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Phosphogypsum: Environmental Repercussions and Incentives

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Abstract
One prominent by-product of the generation of phosphoric acid, phosphogypsum, is recoverable. However, phosphate, fluoride, and heavy metals are among the contaminants found in phosphogypsum that can impair performance and pollute the environment.Crushed blast furnace slag, electrolytic manganese wastes, and inorganic cement-like substances can all be used with phosphogypsum. Surface modifiers, curing agents, and polymers are some instances of additives.Phosphogypsum (PG) is an industrial by-product of the wet process used to produce phosphoric acid from natural phosphate rock. An estimated 100–280 Mt of PG are produced annually worldwide, with 5 tonnes produced for every tonne of phosphoric acid. The majority of this by-product is dumped in big stockpiles without any sort of treatment. These are typically found near phosphoric acid facilities along the coast, where they take up a lot of land and seriously harm the ecology. In order to reduce environmental hazards, this review paper examines appropriate handling,retention, and clearance techniques.Moreover, creative reuse applications are researched, like adding phosphogypsum to building supplies like concrete, plasterboard, and cement as well as using it in farming as a supplement to the soil or for reclamation of agricultural land.

Key words*: phosphogypsum , environmental hazards , reclamation of agricultural land*

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I. Introduction

More than 90% of phosphoric acid is currently produced using the "wet acid method," which processes phosphate rock to produce fertilizer. Phosphogypsum (PG) is a waste by-product of this process. According to different estimates, the world produces between 100 and 280 million tons of PG annually [1](Yang et al., 2009)[2](Parreira et al., 2003). The United States, the former Soviet Union, China, Africa, and the Middle East are the primary producers of phosphate minerals and phosphate fertilizers.

The main constituent of PG is $CaSO_4{\bullet}2H_2O$, but it also contains impurities like H_3PO_4, $Ca(H_2PO_4)_2.H_2O$, $CaHPO_4.2H_2O$, and $Ca_3(PO_4)_2$, as well as leftovers acids, fluorides, which (NaF, Na_2SiF_6, Na_3AlF_6, Na_3FeF_6, and CaF_2), sulphate ions, trace metals (such as Cr, Cu, Zn, and Cd), and organic matter that adheres to the surface of the gypsum crystals as aliphatic
substances of carbonic acids, amines, and ketones [3](Rutherford et al., 1996).

The manufacturing of phosphate fertilizer, which contains a number of important components, including calcium sulphates, rare-earth elements like silicon, iron, titanium, magnesium, aluminum, and manganese, as well as harmful elements like heavy metals, produces phosphogypsum, an almost-unused by-product. Phosphogypsum is often kept in trash dumps in an open manner. Phosphogypsum dumps cover large regions and are situated in open spaces near organizations, natural systems, and even populated areas. Phosphogypsum transportation and dump storage involve financial outlays and ongoing expenses. For instance, the expenses associated with shipping and keeping phosphogypsum can account for as much as 10% of the primary cost of phosphoric acid. [4].

II. Attributes Of Phosphogypsum

Calcium sulphate dihydrate (90 percent gypsum) and sodium fluorosilicate (Na_2SiF_6) make upthe majority of PG, a amourphous like substance with little to no plasticity [5](Berish, 1990)[6]Kacimi et al., 2006).Because the porous PG contains residual phosphoric, sulfuric, and hydrofluoric acids, it is regarded as an acidic by-product (pH <3).

The following are some of the various chemical and physical characteristics of PG:-Composition: Mostly made up of gypsum, with trace elements and radionuclides present in variable proportions. Specific Gravity: Usually falls between 2.3 and 2.6. Particle Size: According to the No. 200 sieve, a sizable percentage of phosphogypsum particles are smaller than 0.075 mm. Typically, the moisture content ranges from 8 to 30%. Impurities: May include organic compounds, naturally occurring radioactive materials (NORM), and trace elements (such as Fe, Mn, Pb, and Cd).

The free moisture percentage of PG from filter cake is typically between 25 and 30 percent. According to reports, PG's vertical hydraulic conductivity ranges from 1 x 10-3 to 2 x 10-5 cm/s [7](Senes, 1987).Depending on local weather conditions and how long the PG has been let to drain after stacking, the free water content can vary significantly.

PG is extremely soluble in saltwater (≈4.1 g/l), and its solubility depends on its pH [8](Guo et al., 2001).It has a bulk density of 0.9 to 1.7 g/cm3 [9][10][11](Vick, 1977; Keren and Shainberg, 1981; May and Sweeney, 1984) and a particle density of 2.27 to 2.40 g/cm3 (Senes, 1987).

III. Pg Waste's Effects On The Environment And Regulatory Frameworks

One of the biggest issues the phosphate industry is now dealing with is PG management. Just 15% of global production gets recycled, while 85% is kept in storage in companies along the coast. Large land areas are needed for the untreated storage of PG, which can seriously contaminate soils, water, and the atmosphere.

3.1 Pollution of the Air, Water, and Soil

Originating from phosphate rock, the main radioactive elements in PG are persistent in the environment. These radionuclides raise radioactivity levels and cause long-term ecological and health issues by leaking from disposal sites into nearby soil and groundwater.[12] As radionuclides build up in plants and animals, they can enter the food chain and raise the danger of bioaccumulation. Long-term exposure to such contamination impairs microbial diversity, lowers soil fertility, and alters ecosystem function.Degradation of soil is caused by fluoride contamination in PG compounds. Hydrofluoric acid and kindred chemicals are forms of fluoride that seep into the soil and alter its nutrient availability and physical characteristics. Excessive fluoride levels limit root elongation, cause chlorosis, and reduce photosynthesis, all of which hinder plant growth.[13][14]

Rainfall and other natural processes exacerbate contamination by disintegrating PG components and creating leachates that contaminate surface and groundwater. Radionuclides and heavy metals are frequently found in PG leachates at levels three to four orders of magnitude greater than in unaltered waters. When these pollutants enter rivers and lakes, they disturb aquatic ecosystems and render the water unfit for human consumption.[15]

3.2 Hazards to Health and the Environment

In addition to causing health hazards and long-term environmental problems, phosphogypsum is a major contributor to airborne pollution. Particulate matter comprising radioactive radon gas and hazardous heavy metals is released from poorly maintained PG waste dumps. Asthma and bronchitis might be made worse by the airborne dust from PG piles. Long-term exposure to the heavy metals in this dust can cause neurological conditions, kidney damage.

Methane, carbon dioxide, and nitrogen oxides are among the greenhouse gases (GHGs) released by landfills and PG stacks as a result of chemical interactions and decomposition, which both favorably and negatively affect global warming. Methane emissions, in particular, have a negative impact on air quality and have a significant potential for global warming. When PG is disposed of with organic waste, it changes microbial activity, suppressing methanogens and encouraging sulfate reducers. This significantly lowers methane (CH_4) emissions, a powerful greenhouse gas that has a 25-fold higher potential for global warming than CO_2.Given below is the glimpse of the health hazards by the phosphogypsum Pollutants in a tabular form.

Table 1: An overview of the health impacts of typical phosphogypsum pollutants

Pollutant	Route of Exposure	Impact on Health	Citations
Radium 226	Water(Leaching)	increased risk of renal damage, soft tissue tumors, and internal radiation exposure.	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17]
Radium 226	Dust-borne by Air	elevated risk of leukemia, anemia, and bone cancer as a result of radioactive decay products (radon gas).	USEPA 1999: Radiation at Superfund Sites[16]
Lead	Crops, Air-borne	Kidney damage, adult hypertension, and neurological disability in children	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17]
Flouride	Water	Chronic exposure can cause dental and skeletal fluorosis; excessive doses can have neurological consequences.	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17]
Chromium	Crops,Water	Exposure to chromium VI can result in skin irritation, kidney damage, and lung cancer.	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17]

Cadmium	Water,Crops	Skeletal demineralization, kidney impairment, and elevated cancer risk due to bioaccumulation	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17] Codex Alimentarius Commission: (CXS 193-1995)[18]
Thorium	Air-borne	elevated incidence of pancreatic and lung malignancies as a result of radioactive decay	WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17] USEPA 1999: Radiation at Superfund Sites[16]
Arsenic	Crops, water	An elevated risk of neurological damage, cardiovascular illness, and skin cancer	Codex Alimentarius Commission: (CXS 193-1995)[18] WHO2011: Guidelines for Drinking-water Quality, 4th Edition[17]

3.3 FRAMEWORKS FOR REGULATION AND DIFFICULTIES

Several steps are taken by different countries to regulate and manage safety disposal practices out of which some are given below :

1.In order to manage Naturally Occurring Radioactive Materials (NORM), including PG, the International Atomic Energy Agency (IAEA) has created comprehensive standards under Safety Reports Series No. 78. The IAEA provides guidelines for worker safety, controlled storage, radiological characterization, and disposal. For instance, leachate collecting systems and impermeable liners are required for PG stacks in order to minimize groundwater contamination, while reuse requirements guarantee that PG with low radioactivity is safely repurposed.[19]

2. The FAO Soils Bulletin No. 62 contains precise guidance for the use of PG in agriculture from the Food and Agriculture Organization (FAO). These include stringent thresholds for contaminants like lead and cadmium to avoid contaminating crops and soil. Crop and soil characteristics determine application rates, with precautions taken to avoid shallow groundwater areas. In order to strike a balance between the advantages of agriculture and environmental preservation, farmer education on safe storage, handling, and application is also prioritized.[20]

3. The Sustainable Use of Industrial By-products framework from the United Nations Environment Programme (UNEP) promotes a circular economy strategy. UNEP encourages alternate applications of PG in agriculture and construction and places a strong emphasis on resource recovery, including the harvesting of REEs. It also emphasizes how crucial statutory assistance and environmental risk assessments are to promoting PG-based product innovation and commercialization.[21]

IV. Conclusion;

The environmental incentives and recupressions of phosphogypsum management are highlighted in this review article, which also shows how valuable it is as a raw material for energy recovery, industrial, agricultural, and environmental solutions. Phosphogypsum's potential has been demonstrated by several studies, and it will be essential for managing the environment and conserving land. In conclusion, a multifaceted strategy is required to maximize the sustainable use of phosphogypsum and overcome the obstacles related to its management. Various new ways can be used to achieve this goal:

The massive PG stockpiles and their detrimental effects on the nearby land, water, and air are environmental concerns. Over 85% of the PG produced annually is disposed of either on land or in the ocean. The impact of specific chemical factors associated to PG stacks is highlighted by data from the examined studies. PG may be used more efficiently if studies are conducted on the removal of impurities and the concentrations of pollutants associated with PG stacks. Moreover, PG recycling is a political and economic issue in addition to an engineering and scientific one. In order to provide on-land PG disposal in an environmentally sound manner, new disposal facilities have been planned and built in recent years, and existing facilities have been renovated to meet higher environmental standards. Additionally, a lot of research has been done to develop commercial uses for PG, but much more work needs to be done in the future. Reduced fertilizer use would undoubtedly aid in preventing steadily growing PG stocks, but it would also require significant adjustments to farming practices in developed nations, particularly in emerging nations who fight for the right to live like developed nations.

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