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CHARACTERIZATION OF WASTE ROCK FROM THE PHOSPHATE MINING FIELD OF BLED EL HADBA , ALGERIA IN AN ENVIRONMENTAL CONTEXT

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Abstract: *In the world the demand and consumption of raw materials and minerals is sharply increasing, which has encouraged countries around the world to intensify the mining of different materials and ores such as phosphate. In Algeria, while phosphates are one of the country's most important natural resources; they are ranked third in the world in terms of proven reserves with 2,200,000 tones, mining of this ore is low. The Bled El Hadba deposit is one of the promising Djebel Onk's deposits with 841 million tons of reserves and which starts mining in 2020. The ore is exploited by the open pit method, therefore a large quantity of waste rock will be evacuated to appropriate surfaces called waste rock dumps, and will consequently induce an increasingly serious destruction of the eco-environment. Intelligent use of solid mine waste to compensate for resource scarcity and protect the environment appears to be a necessity. The main purpose of our research work involves the characterization and environmental management of sand waste rocks from Bled El Hadba phosphate deposit. In this context, we studied a series of runs: Particle size analysis, Cleanliness by the equivalent of sand, and chemical analysis. The results obtained are promising and encouraging for the use of sand waste from the mining of phosphates from Bled El Hadba in the glass and building materials industry.*

Keywords: *Open pit mining, Phosphate, Sand, Waste rock, Environment.*

1. Introduction

Every day open pit mining produces large amounts of waste which occurs in several stages of the mining process and throughout the life of the mine, from the first exploration drilling project to the last processed material before mine closure. Responsible mining can play a key role in developing a more sustainable mining industry. Sustainable mining practices focus on resource sustainability, the environment and socio-economic benefits [1]. The waste generated is inevitable and has generally negative repercussions on the environment but some waste can be used safely in other applications, such as building materials. The reuse of mining waste as an alternative raw material in construction materials is a promising solution that not only equilibrates the deficit between production and consumption but also protects the environment. This solution makes it possible to reduce the volume of waste and to preserve the non-renewable natural resources which are intensively used in construction (clay, limestone, sand, etc.) [2,3]. In the same context, researches have studied total and partial substitution of phosphate waste rocks in ceramic tile manufacturing and they confirmed good adaptability for making traditional ceramic tiles [4].

Mining waste includes materials resulting from the exploitation of minerals during the extraction, beneficiation and treatment processes. Depending on the components and characteristics of the materials treated, the effects on the environment will be

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different. Particular attention is needed to recover this waste and make it ecologically rational. The objective is to mobilize companies on clear environmental requirements and manage to organize construction sites differently [5].

For this, we must allow everyone to:

- ✓ better know the different types of wastes and their disposal systems;
- ✓ integrate waste management into the organization of the worksite and the contractual documents;
- ✓ carry out concretely the wastes sort on the site.

This approach can go further than the simple concept of waste management and deal with all the environmental impacts of construction sites. It will take the form of a clean or green project and thus becomes a part of the process of sustainable development, the aim of our work.

In Algeria, the economics of mining is in a state of great change. Sales opportunities and prices are continuing to increase for most commodities. Profits reached levels not seen in decades. In Algeria, phosphates are one of the country's most important natural resources; that has been ranked third in the world in terms of proven reserves with 2,200,000 tons [6]. However, phosphate has been poorly exploited for over 45 years [7].

Algeria has a significant deficit in building materials. Facing the seriousness of the environmental problems due to the over exploitation of resources, the Algerian government decided in 2001 to devote a significant financial envelope to achieve the objectives set out in the National Action Plan for the Environment and Sustainable Development PNAE -DD [8] relating to the management, control and elimination of waste which constitutes the starting point of this new environmental strategy.

Problems related to mining wastes

The term "mining wastes" actually includes various products from the extractive industry and in particular mine tailings. These are generally geological materials too poor to be exploited in the technical and economic conditions of the moment [9, 10]. This economic distinction is variable over time. These waste rocks are products made up of soils and rocks excavated during the operation of a mine, after recovery of the commercially valuable part that constitutes the ore. Depending on the types of mine tailings and their uses, they could be used directly or dressed in different sizes. Many mining residues have been subject to financial and material "valorization" by being resold or reused as backfill material, or as fuel or raw material for the production of reconstituted fuel from dust. For example, we may cite [11]:

- ✓ A very good material for the construction of roads, depending on the size of the waste rock, coarse can be used for the construction of the platform ,those of the fine size for the pavement of the road;
- ✓ A very good material for construction of dams;
- ✓ A very good material for beneficiating coarse and fine aggregate of concrete;
- ✓ It could be used for making construction bricks when beneficiated to suitable size; and
- ✓ To backfill the mined out area, subsidence area and other area needed to be filled.

The open-pit mining of the Bled El Hadba phosphate deposit consists of removing the covering waste rock and accessing the deposit from the surface, the waste rock is composed mainly of sands. The aim of this work is the characterization of the sands resulting from the mining of the phosphates of Bled El Hadba, for their possible use in the glass industry or the field of construction.

For this purpose, this paper reports results from laboratory tests analysis carried out to determine numerous characterizations of the material, such as particle size, equivalent of sand as well as the chemical proprieties of the sand of mine.

2. Materiel and methods

2.1 Case study: Description of the mining field

Phosphate deposits have two origins: sedimentary which produces 80% of the world production of natural phosphate and 20% of igneous ores often low in P2O5 which requires enrichment [12]. Since the last century, the production of phosphate has grown significantly to provide mainly fertilizers to agriculture and to allow high yields in food production [13, 14].

Phosphorus is produced by mining and beneficiation of Phosphate ores [15]. The greatest production of phosphorus is destined for agricultural or food purposes with 82% for the manufacture of phosphate fertilizers, and 9% for animal feed and food additives. The rest 9% is used for processes in non-food industrial production: for example, phosphates are used for the manufacture of soaps, detergents, ceramics, etc. [16].

The Djebel Onk deposit is a sedimentary deposit [17], located about 100 km south of the city of Tébessa, at the eastern end of the Saharan Atlas, close to the Algerian-Tunisian border (Fig.1). This mining basin contains five deposits: the Djemi-Djema deposit, Djebel Onk North, Oued Betita, Kef Essenoun and Bled el Hadba (Fig.2). It is the natural geographic boundary between the high plateaus Constantine and the Saharan area [18, 19].It contains approximately half the phosphate reserves of Algeria (Estimated at 2 trillion tons of reserves) [20].

Fig. 1. Location map of the study area.

Bled El Hadba deposit is located about 14 km to the East of Djebel Onk anticline. The phosphates of Bled el Hadba have long been recognized [21]. They have been recognized by wells and galleries from the beginning of the century and the geology of the phosphatic zone is described by [22]. Some data concerning the petrography of phosphates are provided by Cayeux [23]. In 1962, Ranchin [24], taking the data indicated in [22, 23] and reported the presence of four layers of phosphate.

With the aim of developing its phosphate output, the Algerian company SOciety of MIning PHOSphate (SOMIPHOS), aims to become a major supplier of phosphate. Therefore, the company has planned to put in exploitation the layer of Bled El Hadba which represents one of the largest phosphates reserve in Algeria. DMT estimated the value of proven and probable reserves at 841 Mt with an average diluted P2O5 grade of 22.2% [25].Lifetime is estimated at 34 years by Taylor's formula developed in 1977[26]:

$$t_{life,n} = 0.2 * \sqrt[4]{res_{exp}} \qquad (1)$$

Where $t_{life,n}$ denotes the lifetime in years and res_{exp} the total reserve tonnage expected in units of tone.

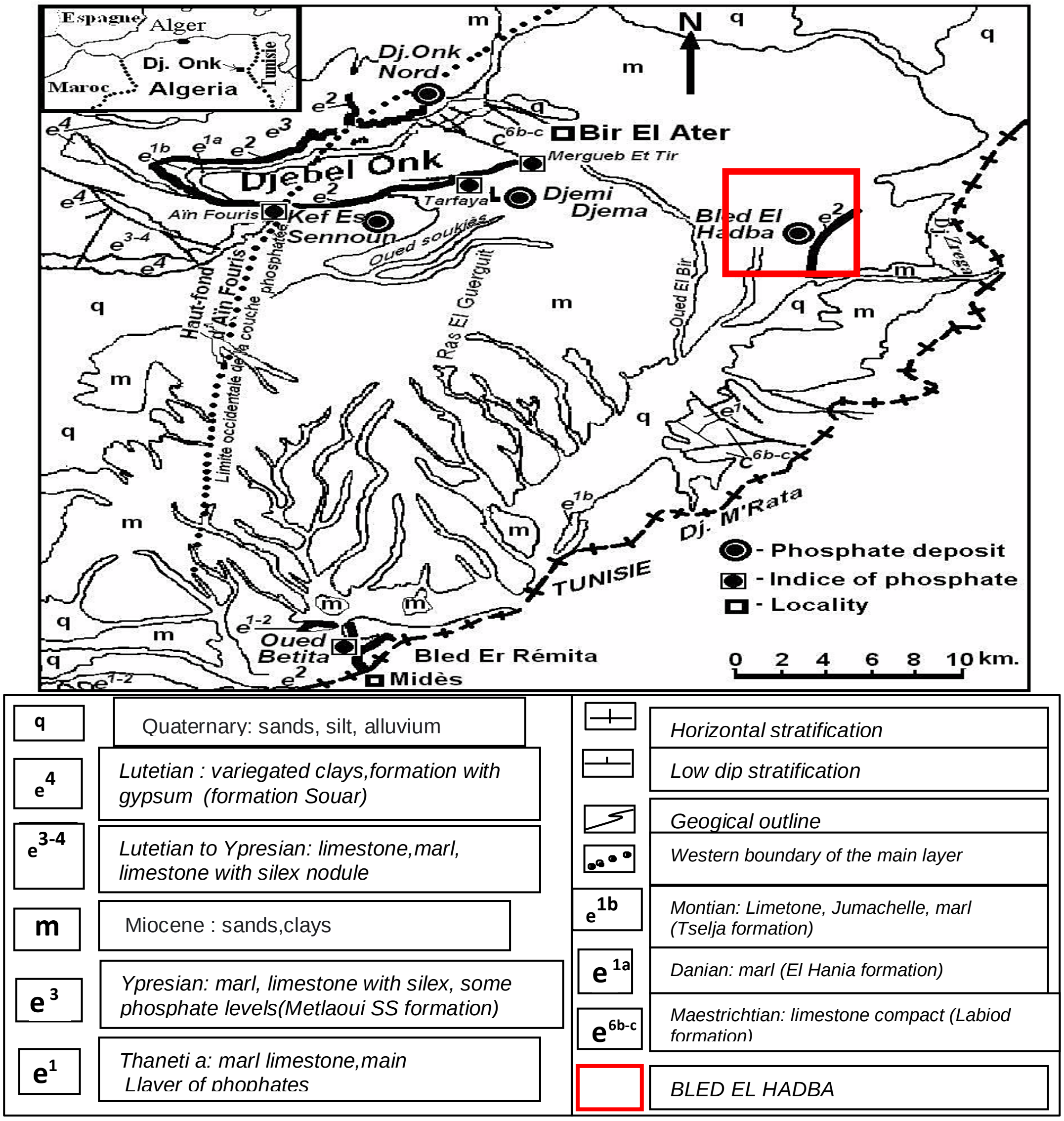


Fig. 2. Map of the geographical and geological situation of the phosphate deposits in the Djebel Onk region [19].

According to the study made by CERAD (Center for Studies and Applied Research Development) the direction of open pit mining is more favorable from the East towards the West because the layer of stripping varies from the east of 10 m to the west up to 100 m.

2.2 Thickness of the sterile cover

The sterile cover consists of the dolomitic limestones of the Ypresian, surmounted by the sands of the Miocene towards the west (Fig.3).The thickness of the overlap increases progressively from east to west from the outcrop of the phosphate beam. On all the eastern band of the deposit, the cover, mostly limestone, is less than 1 m .Towards the west, the appearance of Miocene sands causes a rapid increase in the thickness of the cover from 30 m to 70 m. The maximum thickness of the cover is 123.80

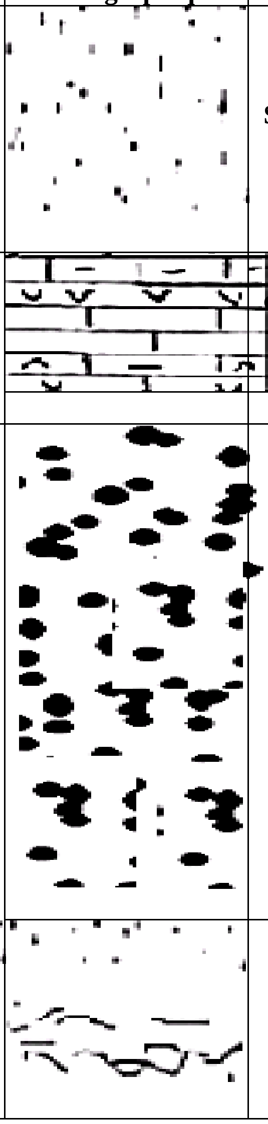
Geological ages	**Log stratigraphique**	**Lithological description**
MIOCENE **13.6 m** **YPERSIAN** **43.9 m**		**Soft yellow sands, powdery, fine-grained to medium.**
THANTIAN SUPERIOR		**Dolomitic limestone, yellow color, porous, neritic and weakly phosphates.**
Phosphated beam **80 m**		**The phosphate horizon. consisting of different sub-layers, we distinguish:** **43.9 - 62.2 m: dolomitic light brown phospharenites and phosphated coquinas.** **62.2-70.2 m: slightly dolomitic brown phospharenites.** **70.2-77 m: dolmotic and clay-like phospharenites.**
		77- 81.70 m: clayey phospharenites + marls and clays

Fig. 3. The stratigraphic column of the Bled el Hadba deposit.

According to the study carried out by the CERAD (Center for Studies and Applied Research), the direction of the exploitation is more favorable from the east towards the west because the covering layer varies from the east 10 m to the west up to 100 m [27].

2.3 Description of the samples

Samples were taken from core drilling SPH.01. The samples were collected from 3.40 to 184 m to cover the layer of sand. These samples are numbered, labeled and sorted by sampling interval. The total number of samples is 10.

Table 1.

The geological description of the rocks of the SPH.01 drills core and location of the samples.

Sample name	Intervals of geological description (m)	Geological description of rocks
Sam1	3.40 - 6.10	Sandy clay of color brownish-yellow compact slightly and consolidated, residually foliated.
Sam2	6.10 - 17.10	Quartz sand with medium and coarse grains of yellow - soft brownish loose and friable
Sam3	17.10 - 21.00	Compact, consolidated brownish-yellow sandy clay with thin, compact, hard green-yellow marl intercalations.
Sam4	21.00 - 68.00	Quartz sand with fine grains of gray-brownish color interspersing a clay passage of centimeter to decimeter order.
Sam5	68.00 - 86.00	Quartz sand with fine grains of gray-brownish color interspersing a clay passage of centimeter to decimeter order
Sam6	86.00 - 102.00	Quartz sand with fine grains of gray-brownish color interspersing a clay passage of centimeter to decimeter order
Sam7	102.00 -114.00	Quartz sand with fine grains of gray-brownish color interspersing a clay passage of centimeter to decimeter order.
Sam8	114.00 -140.00	Quartz sand with fine grained greyish color.
Sam9	140.00 -165.00	Quartz sand with fine grained greyish color
Sam10	165.00 -184.00	Fine-grained quartz sand with a medium-sized fraction of gray-yellowish

3. Results and discussion

Sand samples collected in the area of Bled El Hadba are subjected to tests:

- ✓ Particle size analysis : the test is carried out according to the standard: NFP18-101 by screening on sieves of meshes 0.08 mm, 0.125 mm, 0.25 mm, 0.5 mm, 1 mm, 2 mm, 4 mm;
- ✓ Cleanliness by the equivalent of sand :the test is carried out according to standard NF EN 933-8;
- ✓ For the chemical analysis, Samples are prepared according to the quartering method using Sam1, Sam2, Sam3, Sam4, Sam5, Sam6, Sam7, Sam8, Sam9, and Sam10 to obtain Samp1, Samp2, Samp3, and Samp4.The detail of the chemical analysis procedure is mentioned in the section 3.3.

3.1 Particle size analysis

To carry out the interpretation of the particle size analysis, the fineness module, the uniformity coefficient, and the curvature coefficient are introduced [28, 29]. Sand of Bled El Hadba has a granular class of fine sand with maximum diameters ranging from 0.08 mm to 0.8 mm (Fig.4).

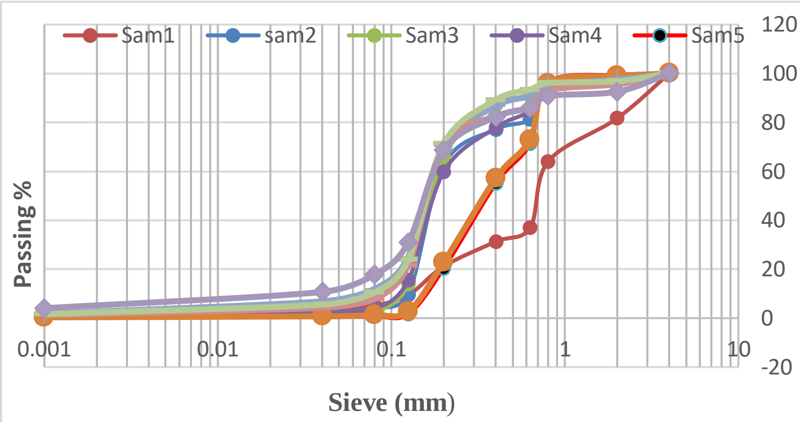


Fig. 4. Granulometric curve of the sands of Bled El Hadba.

a. **The Fineness modulus (FM)**

Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves (0.125mm -0.25mm-0.50mm-1mm-2mm-4mm) and dividing this sum by 100.
FM: 1/100 Σ cumulated refusal in% of sieves (0.125 mm - 0.25 mm - 0.50 mm - 1 mm - 2 mm - 4 mm)

The sands must have such a grain size that the fine elements are neither in excess nor in too small a proportion.

Coefficient of uniformity :

$$Cu = \frac{d60}{d10} \qquad (2)$$

Coefficient of curvature :

$$Cc = \frac{(d_{30})^2}{(d_{10} * d_{60})} \qquad (3)$$

Where d60, d30 and d10 was the grain diameter at 60% , 30% and at 10% passing respectively.

Table 2.

Tests results of fineness module, coefficient of uniformity and curvature coefficient.

	Sam1	Sam2	Sam3	Sam4	Sam5	Sam6	Sam7	Sam8	Sam9	Sam10
FM	1.49	1.05	1.04	1.02	1.03	1.03	0.95	1.03	0.96	0.98
Cu	6.4	1.6	1.6	2.5	3.2	3.2	1.56	1.56	1.56	3.12
Cc	1.6	0.6	0.6	0.93	0.8	0.8	1.5	1.5	1.5	3

The laboratory tests show that the sand of Bled El Hadba has a majority of fine grains. The fineness module is of very low average values for use in the manufacture of concretes. These values are between 0.95 and 1.49. Given its coefficient of uniformity and the coefficient of curvature, it is poorly graded sand (SP) (Table 2).

3.2 Equivalent of sand According to the sand equivalent, 80% of the samples show that the sands of Bled El Hadba are clayey and 20% are very clean sands (Table 3).

Table 3.

Sand equivalent test result

	Sam1	Sam2	Sam 3	Sam4	Sam5	Sam6	Sam7	Sam8	Sam9	Sam10
ES (%)	17.8	44	49	54	83	83	49	7	60	52

3.3 Chemical analysis

To carry out the chemical analysis, the samples must first be prepared in the laboratory. The homogenization operation of the 10 samples is carried out: Sam1, Sam2, Sam3, Sam4, Sam5, Sam6, Sam7, Sam8 and Sam9 to obtain 4 samples. The 4 new samples now named: Samp.1, Samp.2, Samp.3, Samp .4 were obtained by quartering using a divider-sampler which allows the division of the samples in a representative and reproducible way (Fig.5.a). The mass of each of the samples Sam1, Sam2 , Sam3 , Sam4 , Sam5 , Sam6 , Sam7 , Sam8 , Sam9, is 50 g. Therefore, every three samples of the first 9 were combined to obtain 3 samples of 150 g each as mentioned in the (Table4); in addition to the tenth sample Sam10 which has a mass of 150 g. These 4 samples were crushed and reduced to a fine powder for chemical analysis (Fig.5.b).

Table 4.

Samples after quartering and grinding

Samples	*Sam1*	*Sam2*	*Sam3*	*Sam4*	*Sam5*	*Sam6*	*Sam7*	*Sam8*	*Sam9*	*Sam10*
Samples after quartering and grinding	Samp.1			Samp.2			Samp.3			Samp.4

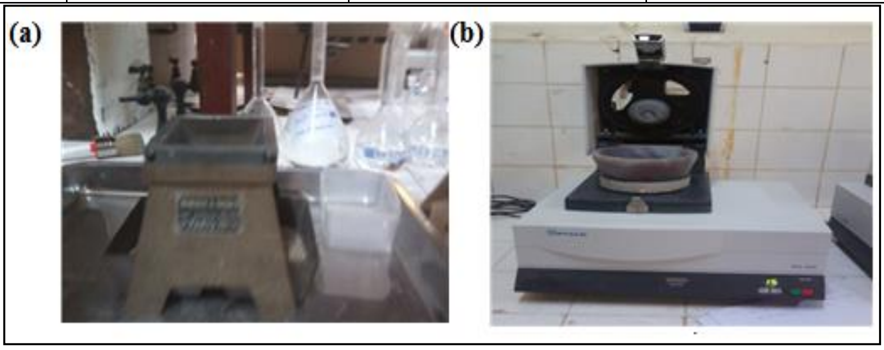


Fig. 5. Chemical analysis, procedures and apparatus: (a) Divider-sampler, (b) Crusher

The chemical analysis showed that the Bled el Hadba sand is 80.6% SiO_2 which means that it can be used for the glass industry (Table 5).

Table 5.

Results of Chemical Analysis Tests

Samples	**Samp.1**	**Samp.2**	**Samp.3**	**Samp.4**
Elements	**Content (%)**			
Total silica (SiO_2)	81.6	81.6	80.20	79
Iron oxide (Fe_2O_3)	0.56	0.31	0.43	1.25
Calcium oxide (CaO)	7.85	2.24	1.12	1.12
Magnesium oxide (MgO)	0.18	0.07	0.10	0.10
Potassium oxide (K_2O)	0.00602	0.00602	0.00602	0.00602
Sodium oxide ($N_{a2}O$)	0.08088	0.06066	0.08088	0.08762
Phosphoric anhydride (P_2O_5)	0.32	0.17	0.18	0.17
Dosage of carbon dioxide (CO_2)	5.15	0.67	0.50	0.83

4. Conclusion

In this study, the laboratory tests showed that the sand of Bled El Hadba has a granular class of fine sand whose maximum diameters vary from 0.08mm to 0.8mm. The average values of the fineness module were between 0.95 and 1.49 very low for use in the manufacturing of concrete, what requires a valorization. In addition, the equivalent of sand showed that 80% of the samples are clay sands and 20% are very clean. In the other hand, chemical analysis have shown that Bled El Hadba sand is 80.6% SiO2 which means it can be used for the glass industry.

As this large mining complex is in preparation for the exploitation of phosphates, which automatically leads to a large quantity of sand waste. This generated waste has environmental impacts that raise deep concerns. As a result, and according to the encouraging results of this study, this waste can be valorized for a sustainable exploitation.

While this preliminary classification of sands is promising to engage in a process of sustainable development, a detailed study should therefore be carried out to consider a beneficial use in order to maintain this land as a beautiful land (area) without wastes.

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