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# PROPERTIES AND POTENTIALITIES OF THE SEWAGE SLUDGE LIKE RENEWABLE ENERGY SOURCE IN CEMENT MANUFACTURE

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Abstract— The **sewage sludge potentiality to decrease the energy demand in cement manufacture was the subject of this study. The initial idea is to replace the ordinary Portland cement clinker by mud of various origins which the technical landfill centers represent the end of its life cycle. This study enabled us to examine the effect of mud of different natures: urban and industrial like source of silica and waste lime like source of lime; in the temperature reduction to obtain a profit of energy.**

**From a mixture of sewage sludge urban or industrial, we can synthesize belitic cement at 1200°C.**

**This study also explored the possibility of produce belitic cement at low temperature (1100°C). In this work, the raw mixture (limestone and clay) of belitic cement was substituted by another mixture made up of waste lime of the industrial gases industry ENGI, of urban sewage sludge and industrial muds resulting from the Company Paper mill and Boarding from Saida GIPEC. The results showed that: a mixture (GIPEC sludge, ENGI residue.) with CaO /$SiO_2$ =1.73 gives belitic cement without free lime. The X-ray Diffraction analysis shows the presence of the most active phase β$C_2S$. The 50% substitution of the Ordinary Portland cement by urban mud produces a belitic clinker at 1200°C where the majority of lime was combined. The X-rays diffraction analysis showed that the strongly reactive phase of the belite (β$C_2S$) was stabilized as well as the crystallization of $C_3S$.**

Keywords— **belite, mud, energy, cement, lime, sludge.**

## I. Introduction

The daily life and several activities (industry, transportation, resource exploitation, agriculture, etc.) lead to massive waste and sludge production, generally derived from liquid effluent treatment processes commonly called sewage sludge. Sewage sludge are solid matrices, often heterogeneous and variable, which makes the characterizations and treatments quite complex. Also, further sludge use or its disposal would be associated with high costs of transportation, combustion or drying, and the sludge to be destroyed would take up too much space in landfills. This is a problem.

In Algeria, the industry has a major responsibility for the global pollution of the country, especially the cement industry [1].

However, it is also recognized that the production industry remains a key driver of economic growth, but reducing pollution and the rational use of resources and energy are imperatives for sustainable development and make frequently unit costs of products lower.

The cement industry is a big heat and electricity consumer. Global energy requirements for cement manufacturing are estimated at about 6 109 GJ / yr for fuels and 200 TWh / yr for electricity [2].

This industry is also a strong emitter of greenhouse gases (carbon dioxide - $CO_2$), coming from the heat energy needs, but also from the cement manufacturing process. The issue of climate change encourages us to look for all means of reducing $CO_2$ emissions: the improvement of specific energy consumption must be coupled with a new approach to replace traditionally manufactured products (clinker) with products with similar characteristics [3-4].

In fact during the decarbonation, a quantity of 520 kg of $CO_2$ per ton of clinker is emitted. The only way to reduce $CO_2$ emissions is to use already decarbonated products [5-7].

They are generally used as a partial substitute for clinker because they have the ability to develop mechanical resistance similar to clinker.

They are beginning to be used as a partial substitute for mixed raw materials when their ability to replace clinker is low [8-9].

This paper presents the possibility to energetically promote sludge from urban wastewater treatment plants and industrial effluents in the cement industry. It includes tests carried out to obtain belitic clinker at low temperature and it presents the results obtained during the evaluation of Portland clinkers produced by substitution of the Portland raw material by the collected sludge.

## II. Materials and Methods

### *A. Materials*


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The urban sewage sludge was collected from the water treatment plant of Saida city, Algeria. The industrial sewage sludge was collected from the effluent treatment plant of GIPEC paper mill group in Saida city, Algeria. The samples initially were dried in oven at 105°C for 24 h, finely crushed and properly stored for further studies. These samples were noted as U-SS and GIPEC-SS, respectively. The chemical composition was determined.

The lime milk rejected by the plant of manufacturing of acetylene of the National Industrial Gases Company (The Linde Group), located in Sidi Bel Abbes was collected from the cesspool.

After fast settling of the lime milk, the residue was dried in oven at 105°C for 24 h and finely crushed noted ENGI-R .

The natural raw materials: clay and limestone are from the cement plant of Saida. The raw meal is removed from the storage tank feeding the oven of the Saida cement manufactory.

### B. Characterization

The chemical analysis of raw materials was performed with X-fluorescence XRF 9900. The loss on ignition (LOI) was determined by chemical analysis according standard norm [10]. The trace elements of the urban sewage sludge and the GIPEC sewage sludge were detected by Perkin Elmer A Analyst 700 atomic absorption spectrophotometer (air-acetylene oxidizing flame, slit width 0.5 nm). X-ray analyses were performed using Bruker D8 Advance diffractometer employing copper K$\alpha$ radiation ($\lambda$= 0.154 nm) operating at 40 kV and 40 mA with a fixed slit. The chemical composition of synthesized clinkers was determined by volumetric dosages in accordance with Algerian Standard Specifications [11]. The residual free lime content is determined by the (glycerine–alcohol) method, according to the European standard [12]

### C. Synthesis experiment

6 g of mixture was prepared with different low $CaO$ / $SiO_2$ ratios = 1.73, 1.87 and 2. The reference mix (M0) was prepared from natural raw materials: limestone as $CaO$ source and clay as $SiO_2$ source, quarried from the quarries of Saida cement plant, Algeria. The two other mixtures were prepared from alternative raw materials. The second mix (M1), the clay was totally replaced by urban sewage sludge and the limestone was replaced by ENGI residue. The third mix (M2) was composed of the industrial sewage sludge from GIPEC and ENGI residue.

The raw materials are finely crushed separately at 90 µm mesh sieve. After homogenization, the mixture was introduced into an alumina crucible and placed in a muffle furnace with a heating rate of 20°C/min. The sample was maintained at the desired burning temperature during 30 min, then quickly cooled by applying air flow and crushed.

## III. Results and discussions

### A. Characterization of raw materials

Table 1 illustrates the percentage oxide composition of the raw materials used. The chemical compositions of alternative raw materials are shown in Table 2. The results indicated that the high value of Loss on ignition (LOI) reported to the sewage sludge is due to important amount of water and carbonates which contained the materials. The silica, alumina and lime are the major oxides of the samples. The iron and magnesium oxides exist as minority elements. The ENGI residue is composed mainly lime

Table 3 illustrates the trace elements determined in the urban sewage sludge and GIPEC sewage sludge samples. The results indicate significant amounts of Zinc (568 and 224.6 mg/Kg), Lead (137 and 45.79 mg/Kg) and Copper (131 and 53.54 mg/Kg) in both sludge respectively. The trace elements content of the alternative raw materials shows highest Zinc and Lead concentrations in urban sewage sludge. Nickel is highest in GIPEC residue

The XRD patterns of alternative raw materials: urban sewage, GIPEC sewage and ENGI residue were shown in figure 1. The X-ray diffraction pattern of urban sewage sludge indicates that it contains some mineral phases concerning montmorillonite (M), illite (I), quartz (Q), calcite (C) and dolomite (D) (Figure 1). In the same figure, the GIPEC sewage sludge is seen to be composed of calcite, Quartz and Kaolinite (K). Also, it is clear from the figure that hydrated lime (HL) is the main phase composing ENGI residue powder.

TABLE I
OXIDE COMPOSITION OF THE RAW MATERIALS (%)

| Raw material | Chemical composition (wt %) | | | | | |
|---|---|---|---|---|---|---|
| | **CaO** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **MgO** | **LOI** |
| limestone | 48.99 | 5.22 | 2.55 | 0.90 | 1.02 | 40.50 |
| Clay | 6.92 | 51.82 | 16.14 | 7.31 | 1.95 | 11.07 |

TABLE 2
OXIDE COMPOSITIONS OF THE ALTERNATIVE RAW MATERIALS (%)

| Alternative raw material | Chemical composition (wt %) | | | | | |
|---|---|---|---|---|---|---|
| | **CaO** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **MgO** | **LOI** |
| U- SS | 14.05 | 21.69 | 3.43 | 1.41 | 3.67 | 60.76 |
| GIPEC-SS | 22.17 | 13.25 | 7.4 | 1.06 | 1.14 | 55.34 |
| ENGI-R | 71.08 | 1.82 | 1.44 | 0.56 | 0.85 | 24.49 |

TABLE 3
TRACE ELEMENTS OF THE ALTERNATIVE RAW MATERIALS (MG/KG)

| Alternative raw material | Element (mg/Kg) | | | | | |
|---|---|---|---|---|---|---|
| | **Cu** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** |
| U-SS | 131 | 568 | 1 | 37 | 24 | 137 |
| GIPEC-SS | 53.54 | 224.6 | <6 | <40 | 28.27 | 45.79 |




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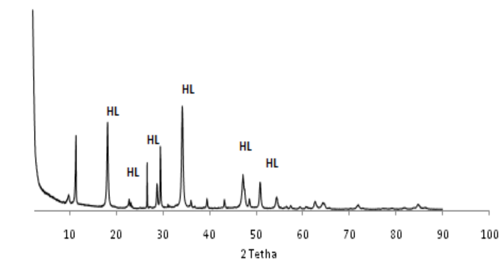
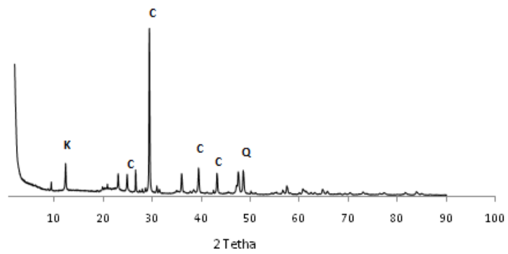
c) ENGI Residue




b) GIPEC sewage sludge




a) Urban sewage sludge

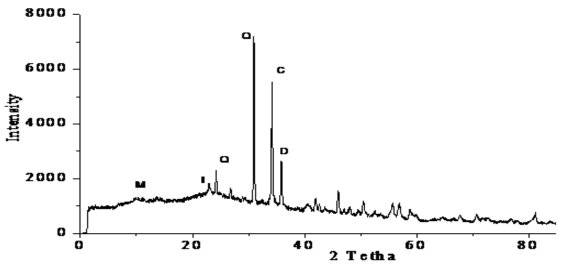



Fig. 1 The X-ray diffraction patterns of the sewage sludge (M=Montmorillonite, Q=Quartz, Ha=Halloysite, I=Ilite, K=Kaolinite, C=Calcite, HL=Hydrated lime).

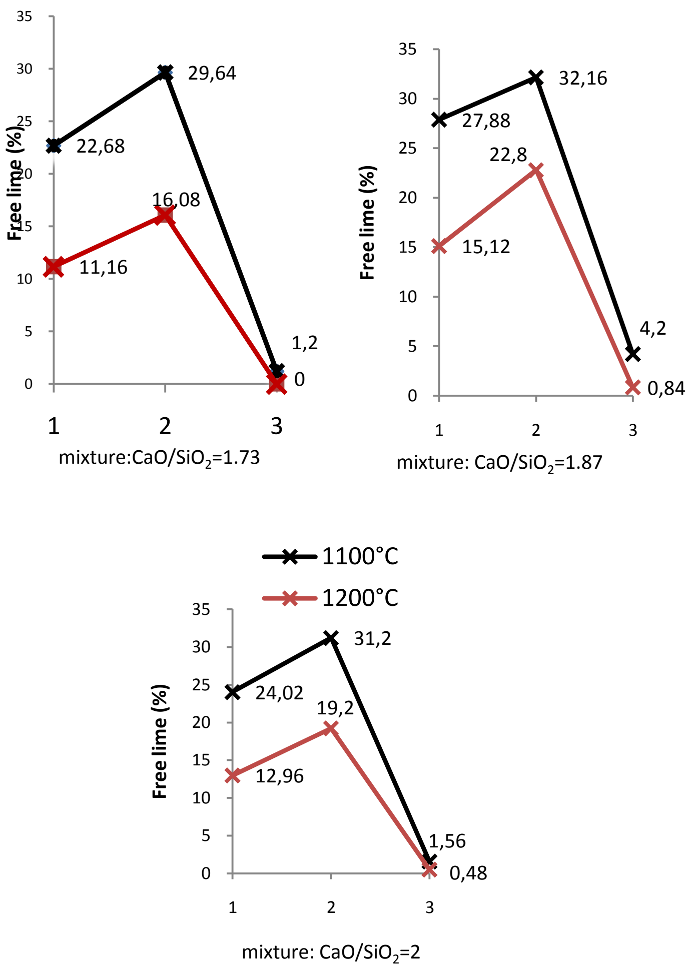



Fig. 2 Variation in free lime content. versus mixture composition (1=M0, 2=M1, 3=M2)

## B. Clinkers

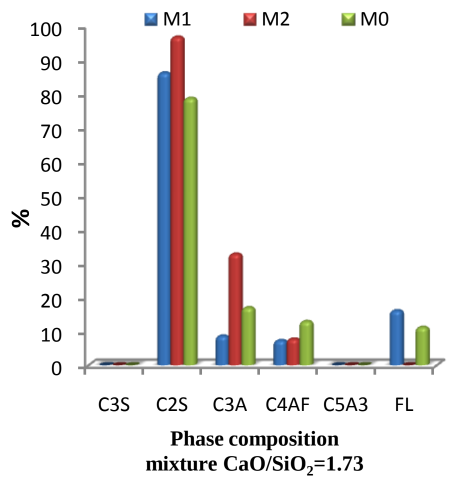
The results obtained from the burnability tests of the mixes are illustrated in Figure 2. The results show that burning at 1200 °C leads to lower free lime contents in the clinkers.

For $CaO/SiO_2$=1.73, the liquid solid reaction is more complete.

The mixtures prepared from alternative raw materials exclusively favors lime combination with the different oxides As the quantity of lime in the mix increases, the combination of this one with other oxides present is not complete.

The free lime quantity in the clinkers prepared from GIPEC sewage sludge and ENGI lime residue is lower than in the clinkers prepared from natural raw materials and the other alternative raw materials (Fig. 2). This result indicates that the calcium element present in GIPEC residue can precipitate the clinker minerals.

Figure 3 illustrates the concentration of the clinker phases resulted at 1200°C as estimated from Bogue equations.

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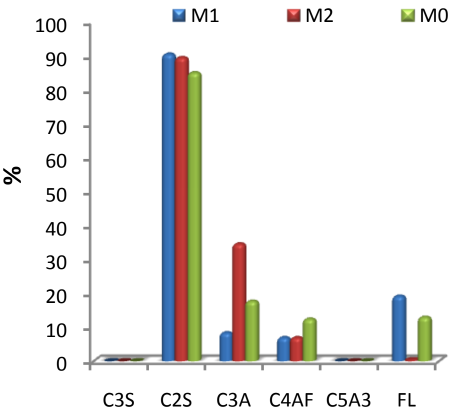
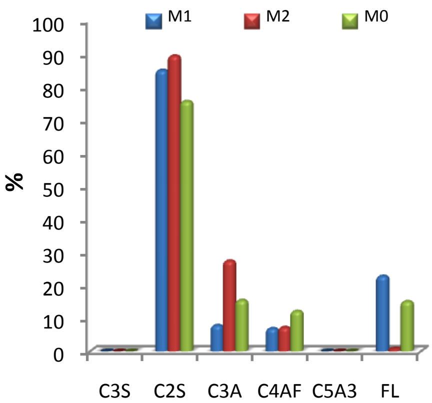



**Phase composition mixture $CaO/SiO_2$=1.87**




**Phase composition mixture $CaO/SiO_2$=2**

Fig. 3: Phase composition of clinkers synthesized at 1200°C

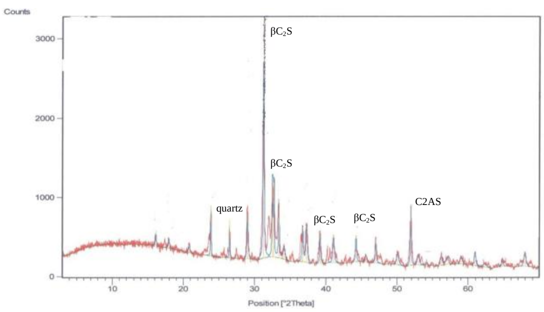



Fig. 4: Phase composition of clinkers synthesized at 1200°C

Belite phase is the predominant in all clinkers. The belite value of clinker synthetized form M2 mixture with ratio $CaO/SiO_2$ = 1.73 is 96.72 %. The X-ray diffractogram of this clinker is illustrated in Figure 4. Active belite $\beta C_2S$ characteristic peak is seen at an angle of 31

## IV. Conclusions

The ENGI residue can be a source of lime. GIPEC mud lime is about twice higher than silica. But also this mud is rich in heavy metals especially zinc. The silica content in urban sewage sludge is highest. Urban sewage sludge is rich in lead. The loss on the ignition is considerable in sewage sludge. From a mixture of waste sludge urban or industrial, cement belitic can synthesized at 1200°c.

These alternative raw materials contain a very high organic matter count which by combustion generates an energy which can contribute to the combination of various oxides present in the mixture believed at low temperatures. the formation of $c_2s$ was clearly supported by the use of the sewage sludge. the rate of $c_2s$ in the clinkers obtained starting from the mixtures of sludge varies between 85% and 96%.cao/$sio_2$ ratio of 1.73 in the raw mixture composed of waste mud makes it possible to obtain a clinker rich in belite of 96.72%.sludge gives different results according to their origin. This can be with the metal elements present or also with the grains shape of mud

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