 mg O2/l	BOD_5/COD	SO_4^{2-} mg/l	NO_3^- mg/L	Cd mg/l	Pb mg/l
E7	8.16	930	55.43	7440	1090	0.07	136	62	ND	1.284
E8	8.23	620	51	5123	351	0.07	116	56	ND	1.260
E9	8.26	634	34.3	8971	1654	0.18	145	46	ND	1.261
Moroccan NORMS	5.5-8.5	250.00	2.70	600.00	300.00	-	500	5	0.2	1.0

These results show that the physico-chemical parameters of the leachate vary from one sample to another. The composition of the leachate evolves rapidly under the influence of several factors [30].
pH measurements range from 5.7 to 8.26. These values are within the range of the pH limits for discharge into the natural environment [31]. For electrical conductivity the values obtained range from 34.3 to 115.37 mS/cm. The limit value is 2.7 mS/cm. The excessive salinity of the leachate from the Tamellast

landfill may be due to the presence of fish waste and the phenomenon of evaporation of the leachate in the storage tanks.

Leachate Turbidity ranges from 620 to 2320 NTU. It is higher than the Moroccan average standard of about 250 NTU. The chemical oxygen demand (COD) measured in this study varies between 5123 and 38135 mg/l, in fact, it is higher than the average Moroccan standard which is about 500 mg/l. As for the biochemical oxygen demand during 5 days of incubation (BOD_5), it varies between 351 and 18062 mg/l, while the standard is 100 mg/l. This organic fraction is strongly related to the incomplete degradation of organic matter in the waste. The BOD_5/CDO ratio gives an indication of the degree of biodegradability of the leachate. For young leachate, this ratio is higher than 0.3, for intermediate leachate it is between 0.1 - 0.3 and for stabilized leachate it is less than 0.1 [32]. The composition of the leachate depends on many factors: the composition of the waste, the water balance, the operating mode of the landfill, the climatic conditions, the thickness of the waste layer, the nature of the cover, the age of the landfill [21]. Table 5 shows the physico-chemical characteristics of the leachate from the Agadir landfill in comparison with some bibliographical data.

Table 5. Physico-chemical characteristics of leachates from the Agadir landfill site in comparison with some bibliographical data

Settings	Discharge Agadir (this work)	Meknes landfill [33]	Rabat Landfill [34]	Oujda's landfill [35]	Essaouira landfill [8]	Taza landfill [36]
pH	5.1 – 8.23	6.42-8.99	7 – 8	5.59-6.08	8.15-8.70	7.35
CE (mS/cm)	34.3 -115.37	2.73 - 7.35	23.13-74.60	0.015 - 0.038	26.90-51.20	24.05
COD (mg O_2/l)	5123-38135	1205-9207	260 – 50112	68036-89472	6106- 13939	5687.18
BOD_5 (mg O_2/l)	351-18062	53-386	10500	38188-70682	207 -851	4220

The leachate from the Agadir landfill is basic. The leachate pH values recorded range from 5.1 to 8.23 with an average of 7.11. The evolution of the pH during this monitoring shows fluctuations of the pH as a function of the residence time of the leachate in the basin and also as a function of the aging of the landfill. The average pH value of the Agadir landfill is higher than those raised at the Oujda landfill (5.83), and lower than the values of Essaouira 8.42 and Taza de Taza (7.35). The electrical conductivity reflects the mineralization of the analyzed sample. It allows to evaluate the global mineralization and to estimate the totality of the water-soluble salts [37]. The electrical conductivity values recorded during this monitoring fluctuate between a minimum of 34.3ms/cm and a maximum of 115.37 ms/cm. This variation in concentration depends directly on the volume of leachate in the pond. The average value of the electrical conductivity for the leachate analyzed is 82.26ms/cm, which is much higher than 2.7 ms/cm, considered as the limit value for direct discharge into the receiving environment [38]. This average value is higher than that recorded in the landfill of Rabat (22.792 mS/cm), Essaouira (av=32.45 mS/cm), Taza 24.05 mS/cm and Oujda (0.015-0.038 mS/cm). The results obtained highlight an important mineralization of the leachate from the landfill of Greater Agadir. It is explained by the burial of the waste from the port of the city of Agadir which contains a very high rate of mineral salts. BOD5 is an indicator of organic pollution. It expresses the level of biodegradability of the effluent [39]. It is variable during our study period and is between 351 and 18062 mg/l with an average of 6607.12 mg O_2/l. These values recorded in this landfill are higher than 300 mg/l, considered as the limit value for direct discharge. However, the average BOD5 recorded is lower than those of the Rabat landfill (10500 mg of O_2/l), and much lower than those of the Oujda landfill (38188 to 70682 mg of O_2/l). The COD represents the amount of oxygen consumed by the chemically oxidizable matter contained in the water. It is representative of the majority of oxidizable organic compounds and mineral salts [39]. The COD contents recorded in our study are variable over time and range from 7440 to 26451 mg O_2/l with an average of 16654.03 mg O_2/l. This average value is 27 times higher than the limit value for direct rejection (600 mg O2/l). The high COD values indicate a high organic load and are higher than those reported by other authors [35-37].

As a result, a leachate can vary from one landfill to another, but also within a landfill depending on the time and methods of operation and landfilling of the waste.

3.3. ***Study of the effect of coagulant or flocculants alone on the treatment of leachates***

3.3.1. Effect of ferric chloride $FeCl_3$

The study presented in this section is part of the general framework for the elimination of Iron(III) pollution, and the results are shown in Figure 4:

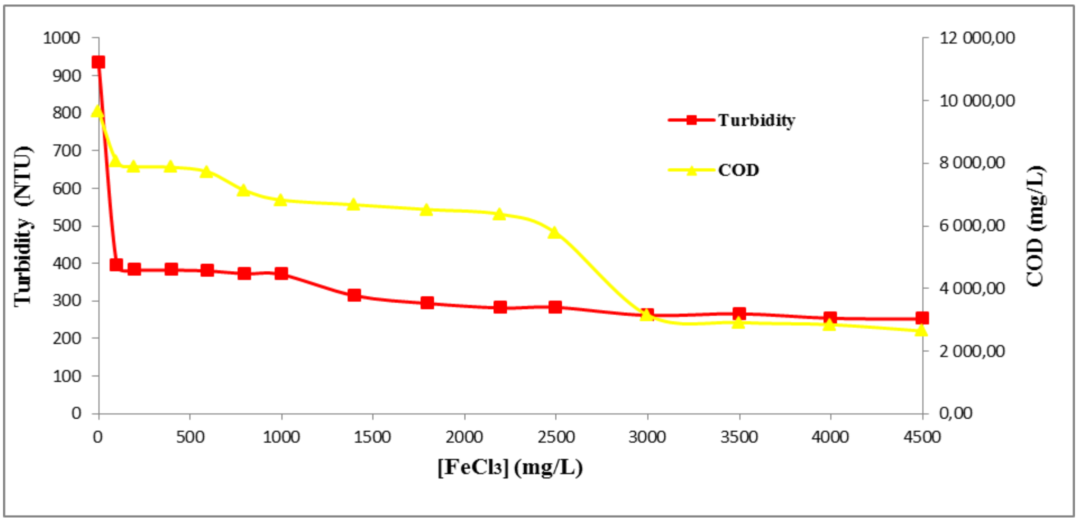

Figure 4. Effect of $FeCl_3$ cencentration on Turbidity removal and COD

These results show that the COD decreases with increasing $FeCl_3$ mass, therefore the optimum dose is estimated at 3000 mg/l with a removal of about 67%, and the Turbidity evolves in the same way as the COD with increasing quantity, with a removal of about 64% for 3000 mg/l of $FeCl_3$. The study of the effect of pH revealed an elimination of 74% of COD, and 77% of Turbidity at pH= 6.55. The results are shown in Figure 5:

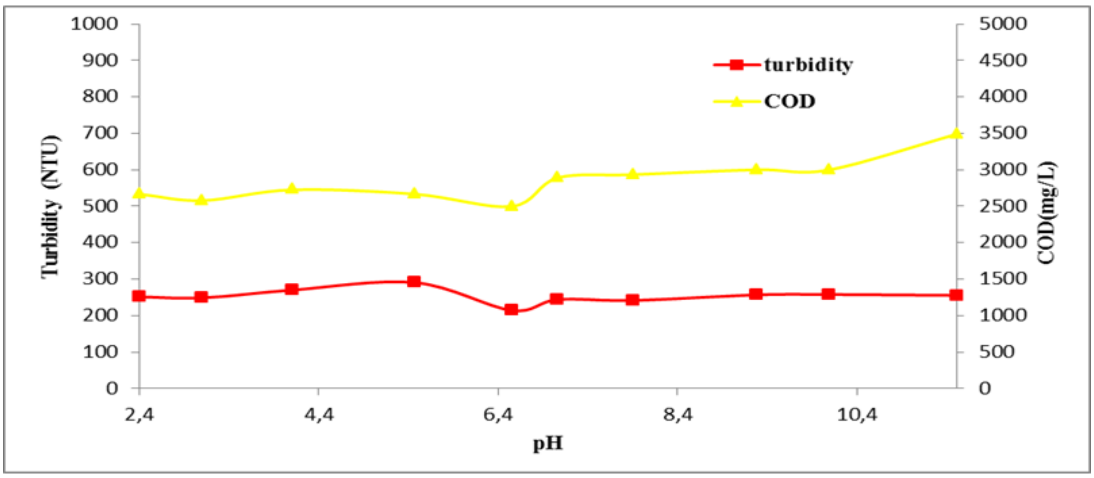

Figure 5. Effect of pH on Turbidity removal and COD ($FeCl_3$ at 3000mg/l)

3.3.2. Effect of alumina sulfate $Al_2(SO_4)_3$

From the results obtained in figure 6 showed a maximum COD removal with a removal of about 51%, and Turbidity with a removal of about 63% at 3000 mg/l, which is lower than that of $FeCl_3$, the Turbidity goes from 934 to 261 NTU (higher than that obtained by $FeCl_3$), and the COD= 4755mg/l. The study of the pH effect showed that the optimum is 5.6, figure 7 shows that the COD increases when the pH is higher than 5.6.

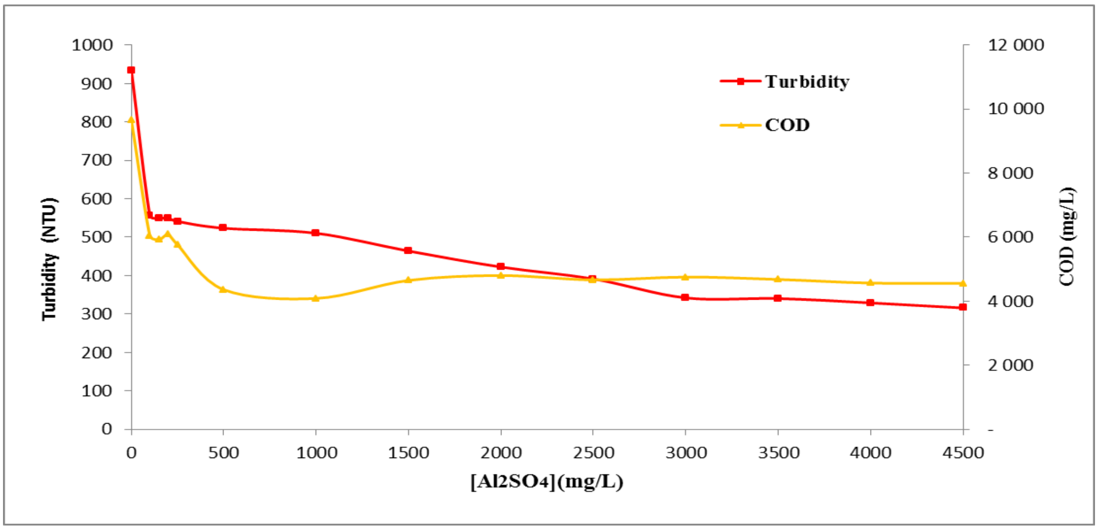

Figure 6. *Variation of Turbidity as a function of the doses of Alumina Sulphate $Al_2(SO_4)_3$*

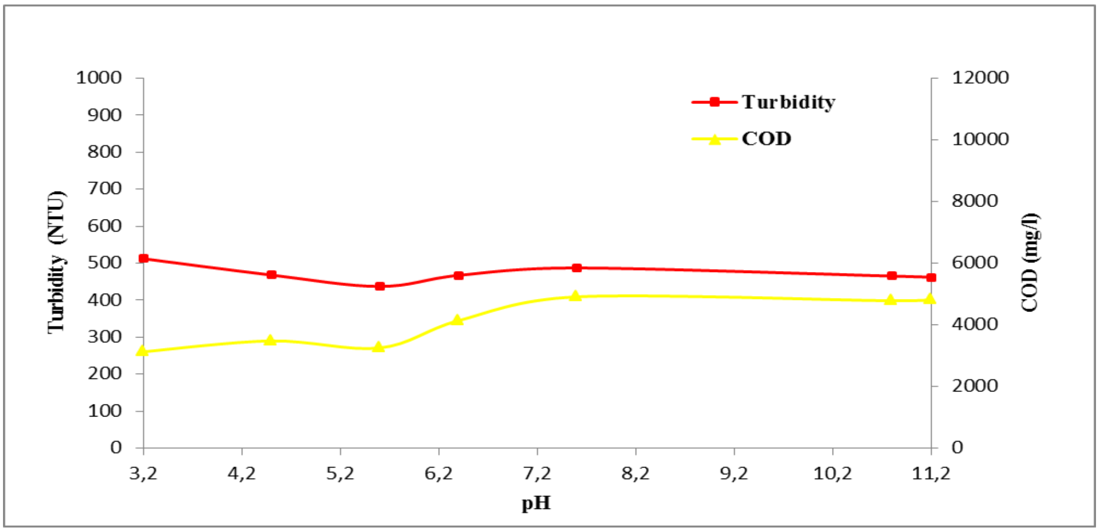

Figure 7. Effect of pH on Turbidity and COD removal (alumina sulfate at 1500mg/l)

3.3.3. Effect of polyacrylamide flocculants

The study of the coagulation flocculation of leachate discharges by the polyacrylamide flocculants is illustrated in figure 8. From these results in figure 5, the maximum COD removal and Turbidity is in the range of 200 mg/l. The COD decreases to a minimum at 200 mg/l and then increases. And the Turbidity remains little variable.

3.3.4. Study of the effect of mixing coagulant and flocculants

Figure 9 shows that the tests carried out using this mixture ($FeCl_3$ and polyacrylamide) have therefore reduced the leachate pollution, and it should be noted that the more the mass of flocculants increases, the more the COD content decreases, while the Turbidity decreases for the different flocculants concentrations. The optimal dose of $FeCl_3$ is 3000 mg/L at pH 6.5 while polyacrylamide is 140 mg/L.

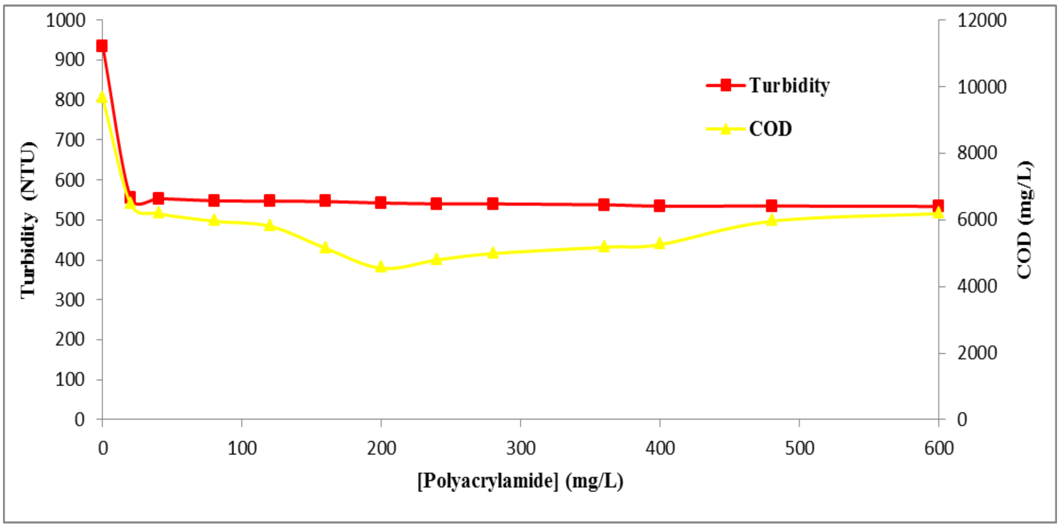

Figure 8. Effect of polyacrylamide flocculants on the removal of Turbidity and COD

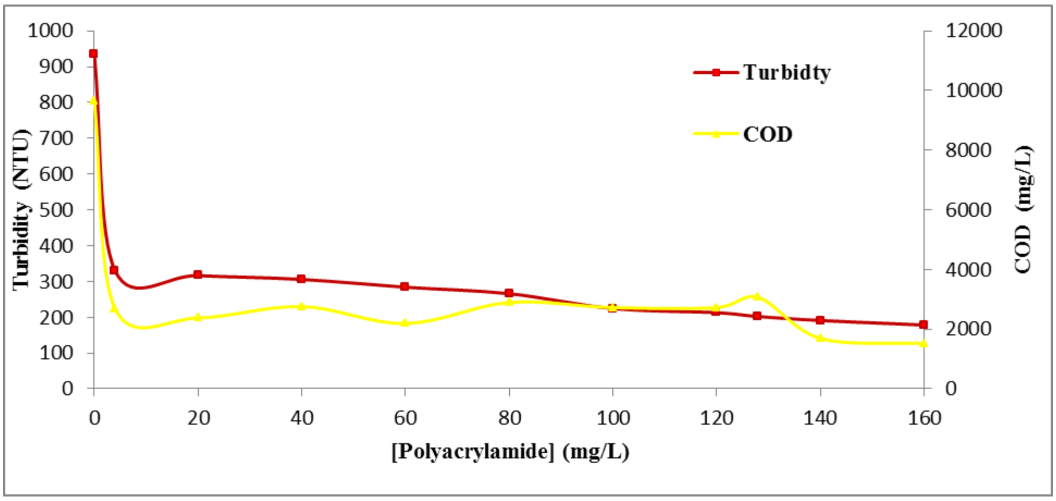

Figure 9. Effect of plycriyamide on the removal of COD and Turbidity ($FeCl_3$ at 3000mg/l)

Conclusion

The main objectives of this study were to assess leachate pollution in order to provide data that could be used as a baseline for leachate treatment in general and pollution abatement. This study shows that organic load, Turbidity and electrical conductivity are relatively high.

The treatment of the leachate from the landfill of Grand Agadir by a coagulation-flocculation process was evaluated. Several jar-test experiments were carried out in order to determine the optimal conditions to eliminate pollution for two coagulants (ferric chloride and aluminum sulphate) and flocculants (polyacrylamide).

FeCl3 allows a COD removal of 74% at pH=6.55, in the case of $Al_2(SO_4)_3$ the Treatment gave a COD removal of about 64% at pH=5.6.

The mixture of $FeCl_3$ /polyacrylamide allows a high removal of COD and Turbidity compared to the results obtained.

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