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Original scientific paper

POSSIBLE INDUSTRIAL USE OF PHOSPHATE WASTES AS A PROMISING ENVIRONMENTAL SOLUTION (TEBESSA, ALGERIA)

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Abstract: Algeria is a country with a highly varied structural and geological context, which has given rise to a wealth of diversified mineral resources (phosphates, base metals, precious metals, etc.). Mining activities have generated a significant volume of economically valueless mining waste. These waste materials can pose environmental risks depending on their condition, composition, and storage methods. In this study, we studied mine tailings from the Djebel Onk phosphate deposit, while carrying out a complete mineralogical characterization including granulometric, chemical and microscopic analyses, as well as heavy metal, X-ray diffraction, and infrared analyses. We investigated two types of mining waste: overburden waste and operating residues (selectivity waste) and proposed specific valorization methods for each type. The operating residues (selectivity waste) have economic potential due to their high P_2O_5 content. Therefore, we propose a valorization method for this type of waste through various treatment approaches such as calcination, washing, flotation, and gravity separation. For the overburden waste, we are proposing to use it as an additive in cement manufacturing processes since it contains commonly elements found in limestone and clay, as well as in additives used in cement production such blast furnace slag and pozzolana (CaO, MgO, SiO_2, etc.). However, these materials do not contain P_2O_5.

Key words: characterization; overburden waste; selectivity waste; phosphate; Djebel Onk

INTRODUCTION

The purpose of mining is to extract minerals or metals from the Earth's surface that have economic value, whether from underground or open-pit mining [1, 2]. This process generates a significant volume of economically valueless mining waste [3], which can be classified primarily as natural products: waste rock (overburden waste, selectivity waste), or artificial products resulting from ore processing and enrichment phases (concentrator tailings and treatment sludges) (Figure 1). The overburden waste and selectivity rock are stacked on the surface in waste rock piles [4], concentrator tailings are stored on the surface in tailings ponds [5] and processing sludges are stored in lined basins (see Figure 1). Therefore, these wastes can present risks to the environment depending on their condition, composition, and storage methods [2–13].

The proportion of mine waste rock can reach 60 % or more in the case of open-pit mines, whereas underground mines produce a lower volume of waste rock, typically between 5 % and 15 % of the exracted rock volume. In open-pit mines, waste rock piles can have considerable dimensions, reaching over a hundred meters in height and spanning several hectares [14, 15, 11–16]. This significant quantity produced each year is continuously increasing [17], which is why the management and the disposal of these continuously produced large quantities are considered one of the major challenges faced by the global and the national mining industry due to the economic and the environmental policies [18].

In the Djebel Onk phosphate mine (the focus of our study), the production of one ton of phosphate ore generates between nine and ten tons of mine waste rock. With the aim of eliminating, the huge quantities of mine waste rock and in order to preserve the environment and act on the notion of sustainable development. To achieve this, a physicochemical characterization is conducted through particle size analysis, X-ray fluorescence chemical analysis, microscopic observations using scanning electron microscopy (SEM), and X-ray diffraction analysis (XRD). The main objective of study is the characterization and management of phosphate waste from an economic and environmental point of view.

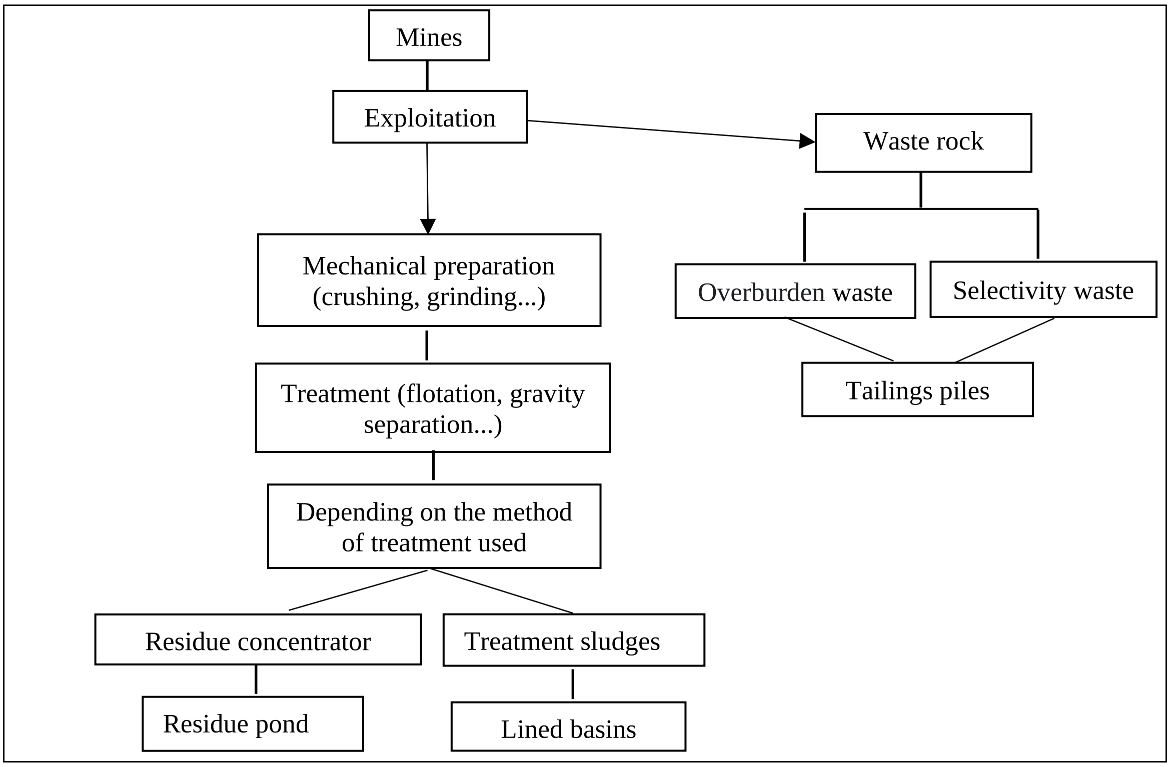

Fig. 1. Diagram illustrating the generation of different types of mining waste

Description and geographic location of the studied area

The Djebel Onk region is located on the northwestern part of the Algerian Sahara. Specifically, in the east of the Nemamcha Mountains, which belong to the Saharan Atlas; and is approximately twenty kilometers from the Algerian-Tunisian border (Figure 2). The region falls within the Tebessa province, which is about 100 kilometers east of Algiers. The most important locality in the area is the city of Bir El Ater. The deposit is connected to Bir El Ater by national road No. 16 (Annaba – El-Oued) and a railway used for transporting phosphates to the port facility in Annaba, which is located 340 kilometers away.

Algerian phosphates are exploited by the Society Meniere of Phosphates (SOMIPHOS). The annual production of this material ranges from 2.3 to 2.5 million tons of ore, with a phosphorus pen-toxide (P_2O_5) content of 25 to 26 % and average of 1.1 to 1.3 million tons of commercial products. This raw material is primarily used (representing 80 to 90 % of global production) for the manufacturing of fertilizers and phosphoric acid, as well as in other sectors such the paint industry, ceramics, cosmetics, pharmaceuticals, the food industry, and others [19–24].

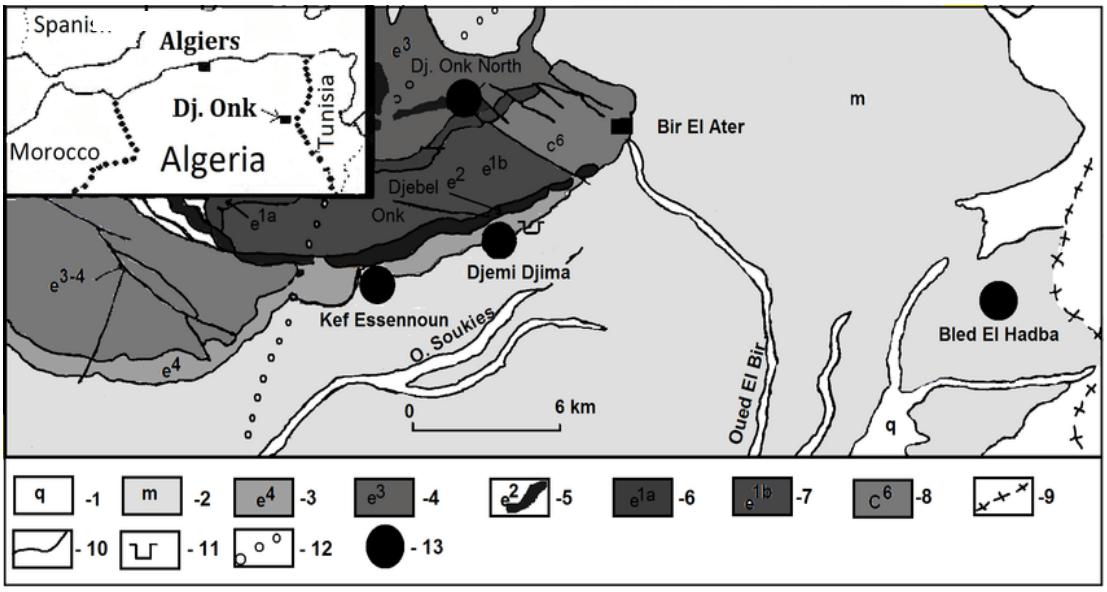

Fig. 2. Geological map and location of Djebel Onk phosphate deposits
Legend: **1.** Silty alluvial deposits (Quaternary); **2.** Sand and clay (Miocene); **3.** Marl and limestone (Lutetian); **4.** Marl and limestone with phosphate level (Ypresian); **5.** Marl, limestone, dolomite and main phosphate layer (Thanetian); **6.** Coquina limestone and marl (Montian); **7.** Marl and limestone (Danian); **8.** Limestone (Maastrichtian); **9.** Algerian-Tunisian border; **10.** Geological outline; **11.** Djemi Djema open pit; **12.** Shallow of Ain Fouris: western limit of the main phosphatic layer; **13.** Phosphate deposit

MATERIALS AND METHODS

We took care to sample a large area of the studied zone. The samples were collected from the waste rock piles. Each sample was taken with a weight of 70 kg and a maximum diameter of approximately 100–120 mm. The collected samples were transported to the sample preparation laboratory at the Djebel Onk mining complex. They were dried and divided into two riffles until obtaining a quantity of 1.5 to 2 kg. This amount underwent crushing, splitting, and successive homogenization steps to obtain a representative sample. An initial sample of this representative sample was characterized using X-ray fluorescence (XRF), X-ray diffraction (XRD), scanning electron microscopy (SEM), and infrared (IR). A quantity of 1000 g from this representative sample was used for particle size analysis and granulometric-chemical analysis.

Characterization of the phosphate waste rock at Djebel Onk

Granulometric analysis. Sieving was performed using 1000 g of the waste rock sample for the overburden sterile fraction and 1000 g for the selectivity sterile fraction to separate the samples into different size fractions. Standard sieves with square meshes were used, including +10 mm, +8 mm, +4 mm, +2 mm, +1 mm, +0.80 mm, +0.50 mm, +0.20 mm, +0.10 mm, +0.080 mm, +0.040 mm, and –0.040 mm. All sterile samples were sieved for 20 minutes using a sieve column in a shaking machine of CISA type, equipped with sieves with a diameter of 200 mm × 50 mm. The quantities of particles retained on each sieve were weighed using a balance with a precision of 0.01 g.

The particles size distribution analysis conducted on samples of overburden and selectivity wastes from the Djebel Onk phosphate mine, crushed to 10 mm, shows the following results:

For the overburden waste, a high yield of 37.54 % was obtained, primarily in the >10 mm size fraction. The results are presented in Figure 3. For the selectivity sterile samples, a high yield of 24.85 % was achieved, also predominantly in the >10 mm size fraction. The results are shown in Figure 4.

Chemical analysis of the overburden sterile from Djebel Onk (for both the sterile overburden and sterile of selectivity) was performed using X-ray fluorescence spectroscopy (XRF). The different granulometric fractions were analyzed using X-ray fluorescence (XRF).

The results obtained are presented in Tables 1 and 2.

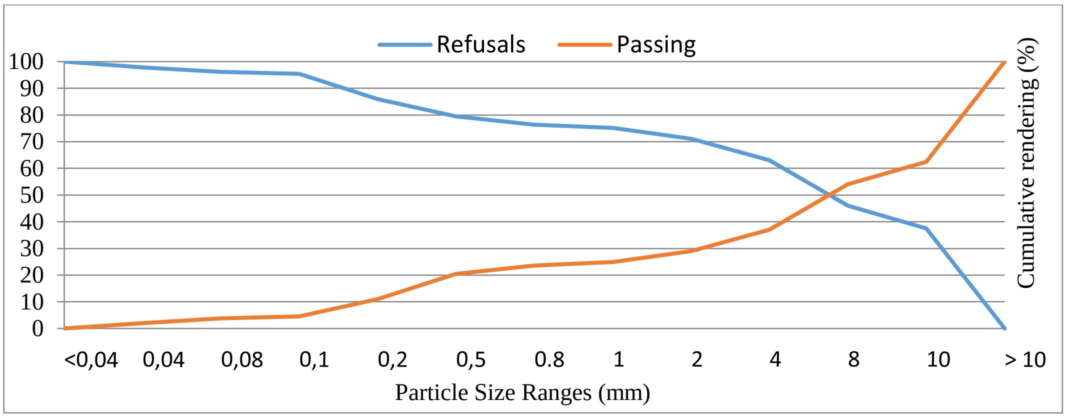

Fig. 3. Particle size distribution curve for an overburden waste

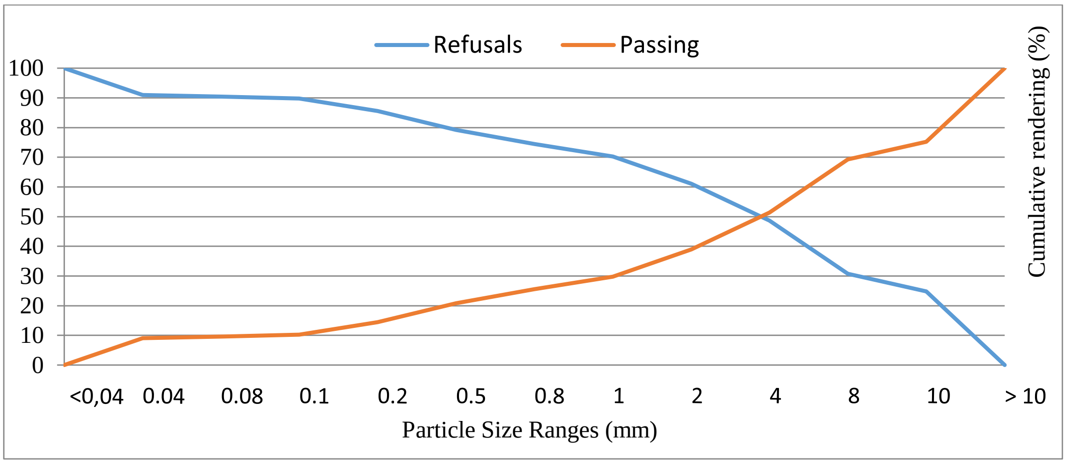

Fig. 4. Particle size distribution curve for a sample of selectivity waste

Table 1

Results of chemical analyses for different granulometric fractions of the overburden waste

Granulometric fractions (mm)	P_2O_5 (%)	CaO (%)	MgO (%)	SiO_2 (%)	Fe_2O (%)	K_2O (%)	Na_2O (%)	SO_3 (%)	LOI (%)
Initial	1.69	28.04	14.39	25.28	0.88	0.25	0.31	0.18	28.70
> 10	1.00	28.38	12.57	24.97	0.13	0.60	0.14	0.20	31.03
– 10 + 8	1.13	32.89	9.31	22.38	0.76	0.70	0.21	0.22	30.65
– 8 + 4	0.87	26.97	11.25	27.07	0.54	0.32	0.21	0.18	29.54
– 4 + 2	1.36	29.03	13.25	27.98	0.45	0.42	0.25	0.09	26.87
– 2 + 1	1.26	27.09	12.35	22.65	0.63	0.19	0.25	0.19	30.98
– 1 + 0,80	2.13	24.98	14.15	19.06	0.79	0.72	0.29	0.15	27.86
– 0.80 + 0.50	2.87	34.76	14.31	24.56	0.84	0.86	0.31	0.13	20.56
– 0.50 + 0.20	5.64	26.78	11.96	22.05	0.35	0.26	0.44	0.15	30.34
– 0.20 + 0.10	7.55	27.87	7.62	14.67	0.56	0.24	0.52	0.12	39.76
– 0.10 + 0.080	4.59	30.04	8.26	28.97	0.67	0.47	0.40	0.09	25.87
– 0.080 + 0.040	2.61	25.98	8.73	29.70	0.34	0.60	0.29	0.09	30.54
< 0.040	0.85	30.97	9.17	25.67	0.76	0.60	0.20	0.12	30.34

Table 2

Chemical analyses by granulometric classes of the phosphate waste sample

Granulometric fractions (mm)	P_2O_5 (%)	CaO (%)	MgO (%)	SiO_2 (%)	Fe_2O_3 (%)	K_2O (%)	Na_2O (%)	SO_3 (%)	LOI (%)
Initial	20.54	44.86	5.17	7.12	0.43	0.12	0.80	0.74	18.54
> 10	18.76	44.42	5.78	6.20	0.75	0.20	0.75	0.34	21.80
– 10 + 8	20.51	42.25	5.40	7.14	0.47	0.28	0.80	0.78	19.37
– 8 + 4	20.83	40.63	8.17	6.23	0.32	0.53	0.82	0.40	20.07
– 4 + 2	20.96	39.61	4.99	5.43	0.86	0.90	0.83	0.76	22.66
– 2 + 1	21.68	40.17	4.67	7.45	0.50	0.60	0.84	0.98	20.11
– 1 + 0.80	22.82	41.25	4.18	5.82	0.35	0.93	0.90	0.56	21.19
– 0.80 + 0.50	24.32	38.40	3.59	6.93	0.63	0.89	1.01	0.65	21.68
– 0.50 + 0.20	26.40	36.20	2.56	4.81	0.75	0.97	0.87	0.23	26.21
– 0.20 + 0.10	22.70	36.43	4.65	7.75	0.95	0.28	0.87	0.65	21.90
– 0.10 + 0.080	14.99	40.63	4.10	8.95	0.37	0.46	0.64	0.35	29.51
– 0.080 + 0.040	14.54	41.40	7.15	5.48	0.73	0.59	0.64	0.19	22.74
< 0.040	17.36	39.40	6.20	4.04	0.97	0.90	0.71	0.87	28.28

This study has shown that:

The overburden waste material has a low content of P_2O_5 (phosphorus pentoxide) and a high percentage of CaO (calcium oxide), MgO (magnesium oxide); and SiO_2 (silicon dioxide), reaching levels of 34.76 %, 14.39 %, and 29.70 %, respectively. These elements are major constituents of the material. There are also other minor elements present, such Fe_2O_3 (iron oxide), K_2O (potassium oxide), Na_2O (sodium oxide), SO_3 (sulfur trioxide), and $Cl^–$ (chloride). The overburden waste material is considered economically unprofitable, due to its low P_2O_5 content. However, it contains elements commonly found in limestone, clay, and additives used in cement production, such as blast furnace slag and pozzolana (CaO, MgO, SiO_2, etc.). It is important to note that these elements do not contain P_2O_5 [25].

The sterile of selectivity contains a CaO content that can reach 44.86 %, indicating a predominantly carbonate gangue. The P_2O_5 content reaches 26.40 %, confirming that this material is rich in P_2O_5 and economically viable. A high yield (24.32 – 26.40 %) of P_2O_5 was recorded in the granulometric range (– 0.80 + 0.20 mm), indicating that the ore liberation size falls within the (– 0.80 + 0.20 mm) granulometric range.

Mineralogical analysis by X-ray diffraction (XRD). The collected samples of waste rock were finely ground in a ball mill and then analyzed by X-ray diffraction (XRD) (Figures 5 and 6) to identify the nature and crystalline structure of the material. The obtained spectra consist of multiple peaks. These analyses were conducted at the laboratory of the Center for Studies and Technological Services of the Construction Materials Industry (CETIM).

According to Figure 5, the mineralogical composition of the initial free overburden waste includes the following minerals: quartz, dolomite, fluorapatite, and calcite. However, we note that: the quartz, calcite and dolomite peaks with a high intensity are well expressed, which makes them easy to identify.

According to Figure 6, the mineralogical composition of the initial selectivity waste sample includes the following minerals: quartz, carbonate-fluorapatite, albite, montmorillonite, orthoclase, dolomite, and calcite. However, we note that: the carbonate-fluorapatite and dolomite peaks with a high intensity are well expressed, making them easy to identify.

Fluorapatite: A phosphate mineral with the chemical formula $Ca_5(PO_4)_3F$.

Dolomite: Calcium magnesium carbonate with the chemical formula $CaMg(CO_3)_2$.

Calcite: Natural calcium carbonate with the chemical formula $CaCO_3$.

Quartz: A mineral species in the silicate group composed of silicon dioxide or silica, with the chemical formula SiO_2.

Carbonate fluorapatite: Carbonate containing calcium phosphate.

Montmorillonite: Montmorillonite is a mineral composed of hydrated aluminum and magnesium silicate, with the chemical formula $(Na, Ca)_{0.3}(Al, Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$.

Albite: A mineral of the feldspar family (silicate group), with the chemical formula $NaAlSi_3O_8$.

Orthoclase: A mineral species of the feldspar group in the silicate class. Its chemical composition is $KAlSi_3O_8$.

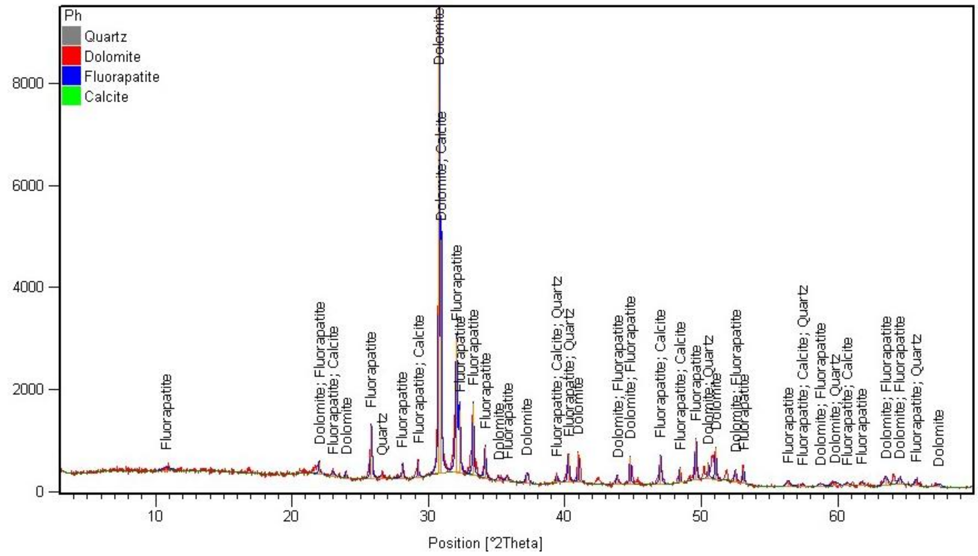

Fig. 5. X-ray diffraction (XRD) analysis of the overburden waste samples

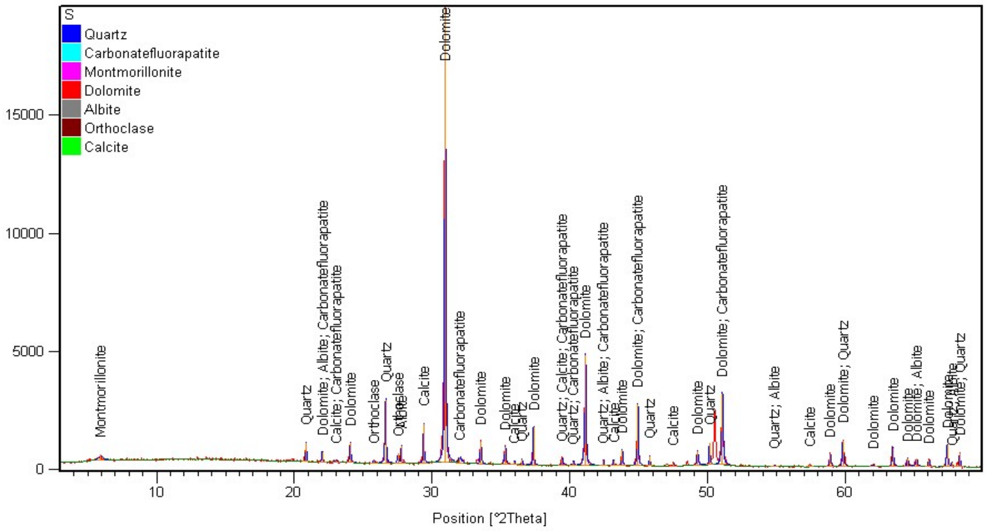

Fig. 6. X-ray diffraction (XRD) analysis of the selectivity waste samples

Scanning electron microscopy (SEM)

For the characterization of the waste rock samples (from overburden and selectivity), a pellet of (2–4 mm) size was prepared and observed using a scanning electron microscope (SEM) of type "SEM7001F". The SEM was coupled with energy-dispersive X-ray spectroscopy (EDX) for chemical analysis, which allowed for the identification of chemical composition. The micrograph of mineral particles obtained had a scale of 10–40 µm approximately.

The results are shown in Figures 7 and 9. This observation revealed the microscopic scale composition of various elements such P, Ca, Mg, Si, Fe, and O. The presence of oxygen is relevant as it is involved in the composition of P_2O_5, CaO, MgO, SiO_2, and Fe_2O_3.

Based on the EDX diffractograms of the surfaces scanned by the SEM (Figures 8 and 10), the presence of P and O is observed, which corresponds to the composition of fluorapatite and carbonate-fluorapatite. The high concentration of Ca confirms the presence of carbonates (calcite, dolomite) as essential components of this ore. The peaks of Mg indicate the presence of dolomite, while the peaks of Si explain the presence of quartz.

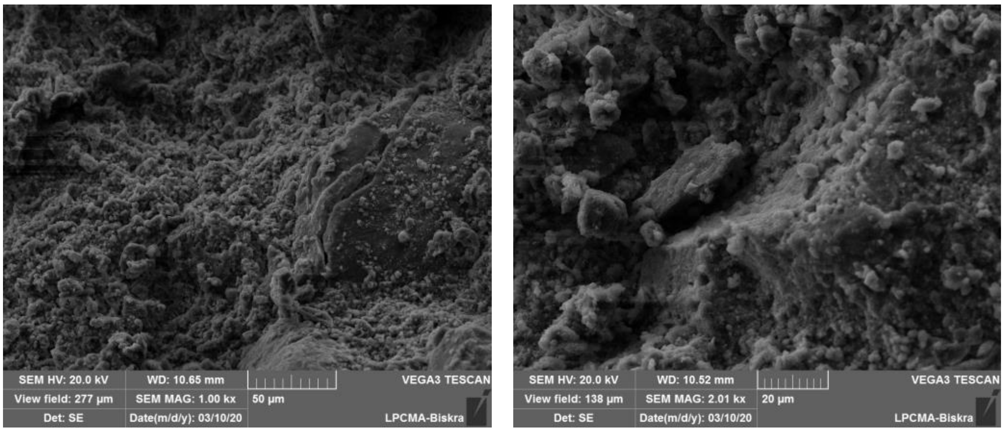

Fig. 7. Scanning electron microscope (SEM) observation of overburden waste samples

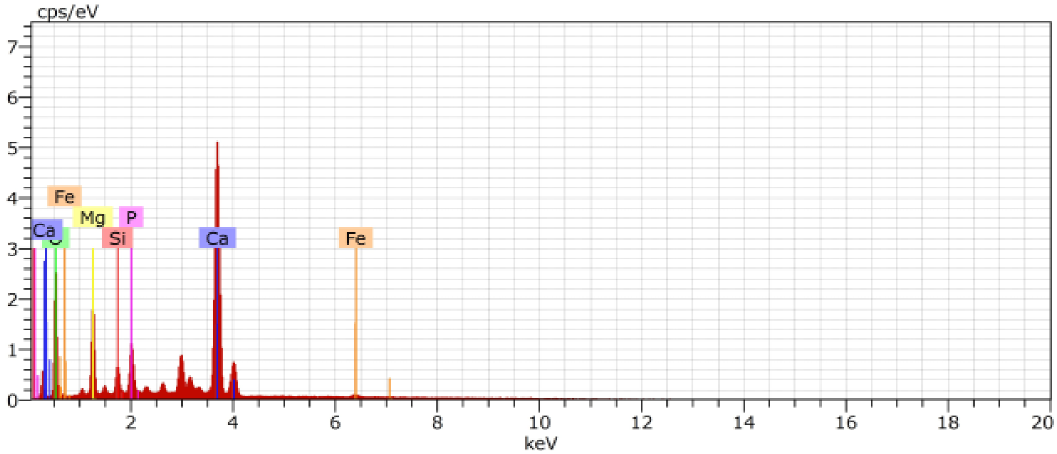

Fig. 8. EDX analysis diffractogram of overburden waste samples

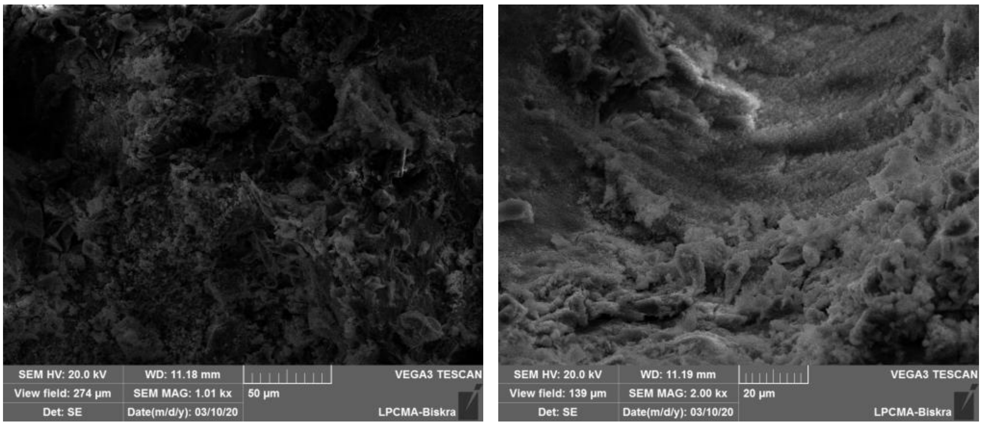

Fig. 9. Scanning electron microscope (SEM) observation of selective waste samples

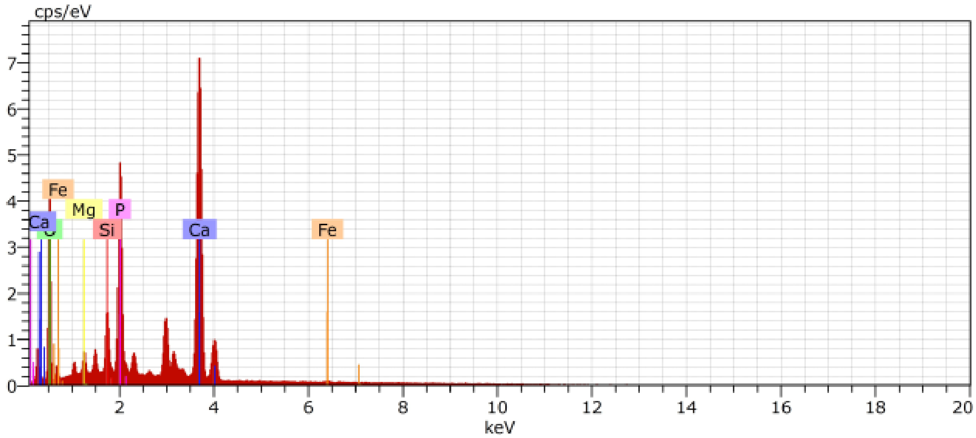

Fig. 10. EDX analysis diffraction pattern of selectivity waste samples

Infrared (IR)

Figure 11 shows the infrared absorption spectrum of the studied selectivity waste samples. The frequencies of absorption bands characteristic corresponding to the normal vibrations of the different radicals used in the studied waste composition are presented in Table 3.

Figure 12 presents the infrared absorption spectrum of the overburden waste samples. The frequencies of the absorption bands characteristic corresponding to the normal vibration of the differrent radicals in the composition of the studied waste samples are presented in Table 4.

Petrographic study of selectivity waste

The mineralogical composition of the selectivity waste sample presented in Table 5 was determined through a petrographic analysis to identify the percentage of different minerals actually observed in the rock. This study involves macroscopic and microscopic analyses of the rocks.

According to the petrographic study (Table 5 and Figure 13), we note:

Macroscopically, the sample is observed to have a light beige color with specks of yellow-orange spots and a massive, relatively hard texture. It also exhibits irregular, granular fractures that are often empty. In certain areas, these fractures appear as elongated voids with irregular boundaries on the sample.

Under microscopic examination, the rock is characterized by a partially recrystallized and dolomitized micritic limestone matrix. This dolomitization is evidenced by the presence of small rhombohedral-shaped dolomite crystals. These crystals can be numerous, varying in size, and grouped in irregular clusters. The dolomite crystals are observed within the matrix, replacing the primary calcite.

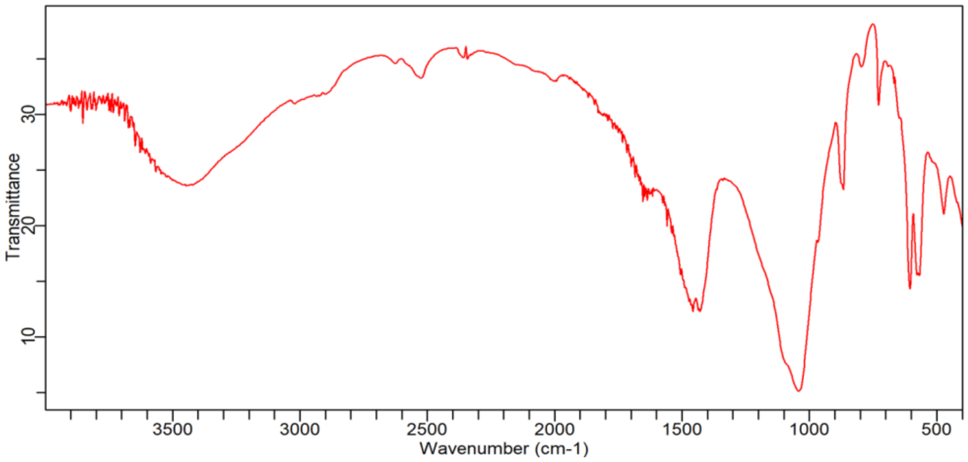

Fig. 11. Infrared analysis spectrum of the selectivity waste sample

Table 3

Identification of bands in the IR spectrum for the selectivity waste sample

Positions in cm^{-1}	Band intensities	Band identifications
3437.11	Strong	Hydroxyl ions (OH^-)
2521.15	Weak	P-H
1429.62	Strong	Carbonates (apatitic CO_3^{2-} ions)
1040.61	Very strong	Phosphate ions (PO_4^{3-})
872.39	Weak	Carbonate ions (CO_3^{2-})
725.19	Weak	P-O-C bond
713.3	Weak	C-S bond
606.19	Moderate	Phosphoric ester group (PO_4^{2-})
856.8	Weak	Grouping (SiO_4)
470	Weak	Phosphate ions (PO_4^{3-})

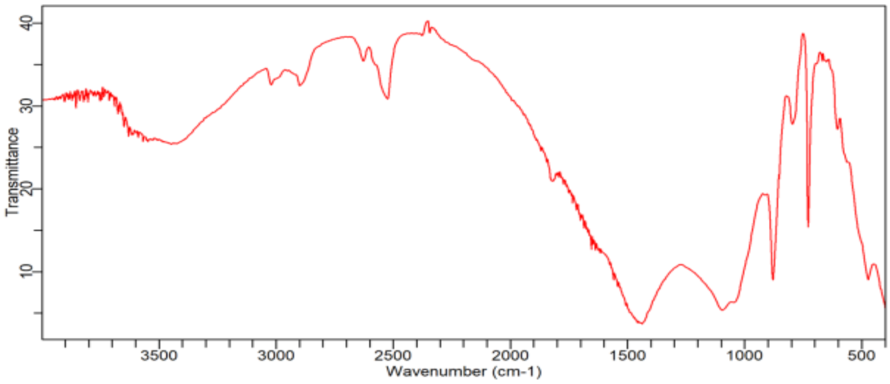

Fig. 12. Infrared analysis spectrum of the overburden waste sample

Table 4

Identification of bands in the IR spectrum for the overburden waste sample

Positions in cm^{-1}	Band intensities	Band identifications
3500	Strong	Constitutional O-H (H_2O) band
3437.11	Strong	Hydroxyl ions (OH^-)
2521.15	Weak	P-H
1429.62	Strong	Carbonates (apatitic CO_3^{2-} ions)
1125	Strong	Si-O vibration band
1053	Strong	Calcite ($CaCO_3$)
950	Moderate	Isolated silicate band
872.39	Weak	CO_3^{2-} ions
856.3	Moderate	Grouping (SiO_4)
725.19	Weak	P-O-C bond
713.3	Weak	C-S bond
606.19	Moderate	Phosphoric ester group (PO_4^{2-})
588.29	Strong	Deformation vibration of Si-O-Al
470	Weak	Ions PO_4^{3-}

Table 5

Mineralogical composition of selectivity waste

Mineralogical composition	Content (%)	Grain size dimensions (mm)
Calcite I (matrice)	45	≤0.01
Dolomite	08	0.08 – 0.1
Quartz	20	0.08 – 0.2
Plagioclases	05	0.05 – 0.2
Microcline	02	
Zircon	<<01	
Phosphatic material	20	
Glauconite	<01	

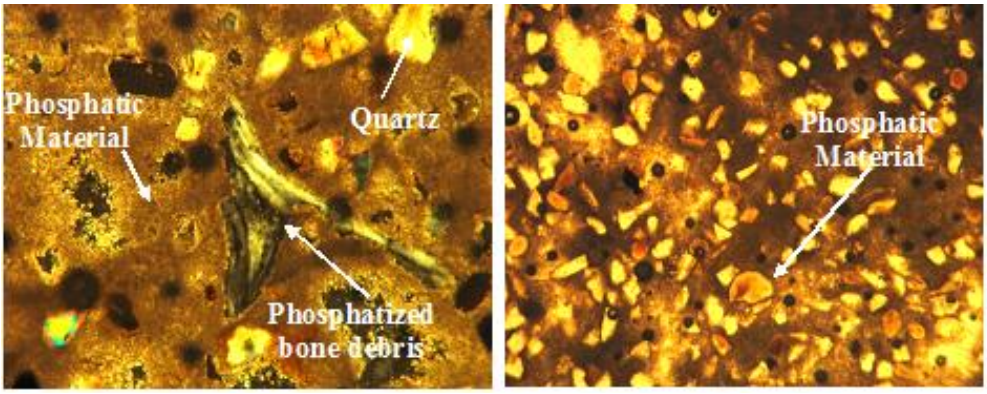

Fig. 13. Microscopic observation of the selectivity waste sample

Within this limestone background, we observe the presence of predominantly quartzitic detrital material. The grains of quartz appear as poorly worn with sub-angular to sub-rounded shapes, highlighted by heavily corroded and carbonate-etched grain boundaries. Additionally, it is notable that these quartz grains are often clouded by very fine pelitic impurities of clayey-iron nature, giving them a dark brownish-yellow hue.

The plagioclase minerals occur as small, stubby prisms with sizes not exceeding 0.2 mm. They are heavily altered by pelitic material and exhibit forked hollow outlines. Polysynthetic twinning is rarely observed in these plagioclase crystals.

Regarding the phosphatic material, it was highlighted by the cold reaction of ammonium molybdate and HNO_3, which imparts a yellowish coloration to the sample. It forms a kind of dark isotropic yellow-orange haze on the tests of bioclasts.

Rounded, ovoid, or irregular phosphatic grains, darkened by the impregnation of organic matter, exhibiting a dark brownish-orange color, also represent it. They are associated with phosphatized bone debris.

Atomic absorption spectrometry (AAS) analysis of the mining waste from the Djebel Onk phosphate mine

The waste rocks samples analyzed using a Perkin Elmer AAS 3110 atomic absorption spectrometer. Hollow cathode lamps suitable for each element were used for quantification after performing nitric acid extractions, except in the case of mercury where hydride treatment was necessary (see protocols). Calibration curves were plotted, and the results are presented in the Table 6.

It is evident that both analyzed soil samples are relatively rich in metals such Cu, Zn, and Pb, which can be attributed to the presence of minerals such as sphalerite and galena. However, mercury is completely absent. Serventite, senarmontite, and stibnite are trace amounts found in antimony. These elements are previously adsorbed onto phosphate riched clay matrices by the phenomenon of chalcophelia on the coprolytic matter of organic matter under suitable Ph-Eh conditions.

Table 6

Atomic absorption spectrometry analyses of the initial samples of selectivity and overburden waste

Metal (ppm)	Overburden waste	Selectivity waste	Methods
Cadmium	7.7	8.4	AAS analysis with nitric acid extraction
Copper	136.3	155.8	
Zinc	203.6	211.7	
Lead	123.4	132.8	
Mercury	ND	ND	
Nickel	8.8	9.7	
Antimony	8.5	6.7	

Phosphate waste can contain varying levels of radioactive materials, primarily due to the natural presence of radionuclides in the phosphate minerals themselves. The main radioactive substances found in phosphate waste are typically uranium and thorium isotopes, such as uranium-238 and thorium-232, along with their decay products like radium-226. These radioactive elements in phosphate waste pose risks to human health and the environment if not managed and disposed of properly. Therefore, industries involved in phosphate extraction and processing must implement specific measures to control radiation exposure. These measures include regularly monitoring radiation levels, following safety protocols, and appropriately treating waste to minimize associated risks during handling and disposal.

This study demonstrates that:

According to the results of the chemical analysis, overburden waste was considered economically unprofitable due to its lower P_2O_5 content.

According to [25] these waste materials contain all the components found in limestone, clay, and additives used in cement production, such as blast furnace slag and pozzolana (CaO, MgO, SiO_2, etc.). This finding leads us to conclude that these wastes cannot simply be considered as waste, but rather as by-products that contain one or more commercially valuable materials. Order to make use of these mining wastes, we recommend their utilization as additives in the raw mix for potential cement production.

In order to understand the impact of using this type of waste as an additive in cement production, a comparative study was conducted, also examining other additives such as slag (a by-product of the steel industry) and pozzolana (of natural origin). This study aimed to evaluate their influence on the quality of CPJ – CEM II 42.5 cement, analyzing physical parameters such consistency, setting time, as well as mechanical properties such flexural and compressive strength.

The results of the various tests demonstrate that the incorporation of phosphate waste rock in cement manufacturing leads to improved flexural and compressive strength, regardless of the age and the percentage of addition. These findings highlight the potential to add a certain amount of waste rock to cement, thereby enhancing its physico-mechanical properties. Moreover, these improvements are observed even with an addition percentage up to 30 %.

According to [26] various studies have been conducted on the use of different types and sources of industrial waste in the production of fired bricks. For instance, waste from the wood industry, paper industries, tobacco industry, as well as sugar cane and biomass industries, are increasingly being utilized in recycling to produce environmentally friendly-fired clay bricks [27–32]. Other studies have explored the production of bricks from industrial waste using processes such firing, cementation, and geopolymers [33]. The utilization of agricultural and industrial waste in the development of clay bricks as a sustainable construction material is a practical solution that has been proposed [34, 35].

This study focuses on the manufacturing of a brick using the clays from Oued Remila (Bejaia) and incorporating natural phosphate waste from Djebel Onk, which possess remarkable qualities. These waste materials consist of mixed grains of dolomite-phosphate, bound together by a carbonate cement and clay [36].

The results of the various tests demonstrate that: The combination of these two materials constitutes a new approach to the recovery of natural phosphates, which has a very high waste rate. Tests of making bricks from these two materials have yielded promising results. From a mechanical point of view, the best flexural strengths obtained at a temperature of 900 °C vary from 3 to 5 MPa deppending on the type of phosphate/clay mixture. The same goes for the compressive strength, which varies from 15 to 27 MPa depending on the type of mixture as well. These results conform to ASTM-C674, 1999 construction standards.

CONCLUSION

In our study, we examined two types of phosphate mining waste: overburden waste and selectivity waste. Overburden waste is considered poor in terms of its chemical composition. However, it contains all the elements present in limestone, clay, and additives used in cement production, such blast furnace slag and pozzolana (CaO, MgO, SiO_2, etc.).

Despite the fact that these elements do not contain P_2O_5, they can still be used as cement manufacturing additives.

On the other hand, selectivity waste is characterized by a high P_2O_5 content, making it economically viable. These phosphate wastes contain significant percentages of P_2O_5, making them valuable. Therefore, both types of phosphate waste cannot simply be considered as waste, but rather as by-products and a source of one or more commercially valuable elements.

To valorize selectivity waste, we propose the use of various treatment methods such flotation and gravity separation, calcination. These methods will concentrate and recover minerals containing P_2O_5, making it possible to exploit this wastes rocks economically.

In summary, overburden waste, although low in P_2O_5, can be used as additives in cement production due to its chemical composition similar to materials used in cement production. On the other hand, selectivity waste, rich in P_2O_5, can be economically valorized by using various treatment methods to recover phosphate. These approaches for valorizing both types of mining waste offer interesting opportunities for efficient resource utilization and reduction of reliance on traditional materials in the cement industry.

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Резиме

МОЖНА ИНДУСТРИСКА УПОТРЕБА НА ФОСФАТЕН ОТПАД КАКО ВЕТУВАЧКО РЕШЕНИЕ ЗА ЖИВОТНАТА СРЕДИНА (ТЕБЕСА, АЛЖИР)

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Клучни зборови: карактеризација; јаловински отпад; селективен отпад; фосфат; Џебел Онк.

Алжир е земја со многу разновиден структурен и геолошки состав, што довело до богатство на разновидни минерални ресурси (фосфати, базични метали, благородни метали, итн.). Рударските активности создаваат значителна количина економски безвреден рударски отпад. Овие отпадни материјали можат да претставуваат еколошки ризици во зависност од нивната состојба, составот и начините на складирање. Во оваа студија ги проучувавме јаловините од рудникот од наоѓалиштето на фосфат Џебел Онк, притоа спроведувајќи целосна минералошка карактеризација вклучувајќи гранулометриски, хемиски и микроскопски анализи, како и анализи на тешки метали, рендгенска дифракција и инфрацрвени анализи. Испитавме два вида рударски отпад: јаловински отпад и остатоци од обработката (отпад на селективност) и предложивме специфични методи за валоризација за секој тип. Остатоците од обработката (отпадот на селективност) имаат економски потенцијал поради нивната висока содржина на P_2O_5. Затоа предлагаме метод на валоризација за овој вид отпад преку различни пристапи за третман како што се калцинирање, миење, флотација и гравитациско сепарирање. За јаловинскиот отпад предлагаме да се користи како додаток во процесите на производство на цемент, бидејќи обично содржи елементи кои се наоѓаат во варовник и глина, како и во адитиви кои се користат во производството на цемент, како што се згура од високи печки и позолани (CaO, MgO, SiO_2 итн.). Сепак, овие материјали не содржат P_2O_5.