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Preservation of Desert Environments from Urban Pollution

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Abstract: The preservation of desert environments from the pollution generated by the urban extension has become an important issue in the protection of fragile ecosystems. Geo-environmental engineers often face this challenge when they design landfills for solid waste or lagoons for wastewater on top of very pervious soils which are characterized by *sabkha soils*. A modern landfill or a lagoon must be designed to prevent fluids in the waste migrating from the site to the underlying soil formations. With the help of sand/bentonite mixtures and geosynthetics innovative solutions can be offered to several situations. This paper gives an overview of these several solutions and the design principles behind these options. Also, the paper give some new insight on which properties of sand/bentonite mixtures are important for designing natural protective liners on sabkha soils. Furthermore, the paper will present the clayey product which can be used into these structures.

Key words: Sabkha · Fragile ecosystems · Landfill · Solid waste · Sand/bentonite mixture

INTRODUCTION

Continuously increasing awareness in protecting fragile ecosystems from pollution generated from waste sites has given rise to the design of well-isolated containment structures. The transport of leachates emanating from surface water impoundments is of great importance to engineers because of the pollution problems these leachates cause in pervious formations like sabkha soils. Sabkha is generally composed of sand deposits mixed with silt and clay intercalated with evaporites The use of liner systems is common in preventing transport of contaminants to these surrounding pollution-prone environments. These measures generally involve the application of low permeability natural clays and sand-bentonite mixtures or synthetic materials [1]. Compacted natural clays are often used in constructing hydraulic barriers underneath waste containment systems. The usual thickness for such liners is between at least a few decimeters to greater than one meter [2]. Typically, the hydraulic conductivity must be less than or equal to 1×10^{-7} cm s^{-1} for soil liners and covers used to contain hazardous waste, industrial waste and municipal waste [3]. In the absence of impervious natural soils, compacted mixtures of bentonite and sand have been used to form barriers to fluids [4]. Sand bentonite mixtures are one of the lowest cost technologies available for constructing an impervious liner for waste water ponds and sanitary landfills. The imperviousness of these liners can be influenced by many factors such as: the matrix material (i.e., bentonite); grain size distribution of sand; and the fines content [5]. The objective of this paper is to present a novel liner materiel composed of sand and bentonite. Bentonite serves as pore sealant yielding low hydraulic conductivity, whereas the sand is utilized in purifying the leachate. Various ratios of bentonite to sand (B/S) are tested to obtain the most desirable mixture ratio of this liner material for the protection of the fragile ecosystems.

Principles of Antipollution Barrier System: Leachate is the medium by which soluble materials inside a landfill may subsequently be transported into the environment. In order to avoid uncontrolled release into the environment, landfills are lined and the leachate is collected ant treated. In the construction of barrier systems different kind of materials, either natural or synthetic, can be used individually or as component of a composite [6].

The functions of the elements of the barrier systems are as follows:

- Bottom barrier should provide impermeabilization to leachate and prevent biogas from escaping into environment, provide mechanical support for the waste mass.
- Side barrier in landfills constructed below surface level should provide impermeabilization to leachate and to external water fluxes, mechanical resistance to water pressure and prevent lateral migration of biogas.

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- Top cover should prevent biogas from escaping into the environment, avoid or reduce rainwater infiltration.

Clayey soil is the most common natural lining material. Beside other mineral liner materials, bentonite and bentonite –soil mixtures play an important role as lining material for landfills [7]. This material is, in general, much more uniform and predictable in its behaviour than, for example, excavated clay without pretreatment. Bentonite is a general term for indicating clay minerals capable of swelling, when wet, up to 15-18 times their dry volume [8]. Mixtures of bentonite and sandy soil can provide a low permeability liner, particularly useful in areas where natural clay soil is not available.

MATERIALS AND METHODS

Experimental Program

Material: Bentonite from the volcanic basins of western Algeria.
Yellow sand.
Heavy metals: Cu^{2++}, Pb^{2++}, Zn^{2+}, Cd, Mn, Ni.
Leachate I and Leachate II

Characterization: Mineralogy of the smectite clay (bentonite) and sand.
Specific surface of the smectite clay (bentonite).
pH of the clay.
Methylene bleu Value of the smectite clay (bentonite).

Micro-Analyses: Morphology of the clay and the sand.
X ray diffraction of the smectite clay (bentonite).
Composition of the smectite clay (bentonite).

Free Swell Tests: Impact of heavy metals on the free swell of bentonite.
Impact of heavy metals on the plasticity of bentonite
Plate Water Absorption test – PWA- for heavy metals
Impact of leachate on the free swell of bentonite.
Impact of leachate on the plasticity of bentonite.
Plate Water Absorption test – PWA- for leachate.

Hydraulic Conductivity Tests: Impact of heavy metals and leachate on the hydraulic conductivity of the bentonite-sand mixtures.

- The smectite clay (bentonite) used in this study is from Maghnia. It is used with no special treatment. It is commercially available and is largely used in civil engineering applications.
- The sand used in the clay-soil mixture is from the Constantine's region. It is a clean fine material. Visually, it possesses a uniform grading curve.
- Metals, which have a density superior to 5 g/cm^3, are termed heavy metals (according to the Geneva protocol relative to the heavy metals). We have qualified as heavy metals, metals which are presenting a toxic hazard to the health and to the environment: lead (Pb), mercury (Hg), cadmium (Cd), nickel (Ni), zinc (Zn) and copper (Cu). They origined from the combustion of petrol, coal and waste. They accumulate in the organism and provoque serious perturbations in the vital functions of the body.
- It is difficult to define one type of leachate because it differs from one landfill to another. The leachate changes also with time in relation with the age of the waste itself. In this study two type of leachate have been used (leachate I and leachate II). Leachate I, which is of organic type, has been obtained from an experimental landfill mounted by the author. leachate II is an industrial leachate originated from an industrial waste.

Tests Procedures: The determination of the size range of particles of the bentonite is determined par hydrometer analysis. For the sand, the mechanical analysis has been used. The specific surface for the bentonite is determined by the Blaine method. The Blaine is an apparatus used to find the specific surface for powder material, the value of which is given in cm^2 /g.The plate water absorption- PWA- test shows the capacity of dry bentonite to absorb water. From a suspension in demineralised water, the pH of the bentonite is measured with a pHmeter. The suspension is agitated for 24 hours before taking the measure. To determine the Atterberg limits, the samples of clay are mixed with the contaminating solutions in an air-tight recipient and kept for 12 hours. The free swell tests are done on samples of bentonite contaminated by solutions of heavy metals. The solutions heavy metals are obtained by mixing metallic ions with distilled water to get a 50 ppm concentration for the purpose of the essays. The procedure of the free swell test is described in the literature.

X ray diffraction tests were performed on a group of clay samples (bentonite) which were previous contaminated by solutions of heavy metals and the two types of leachate of this study.

The hydraulic conductivity tests were realised in a variable head permeameter on different contaminated mixtures of sand bentonite (at 10 % bentonite in weight chosen from preliminary tests). The test procedure is well described in the literature.

RESULTS AND DISCUSSION

Bentonite occurs frequently in Algeria. Some of them stem from the volcanic ash, like those in the chellif River area (Figure 1), while others have been formed by hydrothermal alteration of rhyolite rock [9].

The bentonite formed by ash fall vary in thickness from about 10 centimeters to around 5 meters. They represent Cretaceous and tertiary sediments with interbedded pyroclastics and lava flow, the complex stratification indicating variation in homogeneity and smectite content.Some of them have high smectite content with sodium as major adsorbed cation and with no enrichment of silica below or above.

The bentonite from Maghnia area selected, for this study, corresponds to a sodium bentonite [10] commonly used in Algeria. Other properties of this material are given in Table 1.

X-ray diffraction spectra (Fig. 2) indicate that the bentonite is predominantly a montmorillonite with some quartz and chemical analysis (Table 2) confirms that it is predominantly Na-montmorillonite.

Table 1: Properties of Maghnia bentonite

Specific surface[1]	872 m^2/g
Gs[2]	2.72
Free Swell Index[3]	
(Résultat de l'essai de gonflement libre modifie)	35 cm^3/g
Plate Water Absorption test – PWA-[4] Absorption)	900%
Methylene bleu Value[5]	29.41
pH[6]	10.1
Liquid Limite[7]	216%
Plasticity Index[7]	120%
Shrinkage limit[8]	11%

[1] : Norme ASTM C 204 – 89.
[2] : Norme NF P 94 -054.
[3] : Norme ASTM D 5890
[4] : Procédure ASTM E-946.
[4] : Norme ASTM D 5890.
[5] : Norme NFP 94 068.
[6] : A suspension of 20g de bentonite in 400 ml of distilled water.
[7] : Procédure norme NF P 94 -051
[8] : Procédure ASTM D427-61.

This paper presents also data on the swelling behaviour and hydraulic conductivity of Na-bentonite and bentonite –sand mixtures with various mixtures.

The impact of heavy metals and leachate on the property of free swell de la bentonite was investigated over a range of time until swelling ceased. Figure 3 and Figure 4 show data of the swelling behaviour of the bentonite plotted against time.

Table 2: Chemical composition of the bentonite

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	SO_3	Rb_2O
%	58.455	17.143	4.589	4.364	1.078	7.532	5.512	0.314	0.221	0.107

Fig. 1: Two profiles from Algerian bentonite deposits formed in different ways

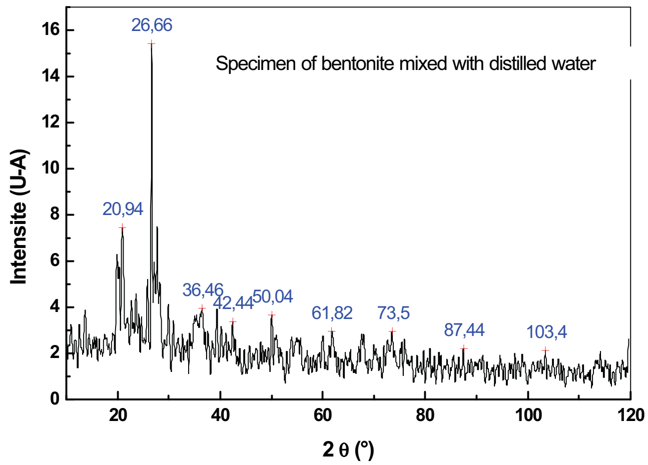

Fig. 2: X-ray diffraction spectra of the bentonite

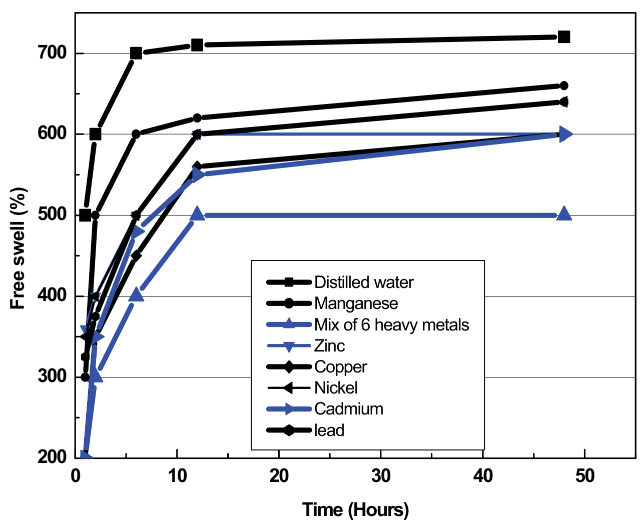

Fig. 3: Free swell in presence of heavy metals

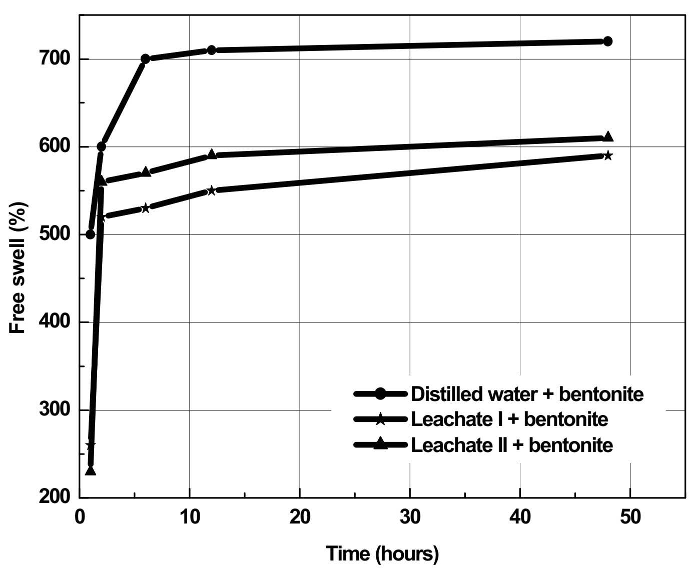

Fig. 4: Free swell in presence of leachate

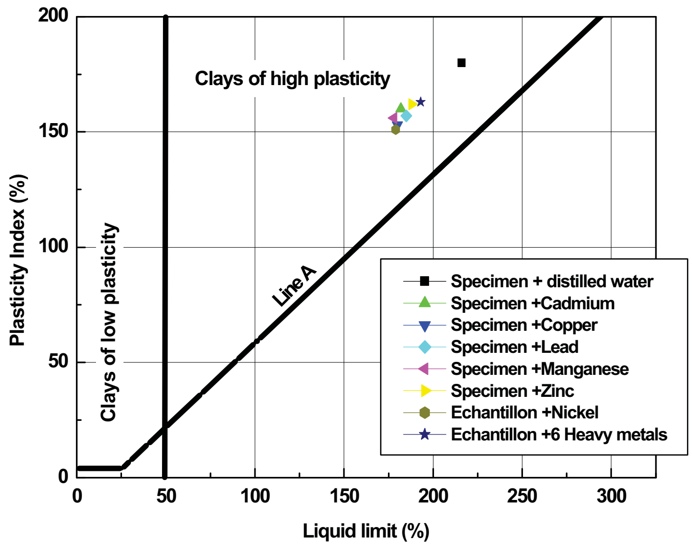

Fig. 5: Impact of heavy metals on the Plasticity of the bentonite

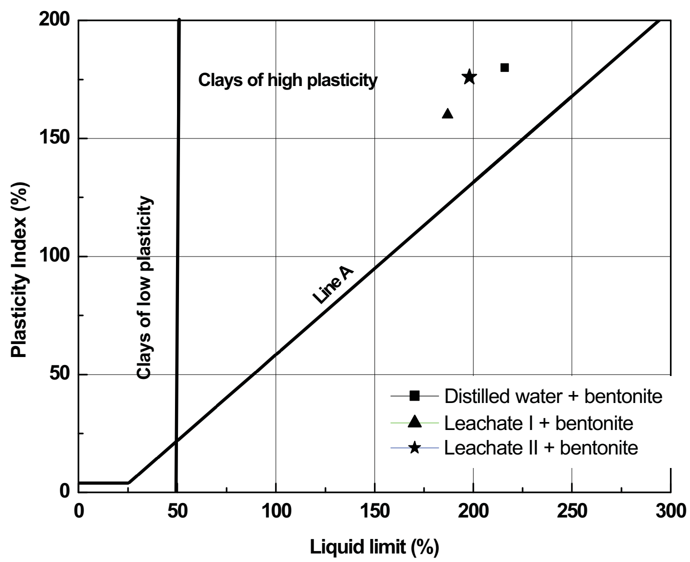

Fig. 6: Impact of leachates on the Plasticity of the bentonite

Figure 5 and 6 shows respectively the results of the impact of the heavy metals and the two type of leachate on the characteristics of plasticity of the bentonite. The results are presented in the Casagrande graph which is a graph of liquid limit versus the liquidity index.

To investigate the effect of the contaminants both organic and inorganic on the swelling of the powdered clay, Table 3 and 4 shows respectively the resultats versus time.

The method used to investigate the hydraulic conductivity of the bentonite –sand mixtures is the direct measurement using the falling head permeameter. Table 5 the hydraulic conductivity data for bentonite-sand mixtures tested with distilled water and solutions contaminated with heavy metals ions of different nature.

The hydraulic conductivity for bentonite- sand mixtures tested with distilled water and the two types of leachate is shown in Table 6.

The swelling behaviour of the bentonite is a function of the fluid. The bentonite swells differently when put in contact with contaminated solutions. The swelling capacity is also differently inhibited by the nature and type of pollutant in the solution.

Table 3: Effect of heavy metals on the powdered weight of the bentonite

Samples	Increase of specimen weight in 18 hours
Distilled water + bentonite	900 %
Solution of copper + bentonite	780 %
Solution of zinc + bentonite	790 %
Solution of cadmium + bentonite	750 %
Solution of lead + bentonite	755 %
Solution of nickel + bentonite	870 %
Solution of manganèse + bentonite	840 %
Solution of 6 heavy metals + bentonite	600 %

Table 4: Effect of leachate on the powdered weight of the bentonite

Samples	Increase of specimen weight in 18 hours
Distilled water + bentonite	900 %
Leachate I + bentonite	710 %
Leachate II + bentonite	790 %

Table 5: The trend of the variation of hydraulic conductivity with time

Hydraulic conductivity (cm/s) Time (days)	Cu^{2+}	Pb^{2+}	Cu^{2+} +Pb^{2+}	Distilled water
1	7.56 x10^{-8}	8.44 x10^{-8}	6.7x10^{-8}	1.9 x 10^{-9}
2	6.01 x10^{-8}	8.04 x10^{-8}	6.1x10^{-8}	1.83 x 10^{-9}
3	5.88 x10^{-8}	7.66 x10^{-8}	5.9x10^{-8}	1.79 x 10^{-9}
4	4.82 x10^{-8}	7.11 x10^{-8}	5.5x10^{-8}	1.7 x 10^{-9}
5	5.09 x10^{-8}	6.55 x10^{-8}	5.4x10^{-8}	1.5 x 10^{-9}
6	5.2 x10^{-8}	5.01 x10^{-8}	5.35x10^{-8}	1.23 x 10^{-9}
7	5.3 x10^{-8}	4.25 x10^{-8}	5.35x10^{-8}	9.6 x 10^{-10}
8	5.0 x10^{-8}	4.11 x10^{-8}	5.35x10^{-8}	9.6 x 10^{-10}

Table 6: The trend of variation of hydraulic conductivity with time

Hydraulic conductivity (cm/s) Time (days)	Leachate I	Leachate II	Distilled water
1	5.58 x 10^{-7}	5.04 x 10^{-8}	1.9 x 10^{-9}
2	5.36 x 10^{-7}	4.2 x 10^{-8}	1.83 x 10^{-9}
3	4.32 x 10^{-7}	3.69 x 10^{-8}	1.79 x 10^{-9}
4	3.65 x 10^{-7}	3.02 x 10^{-8}	1.7 x 10^{-9}
5	3.21 x 10^{-7}	2.46 x 10^{-8}	1.5 x 10^{-9}
6	2.2 x 10^{-7}	2.4 x 10^{-8}	1.23 x 10^{-9}
7	2.32 x 10^{-7}	2.4 x 10^{-8}	9.6 x 10^{-10}

The hydraulic conductivity of the bentonite –sand mixture is affected diversely by the pollutant in the solution. A small amount of bentonite, in the mixture of bentonite-sand, can assure a low hydraulic conductivity to meet the specification for an antipollution barrier and minimise its cost.

The bentonite is particularly effective clay for producing low permeability barriers because it has a high swelling capacity. Depending on the type of bentonite, it can have a free swell (the volume increase when unconfined) between 200 and 1200%.

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