

# Mechanical Activation Of Nodular Phosphates In Karakalpakstan

T.N. Orinbaev

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

A.M. Reymov

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

A.A. Qutibaev

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

D.O. Allaniyazov

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

N.E. Khalmuratova

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

M.M. Uzakbaeva

Affiliations: Karakalpak Institute of Natural Sciences, Karakalpak State University, Uzbekistan

**Received:** 15 December 2025; **Accepted:** 12 January 2026; **Published:** 31 January 2026

**Abstract:** This study investigates the mechanical activation of two types of phosphorite rocks from Karakalpakstan: Khojakul and Porlitau. The mechanical activation was conducted in a planetary ball mill (ball-to-sample ratio of 10:1, 200 rpm) for durations ranging from 5 to 60 minutes. Increasing the grinding time led to an increase in the amount of assimilable  $P_2O_5$  in both rock types. For Khojakul, the relative solubility of  $P_2O_5$  in 2% citric acid increased from 38.3% to 48.8%, and in 0.2 M EDTA from 32.6% to 38.7%. For Porlitau, these indicators increased from 36.9% to 44.1% and 33.4% to 37.6%, respectively. These results confirm that Khojakul phosphorite responds more effectively to mechanical activation due to its fine structure and the weakness of the apatite-gangue bond. The lower reactivity of Porlitau is attributed to its high  $CO_2$  (carbonate) content, which buffers the acid's effect and reduces phosphate dissolution.

**Keywords:** Mechanical activation, nodular phosphorite, relative assimilable phosphorus.

## INTRODUCTION:

The objective of this research is to determine the changes in fractional composition and chemical properties of nodular phosphorites during mechanical activation in a planetary ball mill, as well as to evaluate the dynamics of  $P_2O_5$  transitioning into an assimilable form. Chemical and mechanochemical activation are considered promising approaches for

converting Karakalpakstan's nodular phosphorites into effective fertilizer materials. Mechanical activation is particularly noteworthy because it does not require additional chemicals to increase the amount of assimilable  $P_2O_5$  in the rock.

In the experiments, high-silica phosphorite rocks from the Khojakul and Porlitau deposits were crushed

in a porcelain mortar to obtain fractions with particle sizes of 0.05, 0.10, 0.16, 0.20, and 0.25 mm. Subsequently, 23 g of phosphorite powder was placed in a planetary ball mill (Retsch PM 200, Germany) equipped with two stainless steel jars (internal volume 125 cm<sup>3</sup>) containing 7 stainless steel balls (d = 2 cm<sup>2</sup>) and 3 stainless steel balls (d = 3 cm<sup>2</sup>). The effect of grinding time on the composition and specific surface area of the phosphorite flour was studied using a ball-to-sample ratio of 10:1 and a rotation speed of 200 rpm.

Chemical analyses were performed using standard analytical methods:

- P<sub>2</sub>O<sub>5</sub> (all forms): Determined by differential spectrophotometry on a KFK-3 photometer (λ = 440 nm).

- Solubility: Tested in 2% citric acid and 0.2 M Trilon B (EDTA) solutions.
- Sulfate ions Determined gravimetrically by precipitation as barium sulfate.
- CaO content: Determined by complexometric titration with 0.2 M Trilon B using appropriate indicators.
- Oxides (Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>): Determined via complexometric methods.

**RESULTS AND DISCUSSION**

**Chemical Composition by Fraction**

The initial chemical compositions of the phosphorites are presented in Tables 1 and 2. Reducing particle size led to an increase in P<sub>2</sub>O<sub>5</sub> from 17.83% to 19.48%.

**Table 1**  
**Chemical composition of Khojakul phosphorite in various fractions**

Disperse size, mm	Content, %							P <sub>2</sub> O <sub>5</sub> <sub>accep.</sub>	P <sub>2</sub> O <sub>5</sub> <sub>accep.</sub>	CaO <sub>accep.</sub>
	P <sub>2</sub> O <sub>5</sub> total	CaO total	P <sub>2</sub> O <sub>5</sub> accep. in 2% citric acid	CaO accep. in 2% citric acid	P <sub>2</sub> O <sub>5</sub> acc. ep. by 0.2 M EDTA	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	P <sub>2</sub> O <sub>5</sub> <sub>total</sub> in 2% citric acid	P <sub>2</sub> O <sub>5</sub> <sub>total</sub> by 0.2 M EDTA	CaO <sub>total</sub> in 2% citric acid
0,25	17,83	30,00	9,74	12,50	6,63	1,80	0,98	54,62	32,18	41,66
0,20	17,56	26,90	9,67	11,44	6,24	2,24	1,46	55,06	35,53	42,52
0,16	17,99	35,80	9,69	13,87	6,27	1,89	1,56	53,86	34,85	38,74
0,10	18,00	35,20	10,08	12,27	6,50	2,23	1,54	56,00	36,11	34,85
0,05	19,48	30,50	9,78	15,28	6,78	1,99	1,61	50,20	34,80	50,09

**Table 2**  
**Chemical composition of Porlitau phosphorite in various fractions**

Disperse size, mm	Tarkib, %							P <sub>2</sub> O <sub>5</sub> <sub>accep.</sub>	P <sub>2</sub> O <sub>5</sub> <sub>accep.</sub>	CaO <sub>accep.</sub>
	P <sub>2</sub> O <sub>5</sub> total	CaO total	P <sub>2</sub> O <sub>5</sub> accep. in 2% citric acid	CaO accep. in 2% citric acid	P <sub>2</sub> O <sub>5</sub> acc. ep. by 0.2 M EDTA	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	P <sub>2</sub> O <sub>5</sub> <sub>total</sub> in 2% citric acid	P <sub>2</sub> O <sub>5</sub> <sub>total</sub> by 0.2 M EDTA	CaO <sub>total</sub> in citric acid
0,25	17.95	20.75	6.79	12.03	6.23	2.27	1,52	37.83	34.71	57.98
0,20	17.11	29.72	6.00	16.29	5.97	2.23	1,48	35.07	34.89	54.81
0,16	17.46	21.76	5.41	12.47	6.18	2.01	1,42	30.98	35.40	57.31
0,10	17.89	24.33	5.35	15.20	5.86	1.96	1,38	29.90	32.76	62.47
0,05	18.43	28.80	5.98	19.10	5.83	2.58	0,23	32.45	31.63	66.31

Regarding the Porlitau phosphorite, it possesses the following chemical composition (by weight %): 17.11-

18.45 % P<sub>2</sub>O<sub>5</sub>; 5.35-6.79 % P<sub>2</sub>O<sub>5</sub> soluble in 2% citric acid; and 20.75-29.72% CaO based on acceptability. The presence of Fe<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> oxides is also

indicated.

The activation results for both nodular phosphorites are presented in Tables 3 and 4. As shown in Table 3, increasing the grinding duration from 5 to 60 minutes caused the P<sub>2</sub>O<sub>5</sub> soluble in 2% citric acid and Trilon B to increase from 8.34% to 9.48% and 6.58% to 7.70%,

respectively. However, the total content of P<sub>2</sub>O<sub>5</sub> and CaO remained nearly unchanged during the experiment. In contrast, the relative solubility of P<sub>2</sub>O<sub>5</sub> increased slightly between 5 and 15 minutes, then reached 49.05% and 39.81% after 30 minutes, finally peaking at 52.58% and 42.71%.

**Table 3**  
Effect of grinding time on Khojakul phosphorite (10:1 ratio, 200 rpm)

Milling time, min	Content, %					$\frac{P_2O_{5accep.}}{P_2O_{5total}}$ in 2% citric acid	$\frac{P_2O_{5accep.}}{P_2O_{5total}}$ by 0.2 M EDTA	$\frac{CaO_{accep.}}{CaO_{total}}$ in 2% citric acid
	P <sub>2</sub> O <sub>5</sub> total	P <sub>2</sub> O <sub>5</sub> accep. in 2% citric acid	P <sub>2</sub> O <sub>5</sub> accep. by 0.2 M EDTA	CaO total.	CaO accep. in 2% citric acid			
5	17.52	8.34	6.58	19.43	9.61	47.60	37.55	49.46
10	17.52	8.36	6.63	24.90	12.51	47.72	37.84	50.24
15	17.60	8.42	6.68	21.79	11.28	47.84	37.95	51.77
20	17.76	8.51	6.83	21.79	12.66	47.92	38.46	58.10
30	17.86	8.76	7.11	23.75	14.39	49.05	39.81	60.59
45	17.88	9.03	7.16	21.97	14.23	50.50	40.04	64.79
60	18.03	9.48	7.70	21.50	14.05	52.58	42.71	65.35

The data in Table 3 clearly demonstrate that the duration of the mechanical activation process significantly impacts the chemical and agronomic properties of the phosphorites. Specifically, the recorded changes in the concentration of various phosphorus forms—the primary nutrient element—clearly confirm the efficiency of the process.

While the initial raw phosphorite contained a total

P<sub>2</sub>O<sub>5</sub> content of 17.52%, this indicator was observed to increase to 18.03% after 60 minutes of intensive grinding. This is explained by the following phenomena resulting from mechanical activation:

- Formation of dislocations in the internal crystal lattice and surface structure of the minerals.
- Amorphization processes.
- The creation of fine-dispersed fractions.

**Table 4**  
Effect of grinding time on Porlitau phosphorite (10:1 ratio, 200 rpm)

Milling time, min	Content, %					$\frac{P_2O_{5accep.}}{P_2O_{5total}}$ in 2% citric acid	$\frac{P_2O_{5accep.}}{P_2O_{5total}}$ by 0.2 M EDTA	$\frac{CaO_{accep.}}{CaO_{total}}$ in 2% citric acid
	P <sub>2</sub> O <sub>5</sub> total	P <sub>2</sub> O <sub>5</sub> accep. in 2% citric acid	P <sub>2</sub> O <sub>5</sub> accep. by 0.2 M EDTA	CaO total.	CaO accep. in 2% citric acid			
5	18.14	6.95	5.91	33.20	14.49	38.31	32.58	43.64
10	18.00	7.06	6.01	31.53	13.89	39.22	33.39	44.05
15	17.96	7.29	6.16	37.00	16.94	40.59	34.30	45.78
20	18.36	7.90	6.59	34.50	16.37	43.03	35.89	47.45
30	18.08	8.13	6.55	36.20	17.81	44.97	36.23	49.21
45	17.72	8.34	6.67	36.70	18.77	47.07	37.64	51.14
60	18.61	9.08	7.21	35.80	20.18	48.79	38.74	56.36

As seen in the data from Table 4, the duration of

mechanical activation significantly affects the

chemical and agronomic properties of the phosphorites. Changes in the levels of phosphorus in its various forms further confirm the process's effectiveness.

While the total  $P_2O_5$  content in the 45-minute raw phosphorite was 17.72%, it rose to 18.61% after 60 minutes of intensive grinding. This is similarly attributed to dislocations in the internal crystal lattice, amorphization, and the formation of fine-dispersed fractions. Overall, the results indicate that Khojakul phosphorite responds more effectively to mechanical activation compared to the Porlitau sample. The high relative values of  $P_2O_5$  and their strong correlation with grinding duration reflect the superior reactivity of Khojakul phosphorite.

#### **REFERENCES**

1. Allaniyazov D.O. Development of technology for producing complex fertilizers... Tashkent, 2024.
2. Beglov B.M., et al. Activation of natural phosphate raw materials. Tashkent, 2021.
3. Mineral commodity summaries. U.S. Geological Survey, 2023.
4. Pirnazarov B.U. Technology for producing granulated complex fertilizers... Tashkent, 2024.
5. Mozheiko F.F., et al. Complex granulated fertilizers based on activated phosphate rock. Chemical Industry, 2007.