Magnesium as a Critical Raw Material

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Abstract

The term “critical raw materials” (CRMs) is used to describe raw materials which are economically and strategically important for the European Union (EU) and, their resources are under risk to obtain for a sustainable European economy. The first report concerning CRMs was released in 2011 containing 14 raw materials and, the list was extended to 27 in 2017. Magnesium, borates and antimony which have remarkable resources in Turkey are in the current list of CRMs. Approximately 1 million tonnes of magnesium metal is produced across the World per year (by the year 2017). Magnesium is the lightest structural metal and it makes magnesium strategic for products which lightweight is critical such as transportation, aviation, space and electronic goods. In the present study, classification and properties of CRMs, their importance and the current place of magnesium metal and its alloys were discussed with future predictions.

1. Introduction

Raw materials which are important for the development and the sustainability of economy in the European Union are described as Critical Raw Materials (CRMs). CRMs do not include the raw materials for energy production and agricultural goods [1]. In the member states of the EU, a lot of works are being carried out on the supply risks of CRMs to determine current status and to develop future perspectives [2, 3]. To accept a raw material as CRM, it is necessary to meet with following aspects:

- Limited resources,
- High economic value for key industries in the EU such as environmental, automotive, defence, medical, electronics,
- High import dependency,
- Deposits (or resources) of a raw material located in a few countries across the world,
- Raw materials which are not easy to find substitutional materials in the near future [1].

In the first list of the European Commission released in 2011, only 14 raw materials were included whilst the number was increased to 20 in the revised list in 2014 [4]. The current list was released in 2017 and included 27 raw materials as CRMs as seen in Table 1 [5].

Table 1. Current list of CRMs released in 2017 [5].

<table>
<thead>
<tr>
<th>Antimony</th>
<th>Baryte</th>
<th>Beryllium</th>
<th>Bismuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borate</td>
<td>Cobalt</td>
<td>Coking coal</td>
<td>Fluorspar</td>
</tr>
<tr>
<td>Gallium</td>
<td>Germanium</td>
<td>Hafnium</td>
<td>Helium</td>
</tr>
<tr>
<td>Indium</td>
<td>Magnesium</td>
<td>Natural graphite</td>
<td>Natural rubber</td>
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<tr>
<td>Niobium</td>
<td>Phosphate rock</td>
<td>Phosphorus</td>
<td>Scandium</td>
</tr>
<tr>
<td>Silicon metal</td>
<td>Tantalum</td>
<td>Tungsten</td>
<td>Vanadium</td>
</tr>
<tr>
<td>Platinum Group Metals</td>
<td>Heavy Rare Earth Elements</td>
<td>Light Rare Earth Elements</td>
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</tbody>
</table>

The production of CRMs in the EU, via enhancing recycling rates and launching new mining activities, was wanted to incentivise through the list of CRMs. It also helps to understand how the security of supply of raw materials can be achieved from different geographical sources. CRMs are a priority area in the EU Circular Economy Action Plan. The list was also purposed to increase foreign direct investments in the EU [5].

2. History of CRMs

Raw materials and resources have been critical and strategic in the history, not only for today. For instance, it was well known that Alsace-Lorraine region where has very important coal resources was one of the reasons of World War I [2, 6]. Many countries, including the EU, have conducted works to determine the CRMs and future projections. Particularly, the recent issue between Japan and China on “the rare earth metals” showed the importance of critical raw materials again. The most remarkable works on the CRMs were primarily released by the EU and the UK. Those are “Tackling the challenges in commodity markets and on raw materials” which was released by the EU – European Commission (2011) and the “Risk List” by British Geological Survey (2011) [2, 7, 8].

The list which was released by European Commission in 2011 was included 14 raw materials after the assessment of 41 candidate raw materials. Those were antimony,
beryllium, cobalt, fluor spar, gallium, germanium, graphite, indium, magnesium, niobium, platinum group metals, rare earth elements, tantalum and tungsten. The raw materials for energy production and agricultural goods were not involved in the list regarding to the assessment procedure of CRMs; briefly the list only includes non-energy and non-agricultural raw materials [7]. The original list was revised to 20 CRMs in 2014 by the addition of borates, chromium, coking coal, magnesite, phosphate rock and silicon. Tantalum was excluded from the list and, the rare earth elements were separated into two sub-groups as heavy rare earth elements and light rare earth elements [4]. The last, and the up-to-date, version of the list was formed in 2017 as seen in Table 1. Baryte, hafnium, helium, natural rubber, phosphorus, scandium, tantalum and vanadium were included in the list with the subtraction of chromium [5].

3. Selection Procedure of CRMs

Basically, supply risk and economic importance are two key factors to determine CRMs apart from overall detailed calculation methodology (Figure 1) [5].

![Figure 1. Supply risk vs. Economic importance for CRMs (re-scaled from the original figure)](image)

The assessment methodology of CRMs has been used for the determination of raw materials for the reports released by European commission in 2011, 2014 and 2017 respectively. The methodology has got some modifications from the first one to the third report [9]. Current methodology is being explained with the following statements.

Ad-Hoc working group on Defining Critical Raw Materials (AHWGCRM) in European Commission developed the EU criticality methodology April 2009 and June 2010. For assessment, the Supply Risk is calculated with Equation 1 whilst Equation 2 is used for the calculation of the Economic Importance [9, 10].

\[
SR = HHI_{WGI} \cdot (1 - EoL_{RIR}) \cdot SI
\]

Where SR is supply risk, HHI is the Herfindahl Hirschman Index, WGI is the scaled World Governance Index, EoL_{RIR} is the End-of-Life Recycling Input Rate and SI is the Substitution Index [9].

\[
EI = S(A_S \cdot QS)
\]

Where A_S is the share of demand of a raw material in a megasector and QS is the megasectors’ Gross Value Added [9].

4. Magnesium as a CRM

Increasing use of light components in equipment, devices and vehicles increases the demand of light metals such as aluminium, titanium and magnesium. Magnesium (Mg) is the lightest structural metal with a density of 1.738 g·cm\(^{-3}\) and, its alloys have quite good and promising mechanical properties. Therefore, magnesium is used in lots of industries to meet with weight reduction requirements such as electronics (laptop and mobile phone frames), aeroplanes (construction components), aerospace (satellite components) and automotive (direction wheels, joint components) etc. The Pidgeon Process is the main method of primary magnesium production across the World. It is employed to produce metallic Mg from calcined dolomite (CaO-MgO) ores [10-13]. Lloyd Montgomery Pidgeon developed the process in the beginning of 1940s in Canada because of the increasing demand of magnesium metal during the World War II [14-15].

In the method, calcined dolomite is reacted with FeSi (ferrosilicon) reductant in steel (air-tight) retorts. Thus, the process is carried out under the vacuum atmosphere of ~1 mbar (in practice). Reactions take place at temperatures between 1200 – 1250 °C for about 6 hours. The application of the process under vacuum is a thermodynamical requirement. After cooling of the products, magnesium crown and slag phases are mechanically taken out from retorts. The main reaction of the Pidgeon Process is given with Eq. 3 [11, 16-18].

\[
2MgO\cdot CaO + FeSi \rightarrow 2Mg + Ca_2SiO_4 + Fe
\]

In 2016, 1,010,000 tonnes of primary magnesium metal were produced and, approximately its 880,000 tonnes (~87.1%) were produced in China [19]. 88-90% of global primary magnesium is delivered through the Pidgeon Process whereas remaining production is conducted through the electrolytic process [20, 21].

5. Future Projection
In the next 20 years, it is reckoned that the demand on the raw materials will remarkably increase, particularly regarding to the need on oil recursos. Consumption rates of raw materials increase between 3-5% annually. To mitigate the pressure on natural resources, it is necessary to enhance efficiency on mining operations. It is clear to see that the use of scraps and wastes-containing valuable materials will increase. The recycling of base metals, such as iron-steel, copper, aluminium, lead, is already done with high rates. Furthermore, recycling rates will increase for other metals like magnesium, beryllium, gallium, lithium and rare earth metals. Magnesium is the lightest structural metal and, its demand and production rates increase day by day. It is predicted that the Mg will be in the list of CRMs for the next decades [22, 23].

6. Conclusion

In the present study, the definition of critical raw materials (CRMs), selection methodology, historical background and magnesium as a CRM were investigated and discussed. The current list of CRMs was released in 2017 with 27 raw materials including magnesium. The need on the production of lighter vehicles and devices increases the demand (also the production rate) of light structural metals like magnesium (d: 1.738 g·cm⁻³). This density value makes the magnesium the lightest structural metal and, it is predicted that magnesium will be in the list of CRMs for long years with its critical properties.

References