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A review of ion adsorption clay as a high potential source of rare earth minerals in Malaysia

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ABSTRACT

Rare earth elements (REEs) have emerged as a critical component in manufacturing various products for green technology. This paper aims to comprehensively review the formation of ion adsorption clay, REEs weathering profile, clay minerals' potential in adsorbing REEs, ion-exchange mechanism and method for REEs extraction, and the potential of ion adsorption clay as a REEs source in Malaysia. In conclusion, ion adsorption clay has significant potential as a REEs mineral source in Malaysia, where a higher concentration of REEs has been identified compared to China, a developing country in the REEs minerals industry of ion adsorption clay.

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1. Introduction

The International Union of Pure and Applied Chemistry (IUPAC) specifies rare earth elements (REEs) as a group of 17 elements, 15 of which are lanthanides and range from lanthanum to lutetium, scandium, and yttrium [1–3]. Scandium and yttrium are classified as REEs since they are found in the same ore sources as lanthanides and have similar chemical properties [4]. Promethium is excluded from the literature because it is a radioactive element that resulted from the decay of unstable europium and uranium isotopes [5,6]. REEs is commonly divided into two categories: light REEs (LREEs) consists of lanthanum to samarium and heavy REEs (HREE) consist of europium to lutetium plus yttrium [2,7]. Scandium does not belong to either of these groups because of its lower ionic radius [8]. REEs minerals are not found in nature in their pure state; instead, they are discovered as accessories in other minerals. There are more than 200 REE-bearing minerals in nature, which come in a wide range of chemical compositions, such as oxides, silicates, carbonates, phosphates, halides, and silicates [8,9]. However, only several minerals are reflected as economically beneficial, and even fewer have been effectively extracted, such as bastnasite, monazite, and xenotime. The most common sources of REEs in economic scale concentration include carbonatites, alkaline igneous rocks, ion adsorption clay, and monazite-xenotime-bearing placer.

In recent years, interest in REEs has increased throughout the world. REEs has become an essential element in the production of a wide range of products, including magnets, catalyst, metal alloys, phosphors, polishing powders, glass additives, and ceramics due to their distinctive physical and chemical properties such as specific magnetic and optical properties. REEs are utilized in virtually every modern technological device, including cell phones, computers, laptops, televisions, hybrid cars, wind turbines, solar cells, hard discs, and other REEs high-tech applications [10,11]. In 2014, there was about 118 thousand tonnes annual global market for REEs. By 2025, that demand is predicted to increase to 200 thousand tonnes [12]. The annual global demand for REEs has risen to 60% due to the ongoing development of clean and green technologies in producing electrical and electronic equipment. The price of REEs will reach a new peak of USD 107–150 thousand per tonne by 2025, with the demand for REE increasing by 7 to 8% annually [12–14]. According to the US Geological Survey (USGS) Mineral Product Summary 2022, global REEs reserves were 120 million tonnes at the end of 2021, with China accounting for 36% of the reserve with 44 million tonnes, Vietnam with 22 million tonnes, Brazil, and Russia each with 21 million tonnes, India with 6.9 million tonnes, Australia with 4 million tonnes, and other countries with 0.3 million tonnes.

Over the last two decades, China has dominated global REEs production, with the greatest reserves discovered, Bayan Obo.

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