Technology for Obtaining Potassium Nitrate by Processing Brucite from the Navbahor Deposit with Nitric Acid and Converting it with Potassium Chloride

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Abstract. In this paper, the technology of obtaining KNO_3 from the Navbahor deposit by processing with nitric acid and converting potassium chloride is studied to generate environmentally sustainable and cost effective technology. Some of the technical parameters on the conversion process efficiency are analyzed. The decomposition of $Mg(OH)_2$ in the nitric acid, resulting in magnesium nitrate ($Mg(NO_3)_2$) formation and its subsequent reaction with KCl obtained from sylvinite by flotation, leading to the formation of chloride-free potassium nitrate, are studied. Using a spectrophotometer (energy dispersive type X-ray spectroscopy), the energy dispersion of KNO_3 and the number of elements in its composition are determined. To determine the optimum conditions of the conversion process, several variables, such as reaction temperature, molar ratio of reactants KCl and $Mg(NO_3)_2$, and reaction time, were studied, the final product consisted with 20.05-23.00 % of $MgCl_2$ and 43.55-45.00% of KNO_3 with 96–98% purity. Temperature, crystallization behavior, filtered solid-to-liquid ratio, and other process variables were carefully studied. Additionally, the feasibility of producing a liquid complex fertilizer from potassium nitrate, phosphoric acid, and ammonium nitrate was assessed. The resulting samples were analyzed for density, viscosity, and nutrient content.

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1 Introduction

Today, due to the global depletion of soil nutrients, the demand for fertilizers is steadily increasing [1]. Increasing the number of enterprises producing potassium fertilizers in our country and their proper use are among the priority tasks of young scientists today [2]. The abundance of greater than 90% of brucite mineral with greater than 85–95% purity is available in our country, combined with the discovery of magnesium brucites in the Navbahor deposit, will significantly help us obtain fertilizers beneficial to society from these deposits [3]. Potassium chloride, which contains the undesirable chlorine element [4], currently meets our country's demand for potassium fertilizers are produced in small quantities [5-7], allowing foreign producers to meet the domestic demand for potash fertilizers. [8] Due to the absence of a raw material base for making chlorine-free potash fertilizers [9], there is a shortage of large plants and factories capable of making these fertilizers in Central Asian countries [10]. The primary method for obtaining potassium nitrate involves conversion processes based on the reaction between brucite and potassium chloride [11].

$$Mg(NO_3)_2 + 2KCl \leftrightarrow 2KNO_3 + MgCl_2 + Q \quad (1)$$

where Mg is the ions K^+, Mg^{2+} || NO^-, CI^-, etc.

In the industry, potassium nitrate is obtained through various processes from substances containing potassium [12]. Through various processes, the production yield of potassium nitrate remains below 90% [13], and the disposal of secondary products formed during the process is a significant production challenge, There is a potential of magnesium nitrate recovery and recycling in fertilizer.,The iron and aluminum can be also precipitated and removed as sludge. Air pollution should also be avoided by washing down gaseous emissions. There must be effective systems of water recycling and acid recovery [14].

The proposed method is regarded as a waste-free, effective production method [15]. The magnesium chloride solution produced as a byproduct is used to manufacture the defoliant magnesium chlorate and in cooling systems for industry. Among these potassium salts, potassium chloride (KCl) is the most easily discovered element of the nitrate group, as well as the multi-ton potassium chloride used in the production of potash fertilizers.

A key issue in the inference of global food security in addition to minimizing the ecological footprint of the agricultural input is the development of environmentally sustainable and resource-efficient technologies in the production of fertilizers. The given study addresses the possibility of transforming the magnesium brucite produced in the Navbahor deposit into potassium nitrate using the available imported raw materials less and exploiting the mineral resources of the region more. This technology also helps achieve a circular economy model in the fertilizer industry by maximizing the utilization of reaction pathways and minimizing generation of wastes. Further, plan to use the naturally occurring non-energy intensive mineral, brucite, contributing to a greener alternative to the standard method of potassium nitrate production. The bulk

properties of $MgCl_2$ and KNO_3 in water and their solutions were determined at temperatures of 308, 313, 323, and 328 K, respectively.

This research is aimed to generate environmentally sustainable and cost effective technology that could be used to produce high-purity potassium nitrate through beneficiation of brucite (magnesium hydroxide) deposit at Navbahor. It is carried out by dissolving brucite in nitric acid to form magnesium nitrate, which is then reacts to potassium chloride to form potassium nitrate. One area is to have a goal of reducing the environmental impact through an optimization of reaction conditions, minimizing secondary waste products and increasing resource efficiency.

2 Methods

The following composition (wt.%) of rucite was utilized in the study: $Mg(OH)_2$ - 87.0; SiO_2 - 3.0; CaO - 3.0; Fe_2O_3 - 0.5; humidity - 1.0. To determine the physicochemical parameters of the process of creating a solution of magnesium chloride and potassium nitrate, scientific study was carried out in a laboratory setting. The investigations were conducted in a glass reactor that had a heating and cooling jacket and a mechanical stirrer. The investigation started with brucite ($Mg(OH)_2$), potassium chloride from Dekhkanabad potassium chloride, and nitric acid (concentration 56–58%) from Ferganaazot JSC.

Method of conversion: To create a magnesium nitrate solution, brucite was dissolved in non-concentrated nitric acid (20–30%). Heat is released at the beginning of the process, which causes the solution to boil and forms magnesium nitrate at a concentration of 43–45%.

$$Mg(OH)_2 + HNO_3 \rightarrow Mg(NO_3)_2 + H_2O \quad (2)$$

To prevent foaming and boiling of the water, the neutralization of brucite was carried out with constant stirring and the addition of brucite in portions.

Before being converted with magnesium nitrate, 245 kg of potassium chloride is dissolved in 0.649 m^3 of water at 80–90 °C to create a 28% solution of this salt. Following potassium chloride's full dissolution in a solution with a high concentration, it is mixed in a mixer for half an hour with a 42.5% solution of magnesium nitrate, resulting in the formation of 50.5-52.0% potassium nitrate salt ions and magnesium chloride in the solution.

To get rid of extra brucite and other contaminants, the solution is filtered through a Nutsche filter before being put back into the neutralization phase.

Common procedure for creating complicated potassium nitrate: The reaction was conducted in a glass vessel at either 0°C or -10°C in a cooling mixture (NaCl and ice). $Mg(NO_3)_2$ and KCl (both reactive and analytical) had initial molar concentrations of 1:2 (stoichiometry) or 1,2:2 (20% excess of $Mg(NO_3)_2$). To create a concentrated (>20 weight percent) $MgCl_2$ solution, the solid-to-liquid ratio (S/L = 1.54:1) was chosen. Chemical and crystallographic approaches were used to establish the reaction time needed for full conversion. In the latter instance, the instant at which KCl crystals vanished from the solid phase was ascertained using a MIN-8 microscope. The

concentration of NO^{3-}, potassium ions (tetraphenylborate technique), calcium ions (complexometric titration), and chloride ions (silver chloride precipitation) were all determined chemically. (Fig. 1).

Process assay: Magnesium nitrate was created by dissolving brucite in non-concentrated nitric acid. Heat is released during the procedure, starting the boiling of the solution and the production of magnesium nitrate at a concentration of 43–45%. The neutralization of brucite was done by adding brucite in sections and stirring continuously to avoid foaming and boiling of the water. The following step involved boiling water to 80–90 degrees Celsius in order to dissolve potassium chloride and create a saturated solution (28 percent) of this salt. In this case, the mass ratio of potassium chloride to magnesium nitrate was 1.2:1.

Table 1. Solubility of salts at different temperatures in this system

Solubility, in g/l.							
Name	20°C	40°C	50°C	60°C	70°C	80°C	90°C
KNO_3	24	39	44	52	58	62.8	66.9
$MgCl_2$	36.8	38	38.6	39.2	39.6	40	42
$Mg(NO_3)_2$	42.333	44.788	-	-	-	-	-
KCl	25.4	28.6	29.9	31.3	32.6	33.8	35.1

The conversion equilibrium can be shifted to the right by excess potassium chloride, which lowers the mother liquor's nitrate content. At a temperature of 80–90°C, the potassium chloride solution was then added to the magnesium nitrate solution (Table 1).

3 Results and Discussion

At the stage of preparing the magnesium nitrate solution, the solution should be neutral, i.e., the pH value should be within 6.5-7, if the solution has a strongly acidic pH value. In this case, the HNO_3 remaining during the conversion of KCl salt to $Mg(NO_3)_2$ was not reacted and released nitrosyl chloride with the following equation:

$$KCl + HNO_3 \rightarrow KNO_3 + NOCl + Cl_2 + H_2O \quad (3)$$

Nitrosyl chloride substances are highly toxic one and also they are corrosive that can severely damage equipment, resulting in its rapid failure. Also, in order to sustain the essential pH environment, carbonates or alkali metal-hydroxides can be added into that.

After mixing $Mg(NO_3)_2$ and KCl, the ions of the salts reach equilibrium after a specific time. To shift the equilibrium towards the target products, one of the formed salts must be removed from the system. Magnesium chloride crystallizes poorly; when saturated, it forms tiny crystals which is subsequently coalesce into the monolithic mass.

Table 2. The composition of crystals and mother liquors, evaporated at different temperatures after cooling, is given in

Experiment	Temperature, °C	Initial solution, in (Mg^2, Cl^-), %		KNO_3 crystals in %	
		Cl^-	Mg^{2+}	Cl^-	Mg^{2+}
1	105	13.61	4.35	7.11	2.51
2	106	13.75	4.52	7.33	2.5
3	107	13.8	4.61	7.42	2.49
4	108	13.86	4.67	7.59	2.48
5	109	14.12	4.75	6.45	1.16
6	110	16.13	5.77	6.43	1.51
7	111	14.5	5.19	6.3	1.48
8	112	15.48	5.94	8.13	1.56
9	113	16.38	5.83	7.01	1.67
10	114	16.4	5.81	7.05	1.68
11	115	16.41	5.8	7.09	1.69

It turns out that 110 to 112°C is the ideal evaporation temperature for this system. In this instance, the potassium nitrate content rises to 31% by weight. The solution is not fully saturated below 110°C, and other complex salts, such carnallite, start to precipitate above 112°C.

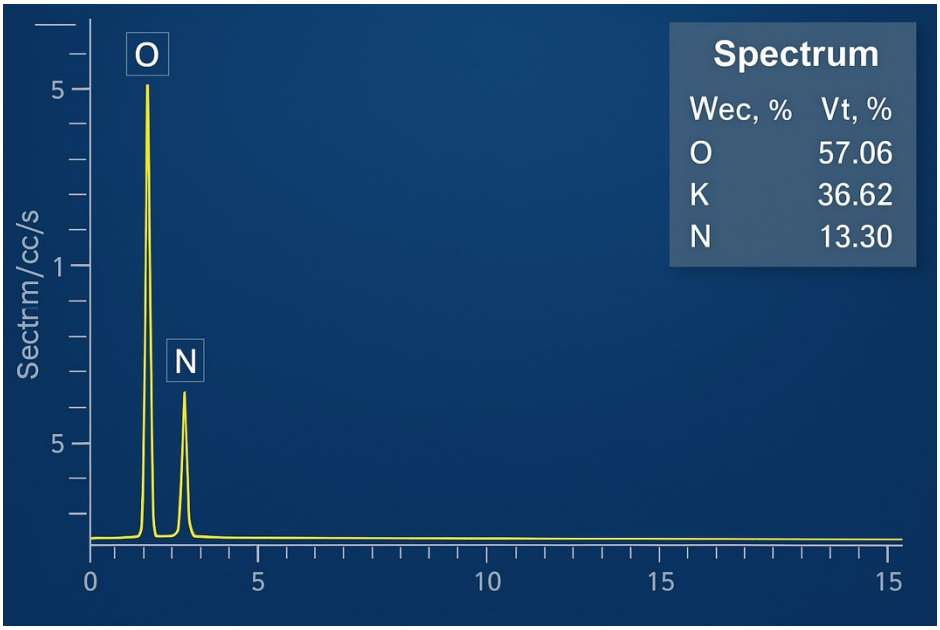

Fig. 1. Energy dispersive spectrum of potassium nitrate and quantitative composition of elements in solution.

After washing, the KNO_3 content increases much significantly, while the chlorine ion content reduced to a required value, which was fully meeting the requirements of GOST 19790-74 standard. Based on the solubility diagram of K, Mg^{2+} // Cl^-, NO_3^-, the following ranges in the primary process parameters was finally selected: $Mg(NO_3)_2$:KCl=1.2:1; conversion duration 5-10 min, crystallization temperature 5-20°C,

crystallization duration 15-20 min. The effects of temperature, conversion time, and the $Mg(NO_3)_2$:KCl ratio were examined, along with the kinetics of crystallization at 5°C, 10°C, and 20°C. Regardless of the conversion conditions at 120°C, the collected data indicates that no solid phase is generated in the system in the ranges examined following the conversion process.

According to the following, the amount of K^+, Mg^{2+}, Cl^-, and nitrogen in the form of nitrate in the resultant solid product and liquid phase was measured.

Table 3. The method of producing KNO_3 by conversion method

№	Ratio of KCl/$Mg(NO_3)_2$ in conversion stage	Conversion duration, min	Crystallization temperature, °C	Crystallization duration, min	Filtration rate, kg/m²*h for solid phase	Degree of K_2O yield, %
1	1:1	5	5	10	1247.82	87.5
2		10			1973.54	88.2
3		5	10	20	1643.32	88.6
4		10			2184.93	89.3
5		5	20	30	1830.14	82.1
6		10			2033.83	81.0
7	1,2:1	5	5	10	1190.18	93.6
8		10			1918.33	95.5
9		5	10	20	1202.68	97.2
10		10			2144.73	98.1
11		5	20	30	1528.97	98.4
12		10			2327.3	98.7
13	1,5:1	5	5	10	1251.42	80.1
14		10			1468.28	81.2
15		5	10	20	1680.03	82.6
16		10			1818.73	83.9
17		5	20	30	1568.47	85.3
18		10			1967.54	86.1

Crystals of potassium nitrate are generated from a suspension with KCl: $Mg(NO_3)_2$ = 1.2:1 (Table 3) as a result of the latter's decreased solubility in the system. Depending on the testing conditions, the degree of clarification within 20 minutes can range from 93.6 to 98.7%.

4 Conclusions

According to the study's findings, potassium nitrate can be used as a potassium fertilizer without chlorine. The degree of K+ ion usage is 97-98%, while the KNO_3 content is 98-99%. Both in industrial cooling systems and in the suggested process for potassium nitrate, a magnesium chloride solution is utilized as a by-product to produce the defoliant magnesium chlorate. This process is regarded as a competitive manufacturing method since it enables you to obtain potassium nitrate at a lesser cost than other methods.

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