Journal of Biotechnology Letters
ISSN: 0976-7045 & E-ISSN: 0976-7053, Volume 4, Issue 1, 2013, pp.-51-59.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000250

PURIFICATION PERFORMANCE OF FILTRATION PROCESS FOR LEACHATE IN MOROCCO BY MARINE SANDS, CLAYS AND FLY ASH

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Received: December 12, 2012; Accepted: January 15, 2013

Abstract- This study focuses on the slow filtration of leachates by marine sands and matrix formed by clays A_1 and fly ash which have already given a satisfactory reduction of physicochemical pollution for the same leachate [1]. The determination of sand particle sizes and the mineralogical characterization of sand is an essential step to choose the best samples of sand filter.

The filtration device selected allowed us to reach high removal rate for all parameters. The removals rates of COD, BOD_5; SS; TP; Electrical conductivity and TKN were 78,46%; 96,13%; 90,23%; 98,54%; 81,53% and 44,82% respectively, according to Moroccan norms of indirect discharges. The metallic ions Al, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn are strongly retained with the concentrations less than Moroccan norms of direct discharges, especially for iron with an abatement rate of 99,32% and a concentration < 0,1 mg/L and chromium with an abatement rate > 97,8% and a concentration of 0,2 mg/L. The fecal coliforms and fecal streptococcus are effectively reduced with respective rates of 96% and 92,80%.

The use of this filtration technique using dropouts materials, whose investment costs are lower and the sustainability is more great both technically and financially, seems the best convenient solution for developing countries.

Keywords- Leachate, Filtration, Fly ash, Clay, Sands.

Citation: El Fadel H., et al. (2013) Purification Performance of Filtration Process for Leachate in Morocco by Marine Sands, Clays and Fly Ash. Journal of Biotechnology Letters, ISSN: 0976-7045 & E-ISSN: 0976-7053, Volume 4, Issue 1, pp.-51-59.

Introduction

Since always the water was inseparable from human activity, the depletion of water resources and the degradation of their quality is a major challenge. Indeed, one of the factors that govern the development of human society is the concern to obtain and maintain an adequate supply of water.

In Morocco, the increasing production of household and industrial waste causes critics pollution problems. The increasingly complex and heterogeneous nature of waste involves difficulties for their treatment and management. Much is landfilled without precautions, which is a real and continuing threat to the environment. The controlled dumping site of Fez in Morocco receives more than 800 tons per day of waste of any kind and could reach 950 tons per day in the summer season.

Indeed, since the deposition phase, the waste is submitting to degradation processes associated with biological and physicochemical complex reactions. The water seeps and produces leachate charged of organic and mineral substances that cause a mainly organic and metallic pollution type. These leachates are a source of surface water and groundwater contamination if they aren't properly treated. Apart to their often substantial pollution load, the leachate must undergo purification treatment before being discharged into the natural environment.

There are various methods of intensive treatment type, requiring energy sources for their running and heavy maintenance loads, the choice of sand filtration technique is often the most economical method in developing countries such as Morocco and offers advantage of high efficiency and simple operation. Thus, it accorded the needs of improving water quality while offering the opportunity to involve the community in the management, maintenance and plant operation.

This Work Aims to

- A physicochemical characterization of raw leachate ;
- A mineralogical analysis and a determination of particle sizes sands for choose the best samples for the leachate filtration;
- An assessment of the treatment performance of the filter device selected through the physicochemical and bacteriological filtrate analysis.

Materials and Methods

Materials

The apparatus listed in [Table-1] were used.

Table 1- Apparatus Used

Measured parameter	Equipment used	AFNOR references
Temperature	Thermometer	-
pH	pH meter G BOYER, JENCO 6173	NF-T-90-008
COD	Behr TRS 300	NF-T-90-101
BOD_5	Oximeter 538(WTW)/ DBOmeter :TS606/2	NF-T-90-103
SS	Filtration	NF-T-90-105
TP	Distillation : BÜCHI/distillation Unit K-350/Minéralisation : BÜCHI Digestion Unit K-424	NF-T-90-023
TKN	Distillation : BÜCHI/distillation Unit K-350/Minéralisation : BÜCHI Digestion Unit K-424	NF-T-90-110
Electrical conductivity	Conductimeter, HANNA EC 214	NF-T-90-031
Colour	Spectrophotometer G BOYER/ ANACHEM 320	-

Parameters Studied

Physicochemical parameters

The physicochemical parameters which have been the subject of this study are: Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5) Total Kjeldahl Nitrogen (TKN) Total Phosphorus (TP), Suspended Solids (SS), Electrical conductivity and colour removal from leachate. The latter parameter was obtained using the following formula:

$$\text{Colour Removal }(\%) = [(DOi - DOf)/DOi] \times 100$$

Where DOi and DO_f are the initial and final optical density of the colour from leachate, respectively, assayed at 455 nm [2].

Bacteriological Parameters

Two types of bacteria were analysed for to evaluate the treatment performance of the filtration system in terms of germs reduction. These are fecal coliforms (FC) [3] and fecal streptococcus (FS), indicators of fecal pollution. The bacteriological analyses were performed according to the method described by Marchal and Maury [4,5].

Analysis Techniques

Analysis Technique of Filter Substrates

Different analyses techniques are performed for filter substrates including:

- Analysis particle size: the size distribution curves were established by passage through sieve columns according to standardized method NF P 18-560;
- Chemical analysis by X-ray fluorescence technique;
- Mineralogical analysis by X-ray diffraction (XRD);
- Analyses by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Analysis Technique of Heavy Metals

For to determine the heavy metals concentrations, a taking of sample test to be analyzed is submitted to acid attack. The acids used are HNO_3 and HCl. After the dissolution of all the elements, the solution is filtered and then analysed by ICP. ICP analyses were performed in the laboratory REMINEX Marrakech (Morocco).

Experimental Device

Our experimental device is constituted of a glass column with a dimension of 6 cm in diameter and 50 cm in height. The effective height of the filter bed is 36 cm (Hs), 14 cm is used for the raw leachate (H_E), which is maintained constant along the experiments in order to keep the same load of leachate on the filter bed [Fig-1].

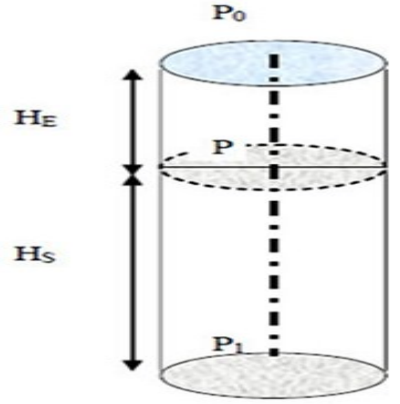

Fig. 1- Experimental Device

Leachate Collection Site

The leachate is collected from the controlled dumping site of Fez, located southeast of the city of Fez, in Ouled Mhamed Sidi Harazem road, it spreads over an area of 120 hectares. The general collector leachate records a flow rate of 15 l/min.

Filter Bed

The filter bed consists of five marine sands samples chosen from nine. These sand samples are collected along the coast of the city of El Jadida, washed with distilled water and then dried in an oven at a temperature of 50°C for 24 h. These sands are then added to the matrix formed by natural clay designated A_1 and fly ash.

The Experimental Protocol Followed

The method is based on the following principle: a slow filtration, the leachate passes under a constant load (14cm of leachate) through the filter bed, the load is kept constant along the experiments.

Results and Discussion

Physicochemical Characterization of Leachates

It is difficult to accurately determine the leachates properties because they evolve in time and space [6]. The volume of leachate required for this work was taken from a storage tank leachate. This sample was transported directly to the laboratory and stored at 4°C for 1 day before use. All the tests were performed in triplicate and the average values are determined according to AFNOR standard techniques.

Table 2- Physicochemical Characteristics of Landfill Leachate from Fez

Parameter	Unit	Raw Leachate	Moroccan Norms of Indirect Discharges
Temperature	°C	19,2	35
pH		8,13	6,5-8,8
COD	mg L^{-1}	5200	1000
BOD_5	mg L^{-1}	1375,12	500
SS	mg L^{-1}	430	600
TP	mg L^{-1}	0,65	10
TKN	mg L^{-1}	3146,5	-
Electrical Conductivity	ms cm^{-1}	37,9	-

[Table-2] summarizes the main physicochemical properties of leachate from controlled dumping site of Fez with the Moroccan norms of indirect discharges.

The pH

As to the landfill aged and the waste stabilised, the organic load reduces and the volatile fatty acids scarce (20 to 30% of the load of leachate) in favor for compounds of high molecular weight. The emergence of these compounds tends to decrease the biodegradability of leachate. Therefore, the pH is near neutral generally corresponding at the stable methanogenic phase [7].

The Chemical Oxygen Demand and Biological Oxygen Demand

The contents in COD and BOD_5 are respectively 5200 mg/L and 1375,12 mg/L, these are indicators of organic pollution of leachate. This polluting power of leachate comes mainly from the domestic use of detergents, pesticides, solvents, and also from storm water: runoff on agricultural land, on road network, etc. It can also come from industrial discharges or even from disinfection treatments of effluent by chlorine (haloforms) [8].

The COD/BOD_5 Ratio

The COD/BOD_5 ratio gives information about the biodegradability of waste. Applied at leachate from controlled dumping site of Fez, the COD/BOD_5 ratio is 3,78 indicating that these leachates are stabilized and poorly biodegradable [9].

The Total Kjeldahl Nitrogen and Total Phosphorus

The kjeldahl nitrogen comprises nitrogen in ammoniacal and organic forms, excluding nitrous forms (nitrites) and nitric form (nitrate). The origin of organic nitrogen may be the decomposition of organic waste, the human or animal organic waste (urea), adjuvants of some detergents.

Kjeldahl nitrogen concentration detected in the landfill leachate from the city of Fez achieved 3146,5 mg/L, which is comparable to the results obtained on landfill leachate from the city of Mohammedia: 3000 mg/L [10].

For the phosphates released into the environment, they are partly responsible for the eutrophication of watercourse. However, the N/P ratio indicator of eutrophication state [11] shows the values exceeding the threshold of 29, which indicates the possibility of the presence of cyanobacteria. This low content in total nitrogen and in total phosphorus of landfill leachate from Fez is explained by their consumption by the biomass with the production of CO_2 and H_2 [12].

Electrical Conductivity

The electrical conductivity is closely related to the dissolved substances concentrations and to their nature. The leachate studied have a very high electrical conductivity in the order of 37,9 $ms.cm^{-1}$, due to the highly mineralised landfill leachate [13].

Characteristics of the Supports Filter Used

Results of Sands Analysis

Particle size analysis

Curves from [Fig-2] to [Fig-10] represents the particle size distribution of each sand sample according to its size.

The results of particle size analysis indicate that the sands 1, 3, 4, 5, 8 and 9 have the predominant size of 160 µm, while the sands 2 and 7 have the same major size of 250 µm. On the other side, the sand 6 has a different size of 500 µm, so generally formed by crushed shells. This particle size distribution allowed us to deduce the Uniformity Coefficient (UC = d60/d10) characterizing each sand sample.

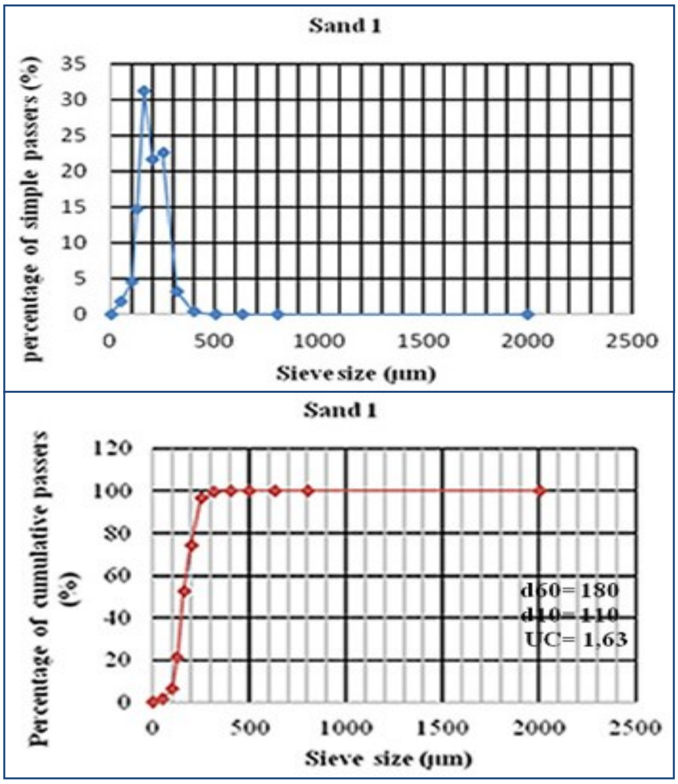

Fig. 2- Particle size Distribution Curves of Sand 1

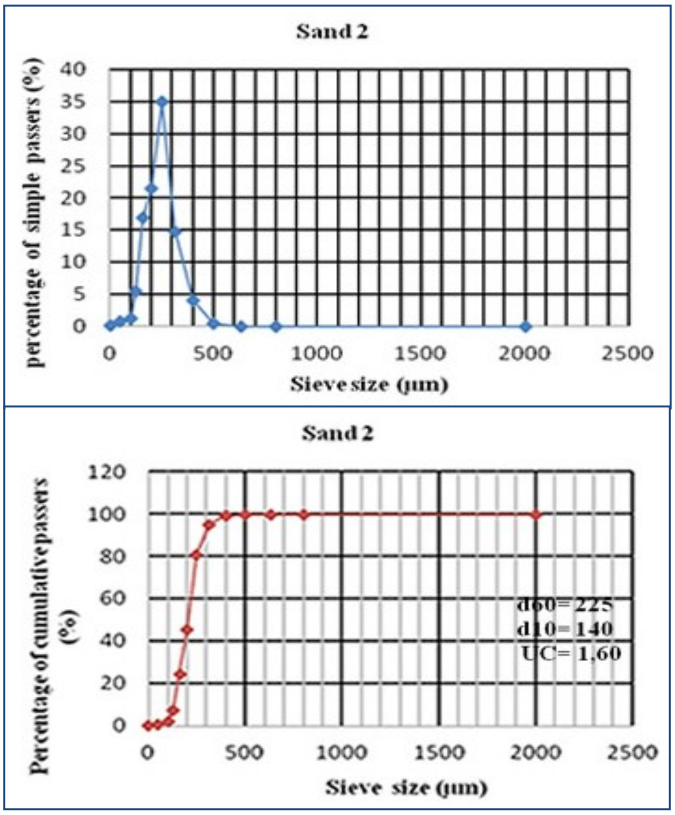

Fig. 3- Particle size Distribution Curves of Sand 2

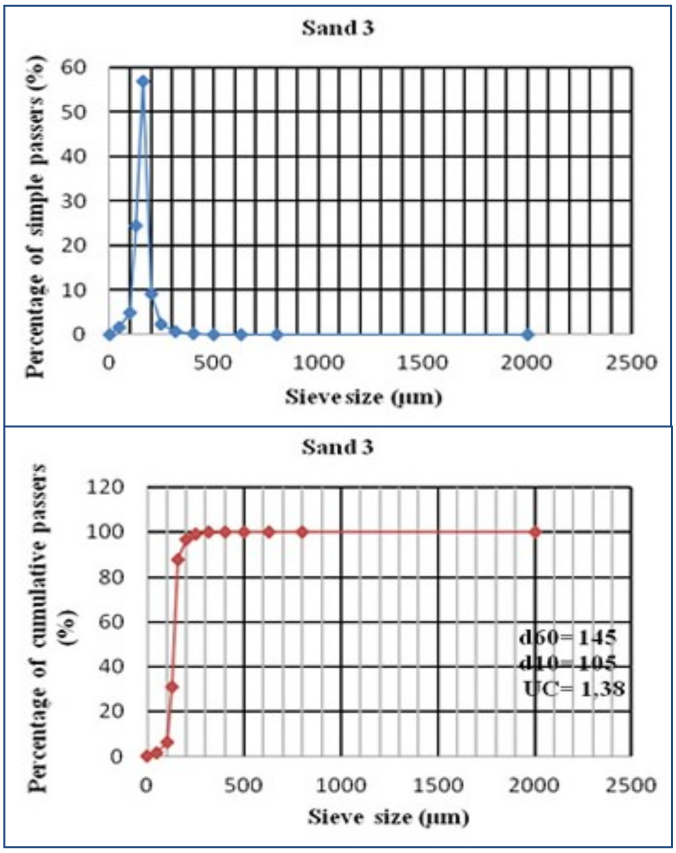

Fig. 4- Particle size Distribution Curves of Sand 3

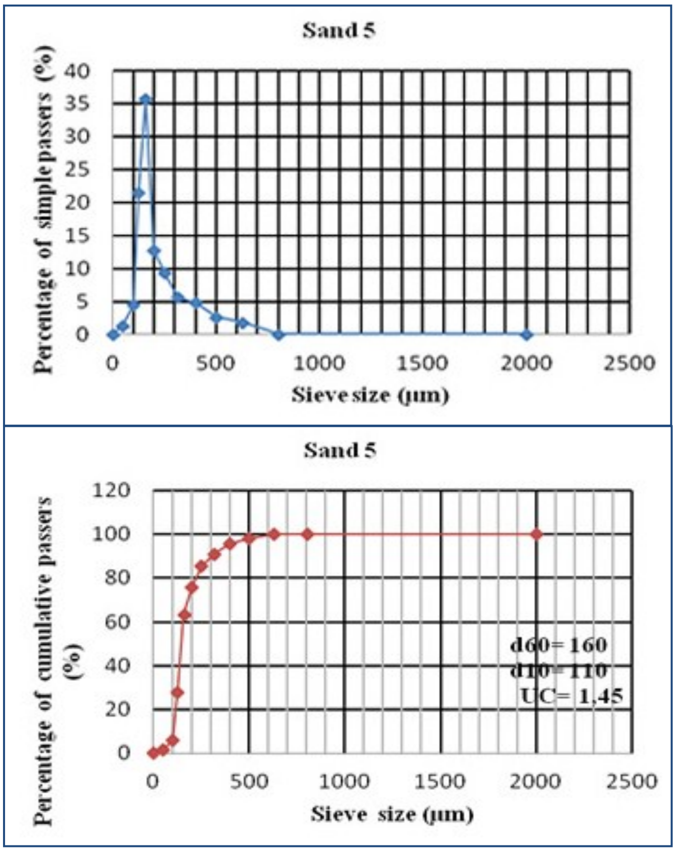

Fig. 6- Particle size Distribution Curves of Sand 5

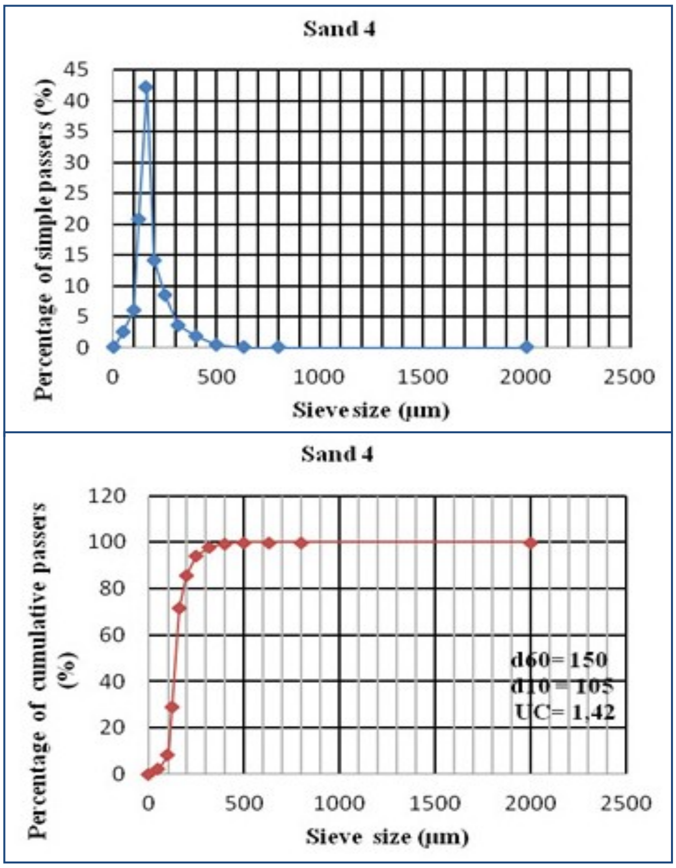

Fig. 5- Particle size Distribution Curves of Sand 4

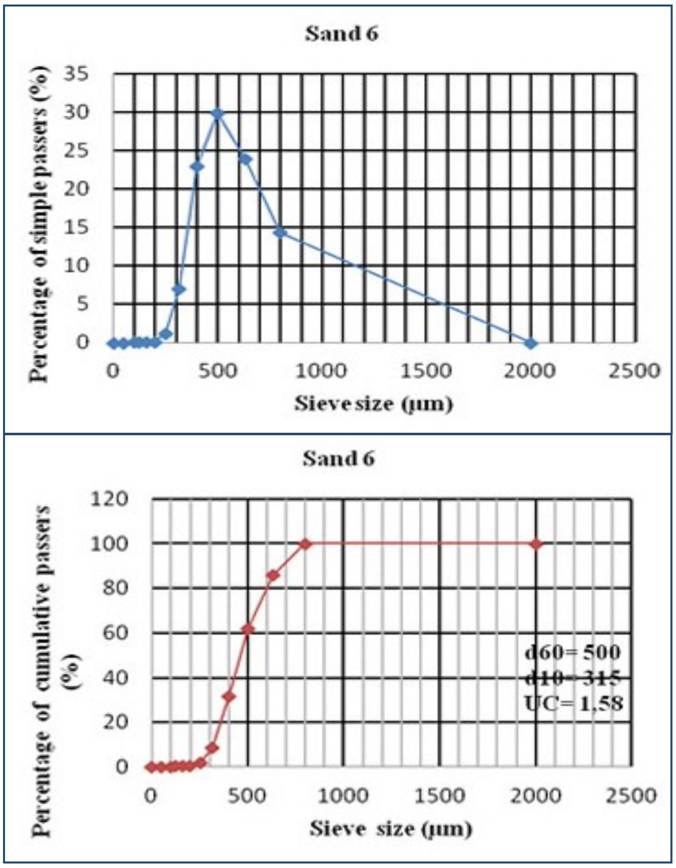

Fig. 7- Particle size Distribution Curves of Sand 6

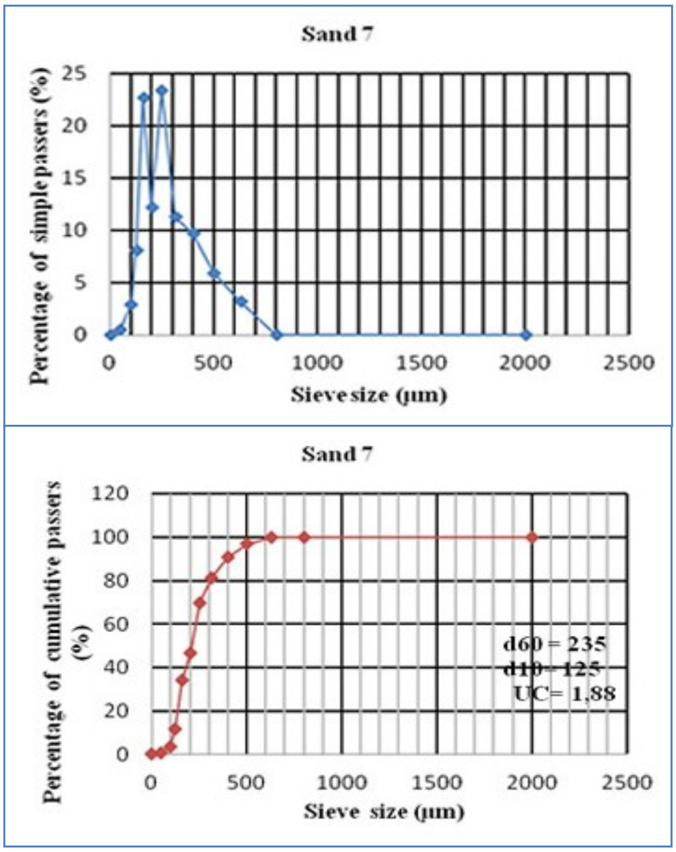

Fig. 8- Particle size Distribution Curves of Sand 7

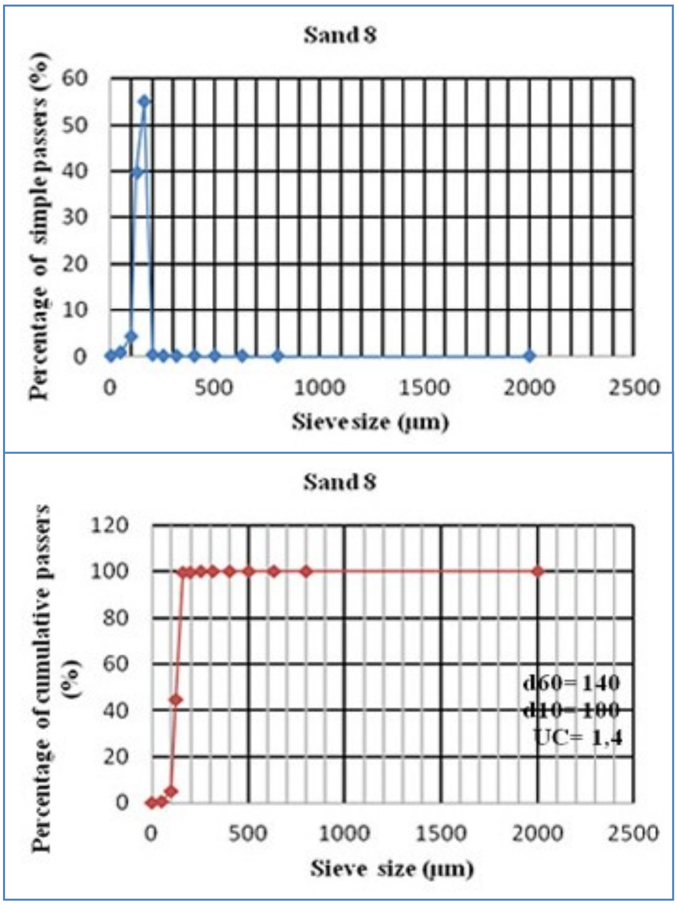

Fig. 9- Particle size Distribution Curves of Sand 8

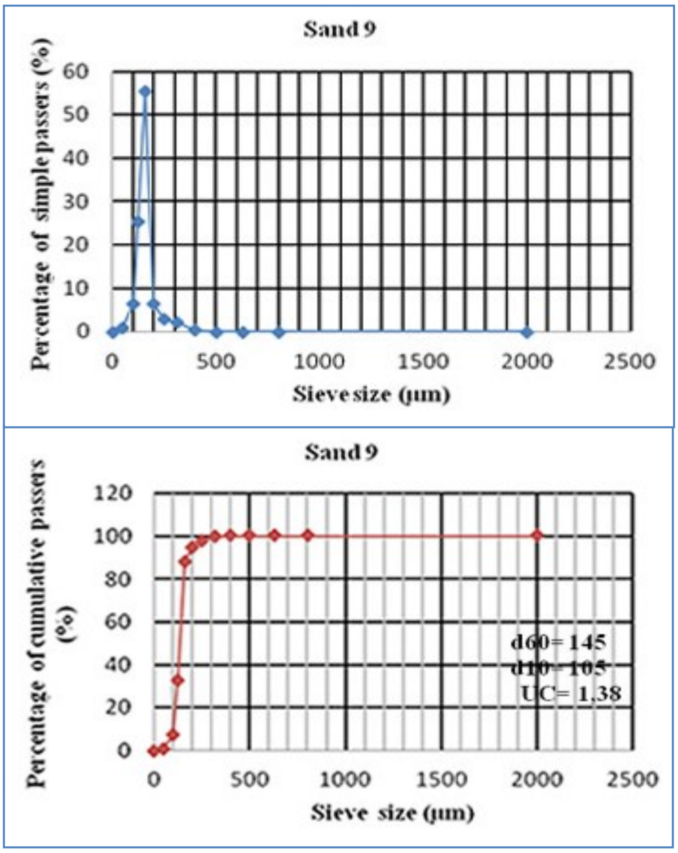

Fig. 10- Particle size Distribution Curves of Sand 9

The sands 3, 4, 5, 8 and 9 are chosen for the leachate filtration because of:

- Their low particle size (160 µm) so they will have the best treatment performance of leachate into increasing the adsorption surface, due to the decrease of grain size of adsorbent;
- Their Uniformity Coefficient UC which is and must be less than 1,5 [14] knowing that more the value of UC is close to 1, the homogeneity for the filter bed is better [14];

These five sand samples were subsequently analysed by ICP, firstly for to know their exact chemical composition and secondly for to determine if there is a probable contamination by the heavy metals, knowing that these sand samples will be used as the filter substrates for the leachate.

Mineralogical Analysis

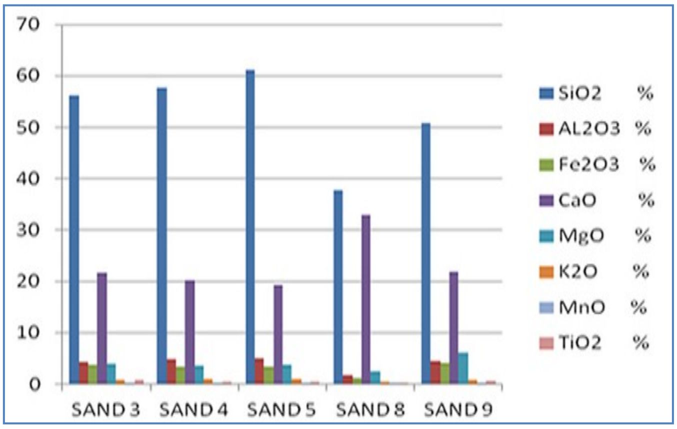

Fig. 11- Results of ICP analysis of sand samples

The results of this mineralogical analysis by ICP are shown in the histogram of [Fig-11].

The five sand samples contain various chemical elements. The most significant concentrations concern the silica (SiO_2) and the lime (CaO). The lowest value was recorded for the titanium dioxide (TiO_2).

The Results of Clay A_1 and Fly Ash Analyses

Chemical Analysis

[Table-3] summarizes the medium values expressed at an oxide percentage of different elements contained in fly ash and in the clay soil A_1 [1].

Table 3- Chemical Composition of Clay A_1 and Fly Ash Expressed in Weight Percentage (%).

Percent of Chemical Element (%)	Fly Ash	Percent of Chemical Element (%)	Clay A_1
SiO_2	57	SiO_2	46,27
Al_2O_3	34	Al_2O_3	12,73
Fe_2O_3	3,4	Fe_2O_3	5,30
$\sum SiO_2 + Al_2O_3 + Fe_2O_3$	94,4	CaO	12,50
CaO	10	MgO	3,21
MgO	0,02	K_2O	1,81
SO_3	0,5	SO_3	0
K_2O	1,2		

For the clays A_1, the sum of the oxides proportions identified is 100%. It consists principally by the silica in the quartz form (46,27%). It also contains a substantial content in alumina (12,7%) and in calcium oxide (12,5%).

For the fly ash, the sum of the elements percentages: SiO_2, Al_2O_3, and Fe_2O_3 is 94,4%, which can be classified among the silico-aluminous ash.

Mineralogical Analysis

For the clays A_1, this analysis allows to highlight the different mineral phases of soil A_1, according to their interplanar spacings. The result of X-ray diffraction is shown in [Fig-12].

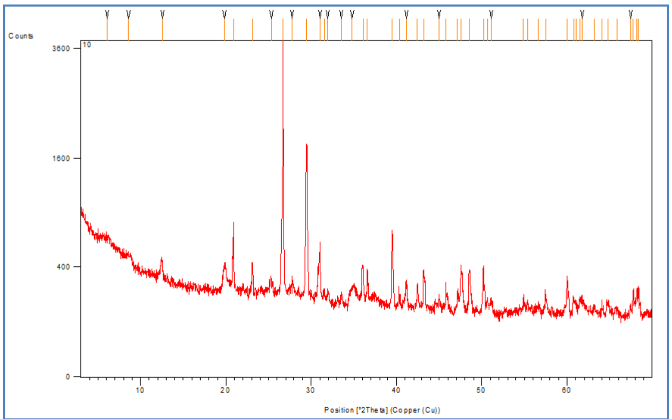

Fig. 12- X-ray Diffraction Pattern of the Clay Soil A_1

The X-ray spectra analysis shows that the soil A_1 is mostly composed by quartz followed by the magnesium calcite. These minerals types are the origin of the clays basicity.

For fly ash, the X-ray diffraction analysis revealed the existence of two peaks: the quartz and the mullite. This result is explained by the coal mineralogy used which is generally composed by the crystallised silica in quartz form and the phyllitic minerals of the clays group (shales) [1].

Pozzolanic Activity of Fly Ash

Cheriaf et al [15] studies showed that the fly ash are pozzolanic, that means when they are mixed with lime, they tend to react and form stable calcium silicate hydrates CSH as shown in [Fig-13]. This property is called pozzolanicity. The pozzolanic power is manifested by two successive phenomena: the combination with the lime to form the insoluble compounds then the curing.

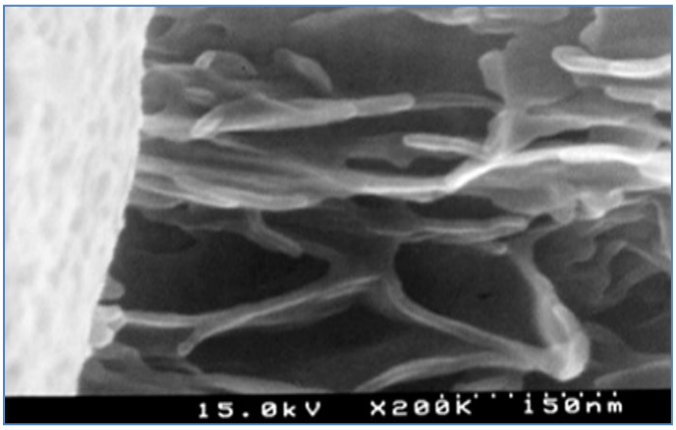

Fig. 13- Enlarged Image of the Pozzolanicreaction of fly ash

Filtration Results

Physicochemical Results of Leachate Filtration

The [Table-4] shows the results obtained after the passage of raw leachate through the filter material bed. At the bed surface, a thin layer is formed called "biological membrane" or biofilm. This thin layer is essential, because this is where the purification process takes place.

Table 4- Physicochemical Characteristics of Leachate before and after Filtration

Parameter	Unit	Raw Leachate	Filtrate	Rate Reduction (%)	Moroccan Norms of Indirect Discharges (mg/L)
pH	-	8,13	7,8	-	6,5-8,8
COD	mg L^{-1}	5200	1120	78,46	1000
BOD_5	mg L^{-1}	1375,12	53,12	96,13	500
SS	mg L^{-1}	430	42	90,23	600
TP	mg L^{-1}	0,65	$9{,}51 \times 10^{-3}$	98,53	10
TKN	mg L^{-1}	3146,5	1736	44,82	-
Electrical Conductivity	ms cm^{-1}	37,9	7	81,53	-

The results of [Table-4] revealed the removal rates of different physicochemical parameters with the concentrations strongly less than the Moroccan norms of indirect discharges.

Chemical Oxygen Demand and Biological Oxygen Demand Reduction

The COD reduction rate achieved 78,46% which is comparable to the result obtained for the leachate from AL Hoceima [16]. The content in COD obtained is estimated at 1120 mg/L close to the Moroccan norm of indirect discharge (1000 mg/L).

We also find a BOD_5 removal rate estimated at 96,13%, a removal rate strongly higher than that founded for the leachate from AL Hoceima [16]: between 60% and 67% at the exit of the bed sands. The content in BOD_5 obtained is 53,12 mg/L, significantly less than the Moroccan norm of indirect discharge (500 mg/L).

These COD and BOD_5 reductions are explained by the physicochemical characteristics of sands:

- The richness in silica exceeding 51% for each sand, it is a strong adsorbent with high electrical polarity ;
- The low sand size not exceeding 160 µm, which permitted to increase the specific adsorption surface;
- Iron ions contribute to neutralise the negative charges of organic matter of leachate.

Discolouration and Odor Reduction

The organic load reduction of COD and BOD_5 affects the leachate colour. This colour reduction of leachate achieved 97,80% with a pale yellow colour, it's a discolouration accompanied by a deodorization which explained by the high adsorption capacity of sands and clays.

Suspended Solids Reduction

There is also a maximum reduction of suspended solids up to 90, 23% with a concentration of 42 mg/L, significantly less than Moroccan norm of indirect discharges (600 mg/L). This elimination of SS could be explained by the physical characteristics of sands filters with UC < 1,5 which permitted to reduce load losses and get a retention in depth of suspended solids [14].

Electrical Conductivity Reduction

The organic matter has ceased to be available in mass and spawned a series of cascade reactions: the first effect, a decrease of microbiological activity causing a drop of amounts of organic material degraded (BOD_5 and COD), thus limiting the mineralization of inorganic substances. Therefore, a significant decrease of the electrical conductivity is recorded up to 81,53%. This high reduction of the electrical conductivity can also be explained by the retention of dissolved salts contained in the leachate (sulphates, calcium, sodium, magnesium, chloride ...) by sandy and clayey materials of the filter bed.

Total Phosphorus Reduction

We also note that there's almost total reduction of total phosphorus to 98,54%, with a concentration of $9{,}51.10^{-3}$ mg/L in the leachate filtered. This large reduction is due to the richness in ferric oxides, aluminum oxides and lime contained in marine sands (exceeding 27% for each sand), in fly ash ($CaO + \Sigma\% \ Al_2O_3 + Fe_2O_3 = 47{,}4\%$) and in clay soil (exceeding 30%). These oxides are considered as precipitating for the physicochemical removal of phosphorus giving insoluble precipitates of metallic phosphates.

Total Kjeldahl Nitrogen Reduction

The Kjeldahl nitrogen reduction is estimated to 44,82% with a concentration of 1736 mg/L in the filtered leachate. Indeed, the pH of the filtrate 7,8 is into the optimum range of pH (7,5 to 8,5) favoring the ammonia nitrification which is converted to nitrate, through bacteria of the genus of Nitrobacter, Nitrocystis, Nitrospira, Nitrococcus.

Analysis Results of Heavy Metals of Leachate before and after Filtration

We analyzed the metallic elements (Al, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in the raw leachate and the filtrate. Each value is the medium obtained after four sampling campaigns.

[Table-5] shows the concentrations of heavy metals in raw leachate which revealed considerable concentrations of iron, chromium, aluminum, manganese and zinc. Cadmium level was almost negligible. The iron concentration reached 14,65 mg/L, this metal is considered among the major stainless steel having an important role in numerous areas: daily life, mechanical industry, food processing, chemistry, medicine and surgery [17].

Table 5- Heavy Metals Analysis of Leachate before and after Filtration

Heavy Metals (mg/L)	Raw Leachate (mg/L)	Filtrate (mg/L)	Abatement (%)	Moroccan Norms of Direct Discharges (mg/L)
Al	3,245	0,5	84,6	10
Cd	0,028	< 0,1	-	0,2
Cr	4,554	< 0,1	> 97,8	2
Cu	0,428	0,1	76,63	0,5
Fe	14,65	< 0,1	99,32	3
Mn	2,002	< 0,1	> 95	1
Ni	0,841	< 0,1	> 88,1	0,5
Pb	0,215	< 0,1	> 53,49	0,5
Zn	1,663	< 0,1	> 93,98	5

The chromium concentration in the leachate reached 4,554 mg/L such as the concentration detected in the landfill leachate from Mohammedia (5mg/L) [10] and remains higher than the value measured in Akreuch dumping (35-120 µg/L) [18]. This is because many industrial units of tannery are installed in Fez. The chromium ion may originate from other types of waste collected with household waste such as cardboard paper and wood (total Cr = 25 mg/g of paper and 80 mg/g of wood) [19].

It should be noted that the dumping site of Fez receives all variety of urban waste and some industrial waste like food industrial waste into absence of regulation leading a rigorous management for dumping site.

The lead concentration reached 0,215mg/L, it is related to the industrial waste, particularly in the printing areas and the paint manufacture of lead-based.

[Table-5] shows that the leachate treatment by this filtration process further reduces heavy metals with concentrations less than the Moroccan norms of direct discharges and with removal rate higher than those founded after 7 days of leachate treatment by aeration [20].

The variability of removal rate of metals is due to the ionic form of each metal, the ability of each bacterium to accumulate the metal and the physicochemical conditions that differ from one organism to another for ensure the metals abatement.

Iron ions which recorded the highest concentration in the raw leachate and persisted at the treatment by aeration [20], are now strongly reduced with the high reduction rate of 99, 32% and a concentration < 0,1 mg/L strongly less than the norm (3 mg/L).

Chromium ions has an abatement rate > 97,8% with a concentration of 0,2 mg/L, strongly less than the norm of directs discharges (2 mg/L). This metal has always presented a major problem for the leachate from Fez, caused by industrial solid waste (tannery) of the city without any prior treatment.

After filtration, the contents in heavy metals of leachate accorded the Moroccan norms of direct discharges. Indeed, with the richness in silica of sand, the surface hydroxyl groups are formed by hydration which allows the adsorption of metallic cations [21]. The pozzolanic fly ash used react with lime of sands, this reaction produces stable calcium silicate hydrates CSH and further allows the stabilization of heavy metals [22] by various mechanisms:

- Mechanical trapping: the metallic contaminants can react as nucleation center and remain trapped in the hydrate thus formed [23, 24].

- Integration into hydrates: CSH can incorporate metallic contaminants by substitution (especially for aluminum and iron) in the crystalline lattice and have the ability to trap these contaminants in their interlayer space [25] This explains the high elimination of iron and aluminum of raw leachate;
- Adsorption: CSH have a good adsorption capacity [26].

Being good adsorbents, the ferric oxides and aluminum oxides contained in the ash (Σ% Al_2O_3 + Fe_2O_3 = 47, 4%) in the clay soil (18%) and in marine sands (9% each sand) have an important role for the retention of metallic ions [22].

Although rare, the manganese oxides of sands play also an important role because they have a particular affinity for some heavy metals (Cu, Zn, Ni, Pb ...) which they can adsorb in large amounts [27].

Bacterial Load Reduction

The research of pathogen germs specifically, is too costly and uncertain, which why we seek the fecal contamination germs (fecal coliforms and fecal streptococcus) to estimate the possible presence of pathogen germs. Indeed, there is a correlation between the presence of these indicators bacteria of fecal contamination and the presence of pathogenic bacteria [8]. The results of this analysis are shown in [Fig-14].

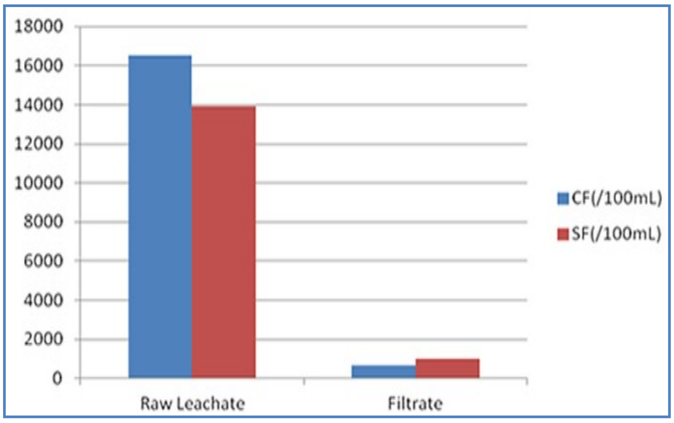

Fig. 14- Evolution for Fecal Coliforms Counts (FC) and for Fecal Streptococcus Counts (FS) of Leachate after Filtration

The bacteriological analysis of raw leachate shows that fecal coliform (FC) and fecal streptococcus (FS) are present at low concentrations in the order of 1,65x10^4/100 ml and 1,39x10^4/100 ml, respectively. The survival of fecal bacteria in these waters may be several months [28, 29]. The reduction rate of fecal coliforms and fecal streptococcus are 96 % and 92,80 %, respectively. The medium number of FC is 660 bacteria per 100 ml, this low content reflects a good bacteriological quality of treated leachate because the water containing 4,3x10^5 FC per 100 ml reached the bacteriological quality required for unrestricted irrigation [30]. The medium number of FS showed also a significant decline with 1000 bacteria per 100 ml in the treated leachate, but as in most cases, the mortality of FC was higher than that of FS according to the results of other studies [31, 32]. However, the FC/FS ratio can provide information about the fecal contamination origin [33, 34] although the significance of this ratio is sometimes disputed [34].

Filters sand can reduce the fecal contamination germs. Indeed, the soil has an important purifying power whatsoever on the physico-chemical and microbiological plane [35-38].

The major decontamination in bacterial load of leachate is ensured by the particle size characteristics, the thickness of the clogging layer, the thickness of the layer of filtered water, the frequency and periodicity of water inputs at the sand filters [39]. Thus, the bacteria retained by filtration or adsorption undergo a decline ensured by the soil microflora [40]. Also, the biological mechanisms namely predation of bacteria by the soil protozoa seems to have a significant effect on the bacterial load elimination [36,40,41].

Conclusion

Summarizing, the leachate filtration by marine sands added to the matrix formed by clay A_1 and fly ash, allowed us to identify the following points:

- The richness in silica of sands allows a higher reduction of COD and BOD_5 in a respective order of 78, 46 % and 96, 13% and a good adsorption of metallic cations;
- Sands used have uniformity coefficients UC< 1,5 which allowed a retention in depth of suspended solids;
- The pozzolanic reaction between fly ash and lime of sands promotes the stabilization of heavy metals of leachate with contents less than Moroccan norms of directs discharges;
- The richness in metallic oxides in substrates filter allows the total phosphorus reduction;
- Sands filter allows an important reduction of fecal contamination germs ;
- The filter substrates selected can be used for the landfill leachate treatment in big scale.

Abbreviations

Al- Aluminum

Al_2O_3- Aluminum oxide

BOD- Biological Oxygen Demand

CaO- Lime

Cd- Cadmium

COD- Chemical Oxygen Demand

Cr- Chromium

CSH- Calcium Silicate Hydrates

Cu- Copper

FC- Fecal Coliforms

Fe- Iron

Fe_2O_3- Ferric oxide

FS- Fecal Streptococcus

ICP- AES-Inductively Coupled Plasma - Atomic Emission Spectroscopy

K_2O- Potassium oxide

MgO- Magnesium oxide

MnO- Maganese oxide

Mn- Manganese

Ni- Nickel

Pb- Lead

SiO_2- Silica

SO_3- Sulfur trioxide

SS- Suspended Solids

TiO_2- Titanium dioxide

TKN- Total Kjeldahl Nitrogen

Total P- Total Phosphorus

UC- Uniformity Coefficient

XRD- X-ray diffraction

Zn- Zinc

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