**Recovery of Rare Earth Elements and Carbon Sequestration of Phosphogypsum: Implications for Climate Action Resource Utilization**

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Phosphogypsum, a major by-product of phosphoric acid production, is generated globally at 300 million metric tons annually and poses environmental challenges due to its radionuclide and heavy metal content. Philippines alone, millions of metric tons PG have accumulated highlighting the need for processing and recycling solutions to mitigate environmental hazards and recover critical minerals. PG contains rare earth elements essential for electronic and clean energy technologies. Additionally, its calcium-rich matrix makes it a possible candidate for carbon sequestration via mineral carbonation, presenting a dual opportunity for strategic material recovery and contribution to climate action. This study presents part 1 systematically evaluating radioactivity and REE concentrations in PG and explore optimized recovery pathways. Multi-technique characterization including HPGE Gamma Spectrometry, XRD, FE-SEM-EDS, and ICP-AES was employed to assess radioactivity, elemental composition and REE distribution. REE leaching experiments were made via Response Surface Methodology using Central Composite Design of Experiment optimizing for four factors five levels—concentration, temperature, leaching time, and solid-to-liquid ratio. HPGE gamma spectrometry revealed Ra-226 as the primary radionuclide in Philippine PG with in-situ radiometric survey shows average radiological profile of PG as TENORM having K (0.10%), eU (77.98 ppm) and eTh (1.15 ppm) and with average dose rate of 1.82 mSv/yr above the 1mSv/yr regulatory limit. Physical fractionation showed that REEs were evenly distributed throughout size fractions, indicating no significant enrichment in any size range to support recovery. FE-SEM EDS examination revealed their composition and microstructure. Due to REE sulfates and fluorides interrupting homogeneous crystallization, agglomerated PG structures have greater REE contents than crystalline forms. EDS showed fluorites were high REE-bearing minerals in PG. Uranium and radium were found homogeneously incorporated in gypsum matrix. PG samples showed calcium sulfate dihydrate and quartz as the main crystalline phases by XRD. REE-bearing minerals were not found, suggesting they are amorphous or below the instrument's detection limit. Second-order canonical models were generated, sulfuric acid leaching showed a maximum REE recovery of 46.32% under optimized conditions, pending experimental validations. Comparative modeling with hydrochloric and nitric acids revealed lower predicted efficiencies 32% and 56%, respectively, faux maximum efficiencies due to the presence of saddle points visualized in the models. Carbon sequestration efforts are currently under development. These findings highlight integrated strategies for TENORMs PG resource utilization for both economic and climate action.