ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 6, June 2024

Organomineral Fertilizers Based on Sewage Sludge and Sludge Phosphorites of CENTRAL KYZYL KUM

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ABSTRACT: The article details the findings of a study on the production of organomineral fertilizers through the composting of municipal wastewater sludge (CMWS) combined with activated sludge phosphate (ASP) treated with nitric acid. The study examines the impact of varying nitric acid rates, composting durations, weight ratios of the initial materials, and the moisture content of the composted mass. It was found that adding ASP with nitric acid at different rates influences the degree and kinetics of humification of organic matter in the manure, affects the loss of organic matter and nitrogen, and enhances the levels of digestible phosphorus forms. The addition of ASP with nitric acid positively impacted the formation of humic substances, reducing the loss of organic matter and nitrogen.

KEYWORDS: municipal wastewater sludge, nitric acid, activated phosphorite, phosphorus, compost, organic matter, sludge phosphorite (SF).

I.INTRODUCTION

Global agricultural experience shows that both mineral and organic fertilizers play a crucial role in enhancing soil fertility. Organic fertilizers are particularly effective in increasing humus content in soils. The primary raw materials for producing organic and organomineral fertilizers are waste from livestock and poultry farming. In Uzbekistan, there is a significant shortage of these fertilizers. Additionally, improper storage and lack of efficient processing technologies lead to the release of harmful substances like CO2, CH_4, H_2O, and NH_3 from livestock and poultry wast [1-3].

Several composting technologies are available. Passive heap composting relies on natural biological disinfection of manure mixed with or without moisture-absorbing materials. This process takes place on concrete sites or specially prepared fields and typically takes 2 months in summer and 3 months in winter. Nutrient emission, particularly nitrogen, ranges from 20-27%[4-5].

Active heap composting involves processing solid manure or litter with or without moisture-absorbing materials on waterproofed sites. This method, which includes triple aeration of the pile over 40 days, results in nitrogen emissions of up to 22%.

Aerobic fermentation in chamber-type installations uses atmospheric oxygen to oxidize part of the organic matter, raising temperatures above 60°C, which destroys harmful microorganisms. This method requires a moisture content of 55-65%, a carbon to nitrogen (C/N) ratio of 15/1-25/1, and a processing duration of 7-9 days. Nutrient emissions range from 13-20%[6-7].

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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Drum-type biofermentation is similar to chamber-type installations but involves rotating the biofermenter housing, ensuring a stable process and uniform compost maturation. This method can operate in cyclic or continuous modes.

Thermal drying technology involves drying manure in special installations, reducing its mass by 3-4 times and making it suitable for application by standard fertilizer machines. However, this method results in nutrient emissions of up to 50%.

Currently, the most common method involves daily mechanical removal of manure, mixing with moisture-absorbing materials, fermentation by mixing on sites, and subsequent compost storage and application. However, these methods often result in significant nitrogen loss as ammonia and organic substances, reducing fertilizer value and causing environmental pollution[8-11].

Notably, the Kyzylkum phosphorite complex has accumulated over 15 million tons of low-grade phosphorites, which are not utilized in industry. Utilizing these phosphorites in agriculture can address the shortage of phosphate fertilizers. Municipal wastewater sludge is also a viable raw material for organomineral fertilizers.

Addressing the main agricultural challenges, such as the shortage of mineral fertilizers, declining humus content, and soil salinization, can be achieved through large-scale production and use of organomineral fertilizers. Composting manure-phosphorite mixtures offers a rational way to process substandard phosphorites and CMWS, reduce harmful gas emissions, and convert waste into valuable fertilizers. This approach utilizes the energy of organic acids formed during composting to decompose phosphate raw materials, resulting in phosphorus-containing organomineral fertilizers.

II.RESEARCH METHODS AND RESULTS OBTAINED

For the study, we utilized SF and OGSV, with their compositions detailed in Tables 1 and 2, and employed 59% nitric acid. Initially, SF was activated with nitric acid, with the nitric acid rate ranging from 20% to 60% of the stoichiometric amount needed to decompose $CaCO_3$ in SHF. At a 40% stoichiometric rate, 60.55 g of 59% HNO_3 is required to treat 100 g of SF. The treatment of SF with nitric acid was conducted in a solid-phase mode using a laboratory setup consisting of a tubular glass reactor equipped with a stirrer. After the addition of nitric acid (over 10-15 minutes), the reaction mixture was stirred thoroughly for 30 minutes. Due to the exothermic nature of the reaction, the temperature of the reaction mass increased to 70°C. Depending on the nitric acid rate, ASF was obtained as a loose granular mass. ASF was dried at room temperature and analyzed for the main component content using standard methods. The determination of all forms of P_2O_5 was conducted in accordance with GOST 20851.2-75. The CaO content was determined complexometrically by titration with a 0.05 N solution of Trilon B in the presence of the indicator fluorexone. The analysis results are shown in Table 4, which indicates that as the nitric acid rate increases, the total P_2O_5 content in the products decreases, while the P_2O_5 content according to Trilon B and in a 2% citric acid solution, as well as the nitrogen content, increases. For instance, with a 20% HNO3 rate, the relative P2O5 content for Trilon B and in a 2% citric acid solution increases from the initial 30.15% and 11.50% to 37.62% and 18.35%, respectively. These values further rise to 49.75% and 34.36% when using a 60% HNO3 rate. These nitric acid decomposition products of SP, obtained at different rates, were then used as the phosphorus-containing component in producing organomineral fertilizers based on cattle manure.

Table 1

Chemical composition of the coal mixtures used for the preparation of composts

Kinds phosphate raw materials	Content of components, %									$P_2O_{5\,ass.}$ / $P_2O_{5tot.}$ %
	P_2O_5	CaO	Al_2O_3	Fe_2O_3	MgO	F	CO_2	SO_3	...	
SF	11.57	41.08	1.84	1.42	0.61	1.52	20.91	0.46	14.09	11.50

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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Table 2
Composition of OGSV manure

Number of components, %								
Moisture	Organic matter (general)	Humic acid	Fulvic acids	Water-soluble organic substances	N	P_2O_5	K_2O	CaO
65.43	24.83	3.05	7.47	2.13	1.17	1.39	0.44	4.14

Table 3
Composition of activated slurry phosphorite with nitric acid

Norm HNO3 , %	P_2O_{5total}	by tr. B, $P_2O_{5ass.}$ / $P_2O_{5tot.}$ * 100 %	according to lim. to-those, $P_2O_{5ass.}$ / $P_2O_{5tot.}$ * 100%	CaO_{tot} .	Nitrogen	Decarbonization degree, %
0	11.57	31.21	11.94	41.70	0.00	-
20	10.90	38.94	19.05	38.43	2.45	16.73
thirty	10.47	41.77	23.20	36.91	3.54	23.87
40	10.06	45.09	27.69	35.47	4.54	30.77
50	9.69	48.51	32.04	34.16	5.46	37.95
60	9.35	51.49	35.67	32.97	6.32	45.35

Composts based on CMWS and ASF with nitric acid were prepared in the following weight ratios: CMWS : ASF = 95:5; 90:10; 85:15; 80:20; 75:25; 70:30. The resulting mixtures were placed in 2.0-liter containers, with water added to achieve a humidity level of 60-70%. A thin layer of soil was spread on top of the mixture. Samples were taken every 5 days, and chemical analyses of the composts were conducted.

Tables 4-5 illustrate changes in the total and relative contents of digestible forms of P_2O_5 for Trilon B and 2% citric acid, depending on the rate of nitric acid, the duration of composting, and the weight ratios of the original components. It is evident that increasing the mass fraction of ASF relative to manure in the composts results in a higher total form of P_2O_5 content and a decrease in the relative digestible form of P_2O_5. With an increase in the nitric acid rate and the composting duration, the relative content of digestible forms of P_2O_5 increases. In the original SF, the relative contents of P2O5 ass. for Trilon B and 2% citric acid are 31.21% and 11.94%, respectively. After activation with nitric acid at a 30% rate, these figures rise to 41.77% and 23.20%, respectively. Following composting at the same nitric acid rate and with a CMWS : ASF ratio of 80:20 for 30 days, these figures further increase to 68.67% and 60.48%, respectively. Thus, with higher nitric acid rates and longer composting durations, the transition of phosphorus from an indigestible form to a plant-digestible form significantly improves.

Tables 6 and 7 demonstrate the relationship between the loss of nitrogen and organic matter and the nitric acid rate, the weight ratio of the initial components, and the compost aging duration. The data indicate that higher nitric acid rates and greater mass fractions of ASF in the mixture substantially reduce the loss of organic substances and nitrogen. For instance, at a 30% nitric acid rate and a manure ratio of 90:10, after 30 days, the loss of organic matter and nitrogen is 10.90% and 12.92%, respectively. In contrast, at a 60% nitric acid rate and a CMWS : ASF ratio of 70:30 after 90 days,

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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the loss of organic matter and nitrogen is only 3.14% and 3.62%, respectively. These findings indicate that preparing composts based on CMWS with the addition of ASF positively impacts all composting parameters.

Table 4
Relative content of digestible form of phosphorus (assimilation to tr. B, $P_2O_{5\ ass}$ / $P_2O_{5\ total}$) in composts prepared on the basis of CMWS with the addition of ASF depending on the holding time and mass ratios, %

Mass ratio CMWS : ASF	Duration of composting, days					
	5	10	15	20	2 5	thirty
Without activation with nitric acid (Slurry phosphorite - SF)						
95:5	31.19	42.64	51.41	58.74	65.63	68.50
90:10	30.69	41.31	49.78	56.37	62.70	65.32
85:15	30.91	40.86	48.56	54.51	60.78	62.76
80:20	30.46	39.16	46.53	52.21	57.91	59.71
75:25	30.16	38.29	45.01	50.52	56.14	57.43
70:30	29.75	37.11	42.94	48.01	52.97	54.11
	Norm HNO_3, 20%					
95:5	35.82	47.94	56.94	64.44	71.64	74.63
90:10	35.91	47.16	55.79	62.43	69.01	71.73
85:15	36.02	46.69	54.69	60.81	67.43	69.53
80:20	36.11	45.34	52.75	58.40	64.28	66.14
75:25	36.13	44.71	51.36	56.74	62.48	63.78
70:30	36.38	44.38	50.31	55.41	60.65	61.83
	Norm HNO_3, 30%					
95:5	40.38	52.29	60.64	67.48	74.37	77.21
90:10	40.75	51.95	60.04	66.18	72.53	75.15
85:15	40.94	51.43	58.76	64.23	70.54	72.52
80:20	41.24	50.17	56.70	61.53	66.98	68.67
75:25	41.33	49.83	55.88	60.66	66.15	67.35
70:30	41.24	49.17	54.52	59.03	64.02	65.10
	Norm HNO_3, 40%					
95:5	43.63	55.38	63.27	69.65	76.31	79.05
90:10	43.71	54.81	62.52	68.27	74.47	77.01
85:15	44.93	55.22	61.92	66.81	72.81	74.67
80:20	44.92	53.99	60.34	64.94	70.36	72.04
75:25	44.95	53.35	58.88	63.18	68.41	69.55
70:30	45.00	52.80	57.62	61.60	66.32	67.34
	Norm HNO_3, 50%					
95:5	45.92	57.66	65.32	71.49	78.06	80.76
90:10	45.65	56.97	64.73	70.50	76.76	79.35
85:15	46.39	56.88	63.67	68.62	74.71	76.60
80:20	47.00	56.24	62.58	67.14	72.61	74.30
75:25	46.99	55.36	60.66	64.72	69.85	70.95
70:30	47.16	54.94	59.51	63.25	67.87	68.85
	Norm HNO_3, 60%					
95:5	48.24	59.57	66.59	72.15	78.35	80.90
90:10	48.16	59.05	66.10	71.23	77.12	79.53

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85:15	48.32	58.69	65.15	69.78	75.70	77.53
80:20	49.14	58.01	63.69	67.67	72.78	74.34
75:25	48.30	56.40	61.24	64.87	69.72	70.75
70:30	48.23	55.65	59.70	62.93	67.22	68.11

Table 5

The relative content of the digestible form of phosphorus (assimilation to lime, $P_2O_{5\ ass}$ / $P_2O_{5\ total}$) in composts prepared on the basis of CMWS with the addition of ASF, depending on the holding time and mass ratios, %

Mass ratio Cattle manure: ASF	Duration of composting, days					
	5	10	15	20	2 5	thirty
Without activation with nitric acid (Slurry phosphorite - SF)						
95:5	21.16	32.01	41.12	48.88	55.72	58.56
90:10	21.17	31.23	40.04	47.07	53.35	55.96
85:15	21.28	30.76	38.90	45.36	51.64	53.66
80:20	21.38	29.58	37.27	43.36	49.02	50.83
75:25	21.45	28.99	36.01	41.91	47.46	48.77
70:30	21.58	28.38	34.36	39.66	44.50	45.63
Norm HNO_3 , 20%						
95:5	25.57	37.26	46.81	54.92	62.19	65.22
90:10	25.67	36.64	45.99	53.38	60.14	62.95
85:15	25.78	36.26	45.04	51.97	58.83	61.04
80:20	25.81	34.89	43.20	49.75	55.93	57.90
75:25	25.88	34.28	41.89	48.25	54.36	55.78
70:30	25.96	33.94	40.93	47.09	52.75	54.07
Norm HNO_3 , 30%						
95:5	31.45	41.31	50.31	57.87	64.88	67.80
90:10	31.19	41.14	50.07	57.06	63.67	66.41
85:15	31.14	40.68	48.92	55.34	61.95	64.06
80:20	30.89	39.39	46.95	52.81	58.63	60.48
75:25	30.77	39.09	46.25	52.15	58.07	59.45
70:30	30.64	38.44	44.98	50.69	56.18	57.44
Norm HNO_3 , 40%						
95:5	35.89	44.19	52.80	59.97	66.82	69.65
90:10	35.78	43.80	52.43	59.11	65.60	68.28
85:15	35.55	44.22	51.94	57.86	64.24	66.25
80:20	34.97	42.99	50.47	56.20	62.06	63.90
75:25	34.63	42.37	49.13	54.63	60.39	61.69
70:30	34.10	41.83	47.94	53.23	58.53	59.73
Norm HNO_3 , 50%						
95:5	37.91	46.12	54.44	61.35	68.06	70.83
90:10	37.72	45.66	54.26	60.90	67.41	70.11
85:15	37.35	45.60	53.34	59.24	65.65	67.68
80:20	36.81	44.94	52.34	57.98	63.84	65.68
75:25	36.42	44.06	50.52	55.74	61.34	62.60
70:30	35.79	43.65	49.47	54.47	59.61	60.76

Norm HNO_3 , 60%						
95:5	40.74	48.07	55.92	62.37	68.83	71.49
90:10	40.09	47.77	55.83	62.00	68.24	70.82
85:15	39.27	47.62	55.26	61.07	67.47	69.49
80:20	38.89	46.87	53.87	59.15	64.81	66.57
75:25	38.06	45.31	51.53	56.52	62.00	63.23
70:30	36.88	44.56	50.07	54.78	59.73	60.84

Table 6
Loss of organic matter in composts after 30 days of aging, prepared on the basis of CMWS with the addition of ASF, depending on the rate of nitric acid and mass ratios, %

Mass ratio CMWS: SF	Norm HNO_3 , %					
	0	20	thirty	40	50	60
95:5	13.20	12.62	12.30	11.93	11.21	10.72
90:10	11.97	11.51	10.90	10.48	10.15	9.78
85:15	10.83	10.22	9.94	9.43	8.71	8.24
80:20	9.86	9.49	8.94	8.42	7.76	7.57
75:25	7.90	7.13	6.66	6.11	5.46	5.04
70:30	6.15	5.44	4.81	4.45	3.85	3.41

Table 7 .
Loss of nitrogen in composts after 90 days of aging prepared from cattle manure with the addition of activated SF depending on the rate of nitric acid and mass ratios, %

Mass ratio CMWS: SF	Norm HNO_3 , %					
	0	20	thirty	40	50	60
95:5	17.27	16.52	15.33	13.68	12.31	10.84
90:10	15.78	14.98	12.92	11.63	10.12	9.04
85:15	14.52	13.70	12.22	10.21	8.88	7.60
80:20	13.12	12.52	10.83	9.09	7.48	6.14
75:25	12.06	11.09	9.18	7.75	6.45	4.89
70:30	10.73	9.46	7.88	6.31	4.39	3.62

III.CONCLUSION

Thus, the research results indicate that under optimal conditions, ASF exhibits superior properties for reducing the release of harmful gases into the environment, enhancing the humification of organic substances, and producing organomineral fertilizers with a higher phosphorus content based on CMWS. This finding is crucial for developing a waste-free and environmentally friendly technology for producing phosphorus-containing organomineral fertilizers. Additionally, incorporating low-grade phosphate raw materials into the production process will significantly expand the phosphate raw material base.

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