"A Review of Magnesite Mineral and its Industrial Application"

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Abstract:

Magnesite or magnesium carbonate belongs to the calcite family and is one of the primary sources of magnesia. It can be used in many industrial applications, especially after calcination. The process leads to intermediate products, which include Caustic Calcined Magnesite (CCM), Dead Burned Magnesite (DBM), and Fused Magnesite (FM). Each of these intermediate products exhibits different physical, chemical, and thermal properties due to the different degrees of heat treatment in the calcining process, mainly among other factors. For example, Reactivity is a significant property and other properties too of (CCM), making it desirable in many different industries and applications. These applications are represented in the manufacture of paper, plastics, building materials, ceramics, glass, cosmetics, agricultural applications (fertilizers and animal feed), and environmental applications (water treatment, fume purification). On the other hand, due to the inertness and other properties of the intermediate products (DBM) and (FM), they are used as refractory materials in significant industrial applications such as iron and steel furnaces. These diverse and essential applications have led to high demand for magnesite, especially intermediate products with high purity of magnesia (MgO) and low impurities. Various treatment methods are applied, including physical, chemical, and physio-chemical, to decrease impurities. These methods are used depending on microscopic and analytical results to characterize the ore, its impurities, and the way they are related. This study aims to review the presence of magnesite in nature and its physical, chemical, and thermal properties in addition to the intermediate products and their various applications in the industry. Finally, the summary of the different processing techniques for magnesite ore and their effectiveness on removing the impurities.

Keywords: Magnesite, Physical; Chemical, Thermal, CCM, DBM, FM, Application, Upgrading.

1. Introduction

The word "magnesia" is used to refer to a variety of products obtained from sources that are high in magnesium. The seventh most common element, magnesium, makes up 2% of the planet's crust (Erdogan, 2017; Kogel et al., 2006). It ranks third in terms of abundance among the elements in seawater. Magnesia is either made from magnesite rock or obtained as magnesium hydroxide from brines, seawater, or mineral deposits (Erdogan, 2017). Magnesite is the most typical source of magnesia, which has numerous important industrial uses. Magnesite ($MgCO_3$), theoretically contain 52.4 % (CO_2)and 47.6% MgO (Chatterjee, 2009; McHaffie & Buckley, 1995). But in nature, the percentages vary because of including different amounts of impurities. These impurities can be divided into two main categories, carbonates (including calcite, dolomite, talc, etc.) and silicates (including quartz, talc, serpentine, etc.) (Wang et al., 2011).

Magnesite ($MgCO_3$) and dolomite ($MgCO_3.CaCO_3$) are the two primary sources of magnesium and its compounds, among all other minerals (Erdogan, 2017). Magnesite is commonly formed during metamorphism and is usually found as a secondary deposit formed because a solution of magnesium bearing replaces dolomite beds. This type of magnesite ore is usually associated with a high concentration of carbonate impurities, and the grain crystallization is coarse (Abu-Jaber & Kimberley, 1992). The other formation type of magnesite is during a chemical weathering of carbonate or magnesium-rich rocks in soil and subsoil, formed by carbon dioxide dissolving magnesium-containing minerals in groundwaters (Kim et al., 2018; McHaffie & Buckley, 1995). The magnesite deposit as a result from an alteration material in magnesium-rich rock formations like serpentinite is usually associated with silicate impurities with the absence or low percent of carbonate impurities, and the grain crystallization is amorphous (Abu-Jaber & Kimberley, 1992). Magnesite also occurs in veins in regional and contacts metamorphic landscapes (Chatterjee, 2009). Magnesite is the end-product of the magnesium isomorphous sequence of carbonates and often manifests in either of two physical states, crystalline or cryptocrystalline (amorphous) (McHaffie & Buckley, 1995).

Magnesite ore is widely used in many fields because of its suitable physical and chemical properties for many industries, such as chemical (Shand, 2006b) , agriculture (Fan et al., 2016), environment (Stolzenburg et al., 2015) and refractory (Hou et al., 2020). Although the name "magnesite" technically only applies to the naturally occurring mineral, it is frequently used to refer to its finished goods. In 2020, a survey of the resource market done by the U.S. Geological Survey showed significant growth in mine production of magnesite ore. Table 1 shows the world production of magnesite ore in 2018 and 2019. China contributes a large share of the world's production of magnesite by about 70% but offset by a **s**ignificant depletion of its reserves. Moreover, Russia maintains its reserves of magnesite ore, which is estimated at about 40% of the world magnesite ore reserve as shown in Figure 1. Magnesite commonly sold as intermediate products of Dead-burned magnesite (DBM), caustic-calcined magnesite (CCM) and fused magnesite (FM). The two most significant magnesite products commercially are (DBM) and (CCM) (Kogel et al., 2006). The percentage of impurities and the magnesia content both affect price. As shown in Table 2, the product with high purity always undergoes repeated processing, which drives up its price.

Table 1. **The world mine production of magnesite ore in thousand tons in 2018 and 2019 (US Geological Survey, 2020)**

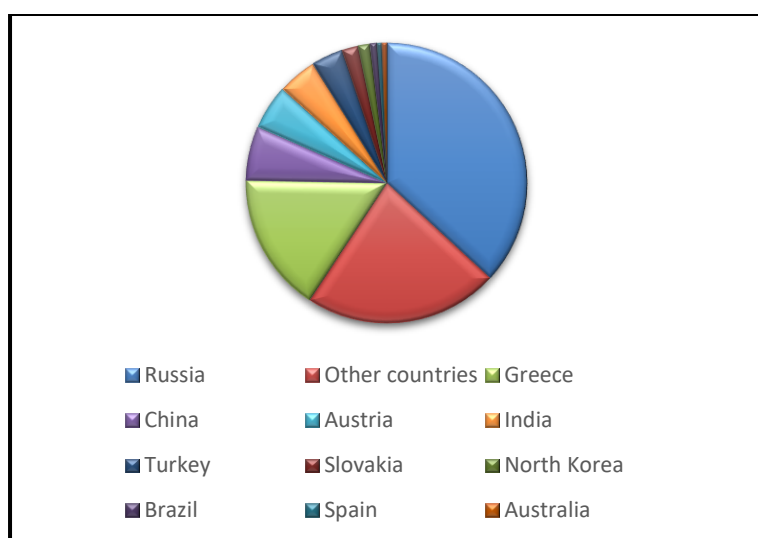| Country	Mine Production	
	2018	2019
China	18,500	19,000
Turkey	1,800	2,000
Brazil	1,700	1,700
Russia	1,500	1,500
Austria	750	740
Spain	550	580
Slovakia	475	500
Greece	450	470
Australia	265	300
India	175	140
North Korea	70	50
Other countries	865	600
World total	27,100	27,580

Figure 1. **The distribution of the world reserve of magnesite ore (US Geological Survey, 2020)**

Table 2. **Magnesite different grades and prices (Kramer, 2003)**

Country and material	Type of Magnesia	Criteria % MgO	SiO$_2$	CaO	Fe$_2$O$_3$	Al$_2$O$_3$	US$
China	CCM	90-92	3.50	2.00	_	0.90	92-98
	DBM	90.00	4.00	2.30	1.20	1.20	90-92
		92.00	3.50	2.00	1.50	_	92-94
		94-95	2.20	1.60	1.00	1.00	122-130
United State	CCM	98.00	0.40	0.90	0.24	0.21	538
	DBM	97.00	0.85	1.05	0.20	0.19	400-406

2. Unique Properties of Magnesite

The distinct chemical, physical and thermal qualities of Magnetite make it useful in various industrial settings and allow it to stand in for other minerals in some cases.

2.1 Physical Properties

Magnesite typically has an opaque cast and its colour range from white to black with shades of yellow, blue, red, or orange (Nasedkin et al., 2001). The material features a unique hexagonal crystal structure. It typically has an earthy or chalky texture and is enormous, coarse to finely granular, compact, lamellar, or roughly fibrous. Magnesite has an X-ray density of 3.0095 g/cm^3 and the hardness of magnesite on Mohs scale is between 3 to 4.5. Magnesite has a specific gravity considerably lower than other hydrates and basic carbonates, ranging from 2.98 to 3.44 (Shand, 2006a). Magnesite is uniaxially negative based on refraction and exhibits refractive indices when purified, which causes it to fluoresce when exposed to X-rays. It has been determined that the average enthalpy of magnesite production from the components at standard temperature and pressure is -1113.28 kJ/mol (Shand, 2006a). The physical mineral properties of crystalline and cryptocrystalline magnesites differ to some extent. Crystalline magnesite is typically more flexible than cryptocrystalline magnesite (Pagona et al., 2021; Shand, 2006a). Cryptocrystalline magnesite is amorphous and composed mainly of small grains aggregates, whereas crystalline magnesite's crystal structure is well-developed (Nasedkin et al., 2001). Because clumped isotopic composition is dictated by complex bonding, differences in the crystal structure are expected to alter how clustered isotopic fingerprints are seen in the structures. As a result, some thermal actions like burial heating and diagenesis may change their initial signatures in various ways (Nichols, 2009; Pagona et al., 2021).

2.2 Chemical Properties

In nature, the mineral periclase contains magnesium oxide, (Gehringer et al., 2019; Wang et al., 2011). Additionally, it may be produced by heating several kinds of magnesium carbonate (magnesite). The temperature and length of the heat processing of the magnesium components during their manufacture determine the reactivity of magnesium oxide (Bassioni et al., 2021). Temperatures used for the magnesite calcination affect the reactivity of the oxide compounds produced (Gehringer et al., 2019). In water without (CO_2), magnesium carbonate is essentially insoluble. The solubility of magnesite is increased by dissolved (CO_2) in water; however, most of the ionic species are available as bicarbonate instead of carbonate. With the rise in (CO_2) partial concentration and heat reduction, magnesite becomes more soluble. Additionally, whether dissolved carbon dioxide is present, the existence of dissolved salts impacts the solubility of magnesite. Chlorides, sulphates, and nitrates also enhance their solubility (Shand, 2006b).

2.3 Thermal properties

At a temperature of 700 °C, magnesite begins to lose its carbon dioxide (CO_2) content, and this loss continues with the continued exposure of the raw magnesite material to the heat. As the temperature increases, the rate of carbon dioxide loss increases (Huang et al., 2020). Between 700 and 1500 °C, the escaped (CO_2) forms cumulative pores, revealing a large surface area for reactions. This leads to a product with reactive properties that can absorb (CO_2) and moisture. These properties make magnesia suitable for many industrial uses (Chatterjee, 2009). When the temperature increases over 1500 °C calcined magnesia starts to fuse, and crystallization growth occurs to form a periclase (a crystallized form of magnesia). Increasing the temperature up to 2300 °C will lead to the full growth of crystallization, causing a porosity closing. These gained properties lead to an inert and high-density product. This new product meets the application of the refractory industry (Chatterjee, 2009; Huang et al., 2020; Shand, 2006b). When the temperature exceeds 2300 °C, the magnesia is recrystallized and fused to form the fused magnesia. This process is very costly and is used in very few cases, however, the process will always show the best results with the purity of (MgO) reaching 99% and close to having zero impurities (Chatterjee, 2009).

The impurities significantly impact the intermediate products of magnesite ore. Carbonates, silicates, iron, and alumina impurities commonly come with various percentages with the magnesite ore (Wang et al., 2011). At high temperature, silica (SiO_2) reacts with lime or burnt lime (CaO), and an unstable compound -beta di-calcium silicate- result from this reaction. The beta di-calcium silicate is converted into gamma, which is associated with the expanding in volume, leading to the magnesite crumbling. In addition, thermal shocks impact, convert silica into three forms of compounds - quartz to beta quartz then to beta tridymite and finally to cristobalite - and these changes are also associated with volume changes, leading eventually to cracks (Chatterjee, 2009; Rudnykh et al., 1988). Alumina also reacts with silica and lime to form a compound - alumina calcium silicate – which has a lower melting point than iron impurities and impact on refractory applications. The

iron impurities react with magnesia to form a compound -magnesium oxide with ferric oxide - which closes the pores by cementing them together. This act leads to less porosity, which means less reactivity. However, the small percentage of iron impurities that react with magnesia can act as a binding agent that will help close the porosity which is beneficial if the aim is to achieve an inert intermediate product (Chatterjee, 2009; Shand, 2006b).

3. Magnesite Intermediate Products

3.1 Caustic-Calcined Magnesia

Caustic Calcined Magnesia (CCM), also referred to as Light Calcined Magnesite (LCM) or active magnesia, is obtained by calcining magnesite at temperatures between 700-1000°C (Figure 2). Also, there is a hard burned magnesite with limited reactivity, is obtained by calcining magnesite at temperatures between 1000-1500°C (Bentli et al., 2017). It is primarily used in rayon production, water purification (Namdeo et al., 2009), waste treatment (Stolzenburg et al., 2015), and stack gas cleaning (Gehringer et al., 2019; Kogel et al., 2006). Additionally, it serves as a feedstock for manufacturing magnesium metal (Keeling & Wilson, n.d.), glassware, ceramics, magnesium cement (Kidalova et al., 2011), magnesia-based oil lubricants, animal feeds, and fertilizers (Fan et al., 2016) (McHaffie & Buckley, 1995). Also, used as a critical tool in abrasive wheels and as a furnace additive to lessen the oxidation of steel tubes. It is also used as an acid-neutralizing ingredient in lubricating oils, as a filler in polymers, as an acid acceptor, as a catalyst in thickeners to enhance pigments, and in the compounding of rubber (Bassioni et al., 2021). It comes in powder form and is either white or yellow. In addition, it is helpful for all these applications since it comes in various purity levels and particle sizes. In chemical, agricultural, environmental, refractories, cosmetics, construction, and steel applications, the demand for CCM is driven by its high purity, reactivity, and surface area (Gehringer et al., 2019). However, the strong demand for CCM from a broad range of applications leads to its scarcity and increased prices, further inhibiting its adoption in many applications (Daigle & DeCarlo, 2022).
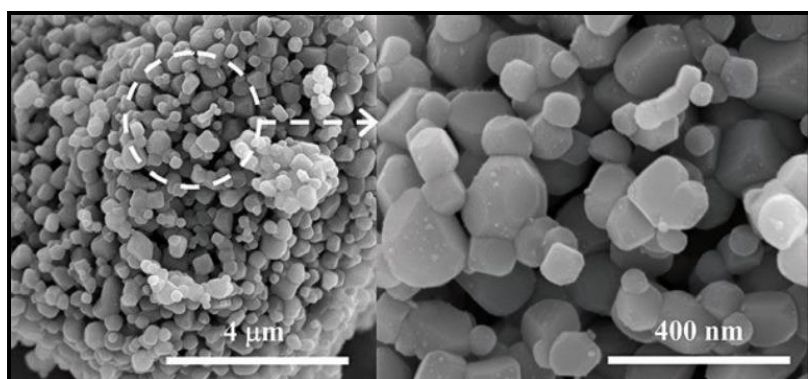

Figure 2. Micrograph of a Caustic-Calcined Magnesia

3.2 Dead Burned Magnesia

Dead-burned magnesia (refractory magnesia) is a significant component of refractory materials and is produced by heating magnesite or magnesium hydroxide (Kim et al., 2018). Magnesite or magnesium hydroxide is calcined at temperatures between 1,500 and 2,300°C range to produce dead-burned magnesite, also known as sintered magnesia, magnesia clinker, or periclase (Figure 3) (Bentli et al., 2017; Keeling et al., 2019). Most magnesium compounds are used in the refractory sector (Hou et al., 2020) due to high purity, submicron, and Nano powder forms (Yousefi et al., 2017). The melting point of dead-burned magnesia is the highest among all commonly used refractory minerals and plays a significant role in many industrial processes. 70% of dead burned magnesite is consumed in steel furnaces and 7% for lime and cement furnaces. It is utilized in basic refractories like magnesia-carbon bricks (Pal & Bandyopadhyay, 2007) or magnesia-chrome for smelting steel, iron, and other nonferrous metals (Sengupta et al., 2014). In addition, 6% is consumed in ceramics, 4% in glass, and the same percentage for chemical uses. The remaining percentage is used in other applications (Kandianis & Kandianis, 2002).
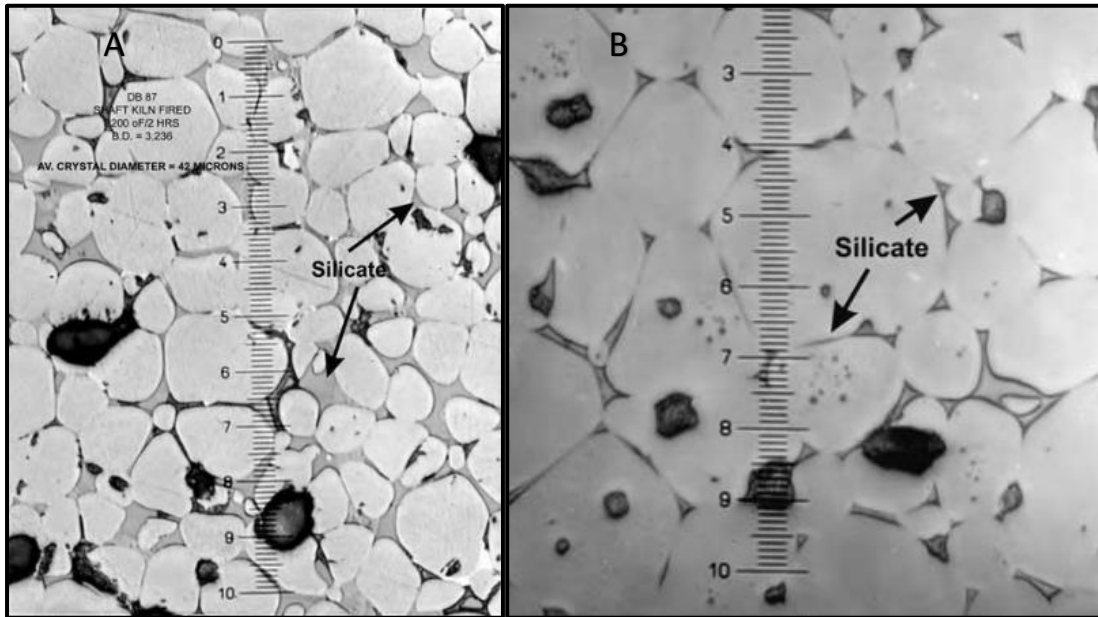
Figure 3. **Micrograph of a dead-burn (A) 87% MgO, (B) 95% MgO (Shand, 2006b)**

3.3 Fused Magnesia

Raw materials for refractory construction that can endure an oxidizing environment at extreme heat are crucial for high-temperature procedures. The most crucial substance for these uses is fused magnesia (FM) (Bilge et al., 2017). High-grade magnesite is melted for up to six hours in electric arc furnaces to a temperature of around 3,000°C to create fused magnesia (Figure 4) (Bentli et al., 2017). In contrast to dead charred magnesia, the approach promotes the production of massive periclase crystals larger in size (Ma & Ren, 2022). With 96% to 99% of (MgO), the result has a substantial density of 3.58 g/cm^3 and a comparatively high chemical resilience, tenacity, and abrasion resistance (Bentli et al., 2017; Kogel et al., 2006). Electricity cost and the quantity and size of electric arc furnaces are the primary variables restricting the capacity of fused magnesia production. The electricity needed to produce fused magnesia ranges from 3500 to 4500 kWh per ton (Yang et al., 2020). Steelmaking refractory bricks are a crucial component of such refractory heat-resistant substances. High density, purity, and giant crystals make fused magnesia one of the finest electrical and thermal insulators. The grade of the electrically fused magnesia is established by selecting the magnesite feedstock, beneficiation procedures, arc furnace electric settings, and sorting. Fusion furnaces can be run using either one or two-step procedures depending on the expense and quality of the energy source (Bilge et al., 2017).
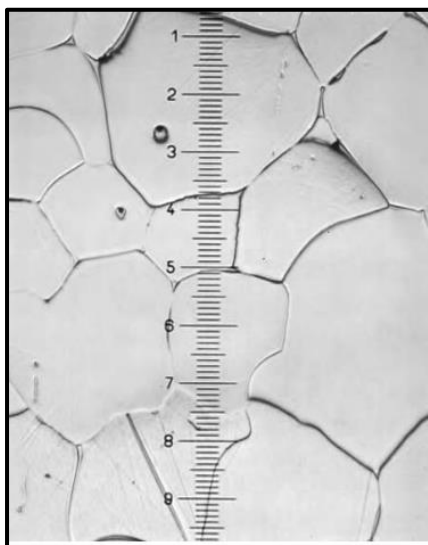
Figure 4. **Micrograph of fused magnesia (Shand, 2006b)**

4. Industrial Applications of Magnesite

4.1 Refractory Application

Magnesite ore is calcined and makes for roughly 90% of the overall usage for the manufacturing of refractory materials (McHaffie & Buckley, 1995; Wang et al., 2011). Magnesia (MgO) is beneficial as a refractory material in the steel and cement industries (Bodenlos, 1954). Magnesium is primarily used in compounds in terms of tonnage in refractory magnesia. In the U. S. and other countries, the iron and steel sector is the biggest consumer of these materials (Kogel et al., 2006). Although several shapes may be generated using magnesia refractories, bricks are the most typical ones. Magnesia can be used alone or in combination with other substances to create bricks with specific properties employed in particular regions of a furnace or as ladle linings (Kogel et al., 2006; Kumar et al., 2012). Magnesia brick is most frequently used as wear and permanent lining in boiler overfires (BOFs) and electric arc furnaces (EAFs).

Bricks are manufactured by mixing different sizes of DBM in specific ratios after being crushed and ground to a size distribution between (5 and 60 μm). 45% of (20–60 μm), 45% of (5 μm), and 10% of (5-20 μm). The mixture is then put through magnetic separation techniques to remove impurities, and 5% CCM is added to the end result of this process (Chatterjee, 2009; Pal & Bandyopadhyay, 2007). After that, water is added to the mixture and bricks are created using processes involving pressure, heat, or fired. Due to the repeated heating and cooling cycle the bricks are subject to spalling which can cause cracking in the furnace lining. To prevent spalling, the bricks are made with a mixture of 15% chrome and 75% magnesia. However, due to its link to health issues, chromium has been outlawed in some nations, and it has been replaced with graphite at a rate of no more than 20% from the brick mixture (Pal & Bandyopadhyay, 2007; Sengupta et al., 2014). One of the most common applications of refractory minerals is the production of iron and steel (Kim et al., 2018).

4.2 Construction/Cement Industry

The construction industry has dominated the magnesite market, which is widely used in the construction sector due to its refractory qualities. The global magnesite market is expanding due to the rising demand for cement and other building materials in the construction sector (Kim et al., 2018). Magnesia-based cement has been used in specialized applications for over 150 years, especially in industrial flooring and insulation boards, adding soundproofing, fire-retardant, dust-free, and low heat conductivity features (Keeling et al., 2019; Yang et al., 2020). The most popular type of cement is magnesium oxychloride, which is manufactured by combining magnesium with a solvent of magnesium chloride. Other cement types include magnesium oxy sulphate and phosphate (Chatterjee, 2009; Kogel et al., 2006). The benefits of reactive magnesia addition to phosphate cement include adjusting for natural shrinking over time and increasing durability when using significant amounts of phosphate cement during synthesizing (Mg(OH)$_2$) in large-scale projects in civil engineering (Keeling et al., 2019).

4.3 Ceramic and Glass Industry

The ceramic part being welded in ceramic welding is bombarded with an oxidizing gas, refractory material particles, and fuel (Sadik et al., 2016). A cohesive refractory layer is created on the welded surface as an outcome of the fuel smouldering and fusing of the refractory material. The refractory material is caustic magnesia, either independently or in combination with (Al_2O_3) and (Cr_2O_3) (Chatterjee, 2009).

Glass is composed of a combination of calcium, magnesium, and sodium silicates (Sadik et al., 2016). Magnesium is present in glass with amounts of 4-5% in regular glass and up to 15% in specific unique glassware (like float glass). A sheet glass form known as "float glass" is exceedingly smooth on both sides and has no internal tension (Chatterjee, 2009; Shand, 2006a). Molten glass at a temperature of 1100°C is released from the kiln onto a layer of molten tin to create sheet glass , where it spreads out evenly into the shape of a long strip. Here, extra (MgO) binds (CaO) and stops it from interacting with the molten tin (Chatterjee, 2009).

4.4 Environmental Protection

To neutralize acidic wastewater and purify sewage waste to preserve pH and minimize odors produced by anaerobic bacterial activity, ($Mg(OH)_2$) slurry from CCM is combined with water. Due to the transition of (H_2S) to sulphuric acid by bacterial activity and corrosion, concrete deterioration results from (H_2S) emission in sewage systems (Stolzenburg et al., 2015), (Keeling et al., 2019). Additionally, it has been said that caustic magnesia effectively removes the divalent metal cadmium from water (Chatterjee, 2009). Consequently, because magnesia is a powerful remediation technique, it is essential for environmental protection (Stolzenburg et al., 2015), (Shand, 2006b). Sulphur dioxide is removed from industrial air emissions magnesia to lower air pollution. By filtering out silica and causing heavy metals to precipitate, it is used to cleanse industrial effluent (Zhang & Duan, 2020). Spills of dangerous chemicals can also be cleaned up due to CCM absorbent qualities (Tian et al., 2021).

4.5 Plant Fertilizer

Magnesium is a chlorophyll molecule component structurally essential for plant photosynthesis (Chatterjee, 2009). Plants can weather and die if insufficient magnesium is present in soil or fertilizer applications (Kogel et al., 2006). In addition, the need for healthier and more inexpensive fungicides and pesticides has rekindled attention to mineral-based treatments as substitutes (Chen et al., 2020; Jandl et al., 2001). The effect is partially ascribed to the ($Mg(OH)_2$) particles' large surface area, permeability, and nanoscale internal/external crystalline surfaces. Reactive oxygen species, which can react with and inactivate fungi and bacteria cells, appear to be stabilized by charge imbalances on edge sites and extremities of nanosurfaces and an alkaline atmosphere (Fan et al., 2016; Keeling et al., 2019).

4.6 Animal Feeds

Magnesium aids in the development of strong bones, the production of proteins, the release of energy from muscle, and the regulation of animal thermoregulation. It is administered in animal feed for this reason in the state of caustic magnesia (Chatterjee, 2009). To prevent hypo magnesia, also known as grass tetany, a potentially deadly condition, grazing animals, such as sheep and cattle, need magnesium in their diet (Kogel et al., 2006; Shand, 2006b). In aquaculture, adding a high surface area of ($Mg(OH)_2$) with a small amount of calcium carbonate has successfully enhanced the parameters of the pond bottom and the water quality. Decreased turbidity, deposition of iron and other heavy metals, decreased hydrogen sulphide, stabilization of seawater's alkaline pH, reduction of sludge, and a rise in phytoplankton production are the outcomes (Keeling et al., 2019).

4.7 Paper and Plastic Industry

Caustic magnesia is used in the sulphite method of producing paper, together with lime and dolomite. (CaO) and (MgO) are transformed into slaked lime or ($Ca(OH)_2$) and ($Mg(OH)$), respectively, by combining water. They are then changed into the acidic ($CaHSO_3$) and ($MgHSO_3$) by passing (SO_2) gas. Besides cellulose, they dissolve every component of wood chips together, although ($MgHSO_3$), which is more reactive, permeable, and resilient than ($CaHSO_3$), boosts the process's effectiveness (Chatterjee, 2009).

Caustic-calcined magnesia is used to make rubber, rayon, and gasoline additives (Shand, 2006b). It is employed in producing magnesium acetate, which is necessary for neutralization, while rayon fabric is produced. The synthesis of magnesium-based sulfonates employed as fuel additives and as acid recipients and sludge solvents in crankshaft lube oils begins with caustic-calcined magnesia as a feedstock (Kogel et al., 2006).

4.8 Cosmetic Industry

In cosmetic products, high-purity light magnesia is used to counteract the effects of sweat's acid, which can irritate skin and corrode materials in touch with it (Chatterjee, 2009). Simplicity, lightness, and free-flowing quality are the primary characteristics of powdered magnesia. Lead and arsenic are unacceptable because they harm the human body. In the cosmetic industry, magnesite has a wide range of dyed hues and low manufacturing costs; hence it creates beautiful, economical costume jewellery and art projects (Gehringer et al., 2019; Shand, 2006b). Magnesite beads make jewellery once cut, drilled, and polished. However, magnesite is less durable than other gem minerals, making it less appropriate for use in jewellery (Schwarzinger, 2017).

5. Upgrading magnesite ore

Many processing techniques remove the impurities and upgrade the magnesia content of magnesite ore. According to Karantzavelos (1984), the processing of magnesite ore can be divided into physical separation and pyro-metallurgical processes such as optical sorting, magnetic separation, gravity separation, electric or electrostatic separation and flotation (Zhu et al., 2022). Each type of physical processing technique effectively removes one type or more of impurities. The optical sorting method targets all impurities depending on the mineral surface properties and can effectively remove (SiO_2), (Al_2O_3), (Fe_2O_3), and (CaO) from low-grade magnesite ore (Bilir & Akdaş, 2012). The sorting method was applied to upgrade a magnesite waste sample and removes 8% of (SiO_2), 1.6 per cent of (CaO), 1% of (fe_2O_3), and 0.1% of (Al_2O_3). Gravity separation depending on density difference and using a ferrosilicon medium was tested to remove (CaO) impurities of magnesite ore from the Gologorsk pit. In addition, the density difference of 0.1 to 0.15 between the magnesite and (CaO) allows the removal of the impurities by 4.5%. Heavy media separation effectively removes the (CaO) gangue from the magnesite ore (Suslikov et al., 1966). Also, a multi-gravity separator was implemented to decrease the calcined magnesite (CaO) impurities by 1.7% from the original ore. The multi-gravity separator separated the achieved magnesite from the (CaO) of calcined magnesite ore, leading to good results (GENCE, 2001). The electric separation method was applied to magnesite ore, decreasing by 3% of (CaO) and 1.5% of (SiO_2) (Urvantsev & Kashcheev, 2012). Also, electrostatic separation is applied to a magnesite ore, and the separation performance between carbonates and silicate is suitable. However, this method is effective for low-grade magnesite with high silicate impurities because they have the same behaviour as magnesite, which is not with carbonate impurities (Gehringer et al., 2020). The flotation process is applied in high-grade and low-grade magnesite ore and effectively removes most impurities. According to Chen et al. (2020), the (SiO_2) and (CaO) impurities decreased by about 0.6% for the high-grade magnesite ore. For low-grade magnesite ore, one of the samples consisted of high (SiO_2) impurities, and the other consisted of a high concentration of (CaO) impurities which were decreased by more than 10% (Li et al., 2010; Peravadhanulu et al., 1979). Moreover, the calcination process is used for the pyro- metallurgical separation method to increase the magnesia content by about 42% after the calcination process (Bentli et al., 2017).

Table 2. **Processing methods and chemical composition of magnesite ore**

Processing method	Ore chemical composition						Results	References
	MgO %	SiO₂ %	CaO %	Fe₂O₃ %	Al₂O₃ %	LOI %		
Optical sorting	_	9.94	2.41	1.22	0.11	_	The optical sorting machine silicate to about 2% and carbonate to 1.6% of Turkey low-grade magnesite ore.	(Bilir & Akdaş, 2012)
Magnetic separation	33.92	9.86	5.73	7.18	_	40.48	Separation of magnesite from dolomite by magnetic field because magnesite was interlocked with hematite	(Yehia & Al-Wake

Processing method	MgO %	SiO₂ %	CaO %	Fe₂O₃ %	Al₂O₃ %	LOI %	Results	References
					and magnetite and carbonates impurities decreased to about 1%.				(el, 2013)
Heavy media separation	41.1	2.1	6.1	_	1.4	49	Heavy media separation effectively removes the carbonates to 1.6% of magnesite ore located in Sweden.	(Suslikov et al., 1966)
Electrostatic separation	36.1	13	2.5	_	_	40.9	Electrostatic separation performance between magnesite and silicate was effective by 90% magnesite recovery. However, poor separation with carbonate impurities.	(Gehringer et al., 2020)
Multi gravity separator	44.87	0.5	3.1	0.3	0.1	51.11	Multi gravity separator removes 1.4% of carbonate impurities of Turkey calcined magnesite ore.	**(GENCE, 2001)**

Processing method	Ore chemical composition						Results	References
	MgO %	SiO₂ %	CaO %	Fe₂O₃ %	Al₂O₃ %	LOI %		
Electric separation	43.1	1.6	4.07	1.28	_	50.6	Electric separation effectively removes silica to 0.19% and carbonate to 1.3%.	**(Urvantsev & Kashcheev, 2012)**
Reverse flotation	38.4	14.7	2	0.09	1.1	42.58	The reverse flotation process effectively separates most of the silicate impurities from the magnesite ore to 1.73%	(Chen et al., 2020)
Calcination followed by Magnetic separation	46	2.06	1.36	0.61	0.07	43.2	Temp. affected the magnetic properties after 400 C. It increased the magnetic susceptibility for paramagnetic minerals, which led to decrease iron impurities to 0.4%.	(Bentli et al., 2017)

Conclusion:

In conclusion, the mineral is formed when magnesium-containing solutions are applied to calcite or when magnesium-rich rocks are altered. Magnesite is an excellent component for various industries due to its low manufacturing costs. The market price of magnetite is affected by the volume of the material and the presence of impurities. Magnesite mainly used as a refractory element in the cement and steel industry, filler and catalyst during synthetic rubber manufacturing, and raw material in magnesium fertilizers and chemicals. Other industrial applications of magnesite, such as the cosmetic industry and environmental protection, make it an essential mineral. However, magnesite manufacturers face tremendous challenges since it is one of the essential refractory minerals.

References:

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