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Lead Production in Morocco at the Zellidja Lead Smelter Company

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ABSTRACT: The subsoil of Morocco is marked by a wealth of mineral resources (phosphate, lead, zinc, coal and others). For this reason, the mining sector is still considered one of the main pillars of the national economy. The Moroccan lead deposits are located mainly in the Atlas region and the Eastern region. The Zellidja lead smelter company has succeeded in distinguishing itself and being among the best lead smelters in Morocco. It is known nationally and internationally for its production of soft lead, antimonial lead oxide, fine silver, copper matte and triple alloy concentrate. The majority of its production is destined for international markets such as Europe, North Africa, Near East and Middle East. In addition, it is also recognized for its large capacity of processing lead concentrate from several mines. This capacity has obviously increased and decreased over time, depending on the number of mines exploited, the presence or absence of ore, the quality of the industrial equipment, the number of employees and other circumstances.

KEYWORDS: Eastern region, Lead production, Zellidja.

1. INTRODUCTION

Due to industrial development, lead has become a metal in high demand around the world because of its use in batteries, pigments, gasoline, ink and alloys. According to 2019 statistics [1], the main producers of lead in the world are China (46.7%), Australia (9.6%), Peru (6.4%), United States (6.2%), Mexico (5.3%) and Russia (4.9%). For the rest of countries, lead production is estimated at 20.9% in total [1]. Moroccan lead production in 1980 represented 3.5 % of world production [2], [3]. This production has increased and decreased over time as a result of the discovery of new deposits or the depletion of old deposits. The Zellidja lead smelter company has been one of the most important factors in the evolution of lead production in Morocco throughout history with a processing capacity of up to 160,000 tons per year of lead concentrate.

2. HISTORY

The Zellidja lead smelter is located in the mining village of Oued El Heimer in the eastern region (about 16 km west of Touissite and 32 km south of Oujda). This village is limited to the east by Touissite, to the west by Guenfouda, to the north by Oujda and to the south by Tiouli. It is defined by these geographical coordinates: 34°27'18" North as latitude; 1°54'08" West as longitude and 959 m as altitude. The company's factory covers a total area of 98,195 m^2. As it is bounded by a fence wall with a total length of 1.57 km. Behind the factory there is a storage of slag resulting from the extraction of lead and other metals which are piled up beside the watercourse of Oued El Heimer. This tailings storage area covers a total area of 96,335 m^2 with an estimated three million tons of slag [4].

The Zellidja company's supply of lead concentrate was mainly provided by the mines of Sidi Boubker and Touissite in Morocco and El Abed and Aïn Arko in Algeria [2]. After the nationalization of the mines of El Abed and Aïn Arko in Algeria, the supply of these two mines stopped and consequently the activity of the smelter decreased. Then, the discovery of new deposits of Touissit, Beddiane and Mekta pushed the company to expand through the extension and construction of a new smelter in 1975. Equipped with the most modern installations, the company was then able to increase its production of lead.

After the discovery of the rich natural deposit of lead and zinc in Sidi Boubker. The Zellidja company was created in 1939 to transform the lead concentrates into pure metal [4]. In 1942, the Zellidja company joined with the Peñarroya company to create another smelter in Oued El Heimer named the Peñarroya Zellidja Smelter to further expand [5]. In 1945, the production of this smelter was about 24,000 tons per year of lead metal and 15,000 kilograms per year of silver [5]. Thereafter, its production gradually increased over the years. Its production was about 35,000 tons of lead per year and 30,000 kilograms of silver per year during the period of 1954 to 1961 [5]. In 1970, the smelter was closed due to the depletion of the Sidi Boubker and Touissit deposits and the

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nationalization of the El Abed and Aïn Arko mines in Algeria [2]. Then, in 1973, another company was created, the Zellidja lead smelter company, following the discovery of new deposits at Touissit and the departure of the Spanish company Peñarroya from Morocco.

The official start-up of the new Zellidja Lead Smelting Company installations was in 1975 with a processing capacity of up to 40,000 tons per year of lead concentrate. The construction of a new furnace in 1980 increased the lead concentrate processing capacity to 60,000 tons per year. From 1980 to 1989, the processing capacity of lead concentrate increased from 60,000 tons per year to 100,000 tons per year. With the beginning of the 90's, Zellidja Lead Smelters Company experienced a decrease in its lead concentrate processing capacity. As a result, it announced in 1995 the probable depletion of the Touissit site in 2002. Then, in 2001, the Zellidja lead smelting company reached its peak lead concentrate processing capacity of 160,000 tons per year. Despite the shortage of lead ore at the Touissit site and the closure of the Sidi Boubker mine, the Zellidja lead smelting company tried in 2004 to rebalance its financial situation through a financial and social restructuring. One year later, the company achieved a benefit of 30 million dirhams after this restructuring. Then, its benefit gradually increased over the years. Finally, the activity of the Zellidja company stopped in September 2012 due to the exhaustion of the Touissit ore. It is currently in the liquidation phase after several years of waiting, hoping and looking for a new mining resource.

3. PRODUCTION PROCESS

The process adopted by the Zellidja lead smelting company for the production of soft lead, antimonial lead oxide, fine silver, copper matte and concentrated triple alloy is based on the passage of the ore bonded to other constituents through one or more phases. This production process can be subdivided into the following five phases: roasting, smelting, refining, passage through a rich workshop, passage through rotary furnaces. In addition, each of these phases presents a succession of different steps. After extraction of the lead concentrate from the mines in the region. It is transported to the Zellidja smelting company. Once arrived at the factory of the company, it is passed by the sequence of the phases below:

- **Roasting:** is the operation of transformation of lead sulfides (PbS) into lead oxides (PbO). It aims to remove the sulfur from the lead concentrate to achieve a sulfur content of the agglomerate low enough between 1% and 3% on the one hand, on the other hand to obtain a partially molten product, hard enough to resist the crushing of the charge in the reduction furnace, and porous enough for the reducing gases to circulate easily [6]. Generally, this oxidation is performed according to the Dwight-Lloyd process based on the principle of subjecting the ore to the oxidizing action of air under high temperature [7]. The preparation of the charge, consisting mainly of lead concentrate, fluxes and some recycled products, is the first step of this phase. Then, following the exposure of the charge to a delimited temperature between 950 °C and 1000 °C, followed by cooling in air, the molten PbS is transformed into PbO and PbSO4 as a result of the following two oxidation reactions [8] :

$$PbS + 3/2\ O_2 \longrightarrow PbO + SO_2$$

$$PbS + 2\ O_2 \longrightarrow PbSO_4$$

Then, during the roasting process, small quantities of lead are formed through the chemical reactions below:

$$PbS + 2\ PbO \longrightarrow 3\ Pb + SO_2$$

$$PbS + PbSO_4 \longrightarrow 2\ Pb + 2\ SO_2$$

At the end of the roasting phase, the sulfur dioxide (SO_2) released is recovered at the caissons by a ventilation system to convert it into sulfuric acid (H_2SO_4) [9]. Thus, the poor amount of lead (Pb) formed from the last chemical reactions is recuperated. Also, some of the roasted lead concentrate is passed directly upstream of the Dwight-Lloyd machine in an effort to stabilize the galena (PbS) melting temperature. Due to the fact that the molten lead concentrate (1114 °C) cannot be further roasted, it is recommended to add previously roasted concentrate to the charge in order to stabilize the melting temperature [10]. Then, the

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agglomerate (PbO) resulting from the first chemical reaction in large quantity continues the lead metal production process via its immediate passage through the melting phase.

- **Smelting:** This is the most important phase in the lead metal production process. It allows to obtain a maximum quantity of lead from the agglomerate resulting from the roasting phase, at the best cost, in the best safety conditions and while respecting the environment. Typically, reductive smelting is performed either in a water-jacket furnace or in the blast furnace [9]. Notably, the Zellidja company uses during the reduction of lead oxide (PbO) by carbon (C) and its monoxide (CO) a water-jacket furnace. Similar to the roasting phase, the preparation of the charge is the first step of the melting phase. However, this time it consists of agglomerate, coke, melting agents and recycled products. The water-jacket furnace is used as a thermal and chemical exchanger, taking into account the advantage of the combination of smelting and reduction. Taking into account that the lead oxide (PbO) obtained at the end of the roasting phase contains about 9% of its weight in carbon (C), it is necessary to release the carbon in order to obtain the lead product [11]. The reduction of lead oxide by carbon and its monoxide is performed according to the following two chemical reactions [9]:

$$PbO + C \longrightarrow Pb + CO$$

$$PbO + CO \longrightarrow Pb + CO_2$$

Lead is the result of the above chemical reactions. It contains approximately 98% of its weight in lead [11]. Because of its impurity, it must necessarily go through the refining phase. The slag from the reductive smelting process is partially recycled [11].

- **Refining:** is the third phase of the lead metal production process. It allows the pyrometallurgical elimination of all the metals present in the lead in order to obtain a soft lead with 99.99% Pb. There are two types of refining: conventional refining and electrolytic refining. Due to the fact that Zellidja's Lead products do not contain high levels of impurities, the type adopted is the conventional refining. This is the most common type of refining used throughout the world. It is carried out in steel tanks with a capacity ranging from 50 to 300 tons of metal.
- The refining process adopted by the Zellidja company is based on the following eight steps: liquefaction, de-copperization, purification, de-silvering, dulcification, de-bismuth, washing and ingotage. Once the lead was put into steel tanks at a temperature that exceeded the melting point of lead, the copper was removed. Then, by adding sulfur (S), the removal of copper (Cu) is continued through the operation of de-copperisation. In the presence of oxygen (O), the addition of sodium nitrate ($NaNO_2$) to the working lead obtained after copper removal allows the removal of the antimonial lead oxide through the purification operation. The zinc is then extracted by passing the resulting mixture through two successive stages: desilvering and dulcification. Refining continues with the addition of calcium (Ca) and magnesium (Mg), which combine with bismuth (Bi) to form an insoluble compound [11]. This compound is then removed from the lead as a scum appearing on the surface of the bath. At the end of the refining phase, nitrates and soda were added to ensure that the lead obtained from the refining phase was free of the last traces of impurities such as sodium (Na) scum. Finally, the lead obtained from the refining phase is the refined lead, also called soft lead.
- **Rich workshop:** is the phase allowing the extraction of the concentrated triple alloy and the fine silver through the addition of the new zinc and that recovered in the cauldron. Then, this mixture undergoes the galvanizing operation at a temperature between 315 and 550 °C for a period varying from 4 to 6 hours. Then, a period of refrigeration for a minimum of 12 hours is required.
- **Rotary furnace:** constitutes the last phase of the production process of the Zellidja foundry company. By putting the copper skimming of the lead enriched by the addition of fondant (Iron, Sandstone) in the rotary furnace, three constituents are recuperated: the copper matte, the lead and the slag.

CAPACITY OF PRODUCTION

The Zellida company started its activity with a processing capacity of lead concentrate not exceeding 40,000 tons per year. After that, the company gradually increased its processing capacity to 160,000 tons per year in 2001. Four years later, Zellidja's lead

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concentrate processing capacity dropped to about 80,000 tons per year due to the exhaustion of the Touissit mine site. Since 2007, Zellidja's lead concentrate processing capacity has experienced slight decreases and increases ranging from 74,592 tons per year to 29,646 tons per year. Since 2012, the company's production has definitely stopped due to ore depletion.

4. CONCLUSION

From its creation until its final closure, lead production at the Zellidja lead smelter has known increases and decreases over time. In 2001, its production reached its highest level with a processing capacity of up to 160,000 tons of lead concentrate per year. The process adopted by the Zellidja lead smelter company for the production of lead is based on the passage of the ore by the following five phases: roasting, smelting, refining, passage through a rich workshop, passage through rotary furnaces.

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