Phosphogypsum Processing Method

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Abstract. The article provides the information on a new method of processing phosphogypsum (calcium sulfate) stacks into a conditioned gypsum binder substance. The authors present the results of the research on creating a technology for phosphogypsum processing with the application of electro-magnetic units for material processing. The developed way for phosphogypsum processing allows eliminating continuous accumulation of tons of environmentally dangerous wastes. In addition, it facilitates reducing harmful impurities' content in the processed phosphogypsum to maximum permitted concentration. It provides for elimination of harmful impurities from washing water and allows water reuse which results in saving funds for the construction of expensive wastewater treatment facilities. The comparison of the developed phosphogypsum processing method with well-known national and foreign analogues showed that its cost-efficiency is 2-3 times higher; the area necessary for the plant is 4-5 times less; the energy consumption reduces by 1.5-2 times; the costs for phosphogypsum disposal is lower by 30-50 %; the technological line performance is by 1.5-2 times higher.

1. Introduction

At present significant volumes of phosphogypsum (calcium sulfate) have been accumulated in stacks all over the world. Phosphogypsum is a large-capacity waste material resulting from the production of wet-process phosphoric acid in the process of sulfuric decomposition of apatites and phosphorites. The phosphogypsum contains approximately 3% of potassium phosphate, sodium, aluminum and ferrum as well as phosphoric acid and salts of heavy metal.

Today in Russia phosphogypsum is formed at 12 plants [1-4]. Annual waste release is equal to more than 10 million tons. Phosphogypsum stacks cover large territories of plowing lands facilitating soil degradation. Phosphogypsum disperse particles are diffused by wind for 10 kilometers from stacks, and great territories around stacks lose vegetation and have negative impact on the health of region residents. Phosphogypsum with surface water flows penetrates ground waters and poisons waters. According to the estimates of specialists the content of phosphates in adjacent rivers and lakes exceeds maximum permitted concentrations ten and hundred times while in ground waters - even thousand times. The mentioned problems require taking urgent measures on the disposal of...
phosphogypsum stacks in the volumes comparable with the amount of photogypsum stored in stacks and formed at existing plants.

![Phosphogypsum stacks](image)

Figure 1. Phosphogypsum stacks of the plant JSC “Nevinnomysskiy Azot”.

Today phosphogypsum is applied in various national economy sectors: in agriculture - for dealkalization of alkaline soils; at cement production - as admixtures; in road construction - for road topping; in chemical industry - to obtain sulfur and sulfuric acid; as a filler at paper production, plastic production, etc. However, small consumption volumes cannot provide for a full disposal of these wastes.

The potential key consumer of gypsum containing wastes should be the construction material industry which is able to use gypsum-containing raw materials in the amount comparable with the yield of phosphogypsum wastes. However, phosphorous impurities contained in wastes do not allow obtaining gypsum binder with the required strength characteristics. The processing and use of phosphogypsum in the production processes are reasonable as the expenses for its storing, keeping and maintenance of stacks can reach 200 rubles/tons. In addition, the use of phosphogypsum allows preventing environmental harm.

The suggested method for manufacturing items reduces the heat energy consumption in comparison with well-known analogues which has a positive impact on the cost of manufactured products.

2. Research results

In FGBOU VO DGTU the research were conducted on creating a technology for phosphogypsum [2, 3] processing with the application of electro-magnetic units for material processing (MPU).

The purpose of the research was the development of the efficient and cost-effective of obtaining binder from phosphogypsum without using heat treatment processes. The suggested method for manufacturing items reduces the heat energy consumption in comparison with well-known analogues which has a positive impact on the cost of manufactured products.

The proposed method for processing phosphogypsum includes the following technological operations (see Figure 2).
Phosphogypsum from the stack or the industrial process of the basic plant (1) is fed to the pre-grinding point (2) in the hammer grinder and the point of obtaining the waste fraction of less than two millimeters. The ground phosphogypsum is transported by the elevator (3) into the homogenizer (4) where it is mixed with water. It is established that a reasonable ratio of water and phosphogypsum is 5:1. The obtained suspension is pumped into the MPU (5). Material processing units are the apparatuses with vortex layer using the energy of the rotating magnetic field. In the material processing units rotating ferromagnetic elements induce active material dispergation and significant acceleration of physical and chemical processes. As a result of the treatment of phosphogypsum suspension in the MPU phosphorus and heavy metal salts pass into solution. To disintegrate solid particles of calcium sulfate dihydrate from water solution the suspension is fed to decanters (6). From decanters the water solution cleaned from weighted particles is pumped into the secondary cleaning stage in the MPU. The secondary treatment of water solution in the MPU facilitates the acceleration of layering process by 3-5 times. The water solution processed in such a way is forwarded to the precipitators (12) where a special reagent (13) is added. It activates the process of forming phosphorous oxides and heavy metal salts, their coagulation and precipitation in the form of sludge. The cleaned water is pumped into the process onset and then reused. The separated sludge is environmentally safe and can be applied as admixture for organic fertilizers or the filler at the production of construction materials.

Phosphogypsum after the first processing stage passes for the second cleaning stage into the homogenizer (7) and mixed with water. The obtained suspension passes for the secondary processing in the MPU and is further subject to dehydration in two stages. At the first stage partial dehydration occurs in the centrifugal machine (8) and then in the vacuum drier (9) – to the humidity of 40 %. Water from the centrifugal machine and vacuum drier passes for the reuse in the industrial process.

Humid calcium sulfate dihydrate cleaned from phosphorous impurities and heavy metal salts is delivered into the drying drum (10) where drying occurs up to the humidity of 6%. Dried calcium sulfate dihydrate is then delivered to the storage (11) as finished product.
sulfate dihydrate is supplied into the hammer grinder after which the raw material grinded with a screw conveyor is delivered for heat treatment into the gypsum-cooking boiler (11). In the cooking process 1.5 molecules of hydrate water are removed from calcium sulfate dihydrate and gypsum plaster (β-hemihydrate) is obtained.

It is established that one ton of phosphogypsum can be used to produce up to 900 kg of gypsum plaster.

Possible area of application of binder obtained from processed phosphogypsum is given in Table 1.

| Item No. | Application area                                                                 | Key characteristics of binder                                                                 |
|---------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| 1       | Foam&gypsum and gas&gypsum items                                                 | Density 300-800 kg/m³; fine grinding, regular and slow hardening.                            |
| 2       | Gypsum board items                                                               | Fracture load for samples, in kgf, not less: - longitudinal – 45-60; - transverse – 15-18. |
| 3       | Gypsum boards for partitions                                                      | Tensile strength, MPa (kgf/cm²): - at compression – 5.0 (50); - at bending – 2.4 (24).     |
|         |                                                                                 | Plate density kg/m³: - highest quality class – 1,000; - first quality class – 1,500.      |
| 4       | Gypsum panels (including gypsum cement and pozzolanic, gypsum&lime and slag, gypsum-slag) | Average concrete density, kg/m³: not less than 1,100; not more than 1,500.                  |
| 5       | Gypsum-fiber sheet (GFS)                                                         | Ultimate bending strength, MPa, at nominal sheet thickness: - up to 10 mm inclusively – 6.0; - more than 20 mm – 4.3 |
| 6       | Dry mortars                                                                      | In compliance with the application area                                                     |
| 7       | Filler at production of plasters and putties for all surface types.              | Surface type: gypsum; concrete; brick; stone                                                |
| 8       | Heat and sound insulation items (inserts)                                         | Density – 300-800 kg/m³                                                                   |
| 9       | Porcelain and faience and ceramic ware                                           | Grade G-5 – G-25; grinding fineness on rest on a sieve No. 02 – not more than 1.0 %; water absorption, % – not more than 30. |
| 10      | Plastic and figure-casting items                                                  | Grade – not less than G2; density – 900-1,100 kg/m³                                      |

3. Conclusion
The tests of phosphogypsum samples from the stacks of the plant JSC “Nevinnomysskiy Azot” processed with the help of the suggested method demonstrated that the content of phosphorus oxide in the processed gypsum reduced from 1.5% (in the initial product) to 0.0001%. The water cleaned after processing the phosphorous content is less than 0.00002 %. These indicators correspond to the requirements on the maximum permitted concentration. The tests of gypsum plaster obtained by means of the developed technology showed that the binder corresponds to the Grade G7 and meets the regulatory requirements.

The comparison of the developed phosphogypsum processing method with well-known national and foreign analogues [4,5,6,7] showed that its cost-efficiency is 2-3 times higher; the area necessary for the plant is 4-5 times less; the energy consumption reduces by 1.5-2 times; the costs for
phosphogypsum disposal is lower by 30-50 %; the technological line performance is by 1.5-2 times higher.

The developed way for phosphogypsum processing allows eliminating continuous accumulation of tons of environmentally dangerous wastes. In addition, it facilitates reducing harmful impurities’ content in the processed phosphogypsum to maximum permitted concentration. It provides for elimination of harmful impurities from washing water and allows water reuse which results in saving funds for the construction of expensive wastewater treatment facilities. The process of manufacturing gypsum binders by the new technology is zero-waste and can be fully automated and mechanized. At this the production culture and labor practices improve.

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Acknowledgment
The reported study was financed by FGBOU VO “DGTU” in compliance with the contest of university grants for publishing scientific articles in the journals indexed in international information&analytical systems Scopus and Web of Science.