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Review on high-value utilization of phosphogypsum: Utilization of calcium and oxygen resources present in phosphogypusm

Jie Yang [a], Senlin Dong [a,b,*], Liping Ma [a,*], Quxiu Dai [a,*], Dalong Zheng [c], Bing Huang [a], Mingyi Sun [a], Bo Hu [a], Wang Du [a], Longgui Xie [a], Li Duan [a], Xiang Yan [a]

[a] Faculty of Environmental, Science and Engineering, Kunming University of Science and Technology, Kunming, Yunnan 650093, China
[b] University Strasbourg, Institute of Chemistry and Processes for Energy, Environment and Health (ICPEES) UMR 7515, CNRS, 25 rue Becquerel, F-67087 Strasbourg, France
[c] Zibo Vocational institute, Zibo 255300, China

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ABSTRACT

The world's annual production of phosphogypsum (PG) is up to 200 million tons at present. It was found that 15 % of PG produced worldwide is recycled. Therefore, it is imperative to seek a new pathway to recycle PG. This work provides an overview of the state-of-the-art scheme for high-value utilization of PG. Compared with previously published works, this review focuses on the utilization of oxygen (O) and calcium (Ca) resources. The state-of-the-art technology of utilizing O in PG consists of lignite's chemical looping gasification (CLG) with PG-based oxygen carrier. The state-of-the-art technology for utilizing Ca in PG is the low-temperature decomposition of PG for producing CaO and $CaCO_3$ from the reductive decomposition of PG. The process and the reaction mechanism of state-of-the-art technology for application of O and Ca in PG are summarized. Based on current research status, it is suggested to apply two or more solid wastes in cement, bricks and other aspects of large-scale. When utilizing PG, the migration transformation of impurities in PG and their reaction mechanisms at the molecular level deserve to be focused on. The key to solving the problems caused by PG large consumption, high value-added utilization and the introduction of policies providing incentives to this end. This research provides guidance for new engineering techniques for PG to achieve high-value and efficient use of resources in the large-scale utilisation of PG.

1. Introduction

China produces and consumes significant quantities of phosphate fertilizer [1–4]. Phosphoric acid is an important raw material for preparing the phosphoric fertilizer [1,5–8]. The preparation of wet phosphoric acid is one of the main sources of producing phosphoric acid [9–11]. In this process, industrial solid waste of phosphogypsum (PG) is produced [12–15]. Every ton of phosphoric acid produces around 4.5 – 5 ton of PG [16–19]. In order to bring high yield and economic benefits to crops, a huge number of by-products PG generates via the wet production of phosphoric acid [20–25]. At present, the world's annual production of PG was up to 200 million tons [26–28], whereas the amount of PG produced has continued to increase over the past decade [29–31]. Nearly 300 million tons of PG is produced annually globally [32]. To date, more than 7 billion tons of PG has been produced worldwide [33], out of which, 58 % is dry or wet stockpiled [34], whereas 28 % is discharged into coastal waters [35]. According to a previous study, 15 % of PG produced worldwide is recycled [36]. In 2010–2022, the average annual production and the average annual utilization of PG were around 7.3 million tons and 2.5 million tons in China, respectively (Fig. 1) [37,38]. For a long time, the recycling of PG has been slowly increasing for protecting the ecological environment based on Chinese "The Yangtze River 'three phosphorus' special investigation and remedial action implementation plan" and other laws and regulations [39–41]. China's 14th Five-Year Plan provides guidance on the comprehensive utilization of bulk solid waste [42–44]. Chinese researchers should pay more attention to improving the rate of reuse of solid wastes (such as PG) and expanding the application pathways of PG [42,45–48]. According to the "Environmental Protection Tax Law", China has levied a solid waste tax ($25/ton) since 2018, and no new storage sites have been approved. Many areas in Southwest China even "set production based on

* Corresponding authors at: Faculty of Environmental, Science and Engineering, Kunming University of Science and Technology, Kunming, Yunnan 650093, China (S. Dong).
E-mail addresses: senlin_d123@163.com (S. Dong), LipingMaKMUST@163.com (L. Ma), daiquxiu@163.com (Q. Dai).

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