

SUPPLEMENTARY MATERIAL

Is K-Struvite Precipitation a Plausible Nutrient Recovery Method from Potassium-Containing Wastes? — A Review

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Table S1. Results of MPP and MAP precipitation conducted on various wastes and using different reactors

Sample	Compound recovered	Reagent for pH setting	Reagents	Optimal pH	Optimal molar dosages	Recovery efficiencies	Reactor Type	Working Mode	V or Q	HRT/ Reaction time	Economic analysis	Remarks	Ref.
SPU	MPP	NaOH	MgCL ₂ ·6H ₂ O	11	Mg:K:P= 2:1:2	98 % P 77 % K	CSTR	Batch	0.5 L	-	-	Co-precipitation of struvite-type compounds significantly reduced the K removal.	[14]
SPS	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	11	Mg:P=0.7 K:P=1	95.5 % P	BCRDT	Continuous	10 L	1.98	-	MPP is more effective fertilizer than compost	[15]

SPU	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	9	Mg: P = 1:2	89 % P	CSTR	Continuous	0.77 L	1.63 h	-	At volume index of 500 mL/g P ^b ; 1.2% of influent P scaled on the reactor wall at 100 rpm mixing speed. At volume index of 310 mL/g P ^b ; 5.3% of influent P scaled on the reactor wall at 300rpm mixing speed.	[17]
SPU	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	11 ± 0.1	K:Mg:P= 1:1:1	64 ± 2% K 96 ± 1% P	CSTR	Continuous	4 L· h ⁻¹	10 min	-	Order of the effect is as NH ₄ >Ca ²⁺ >Na ⁺ on the K-struvite precipitation performance.	[23]
Sugarcane vinasse wastewater	MPP	NaOH	MgSO ₄	10	Mg:K:P= 2:1:2	72%K	Integrated electrodialysis reactor	Batch	-	-	-	K recovery of 72 % and energy consumption of 0.4 kWh m ⁻³ .	[26]
Semi-conductor wastewater	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	9	Mg:N:P =2.5:15:1	92.5 % P	CSTR	Batch	1 L	40min	-	High Mg concentration increased removal efficiency of PO ₄ ³⁻ but altered struvite purity. Bobierite became the dominant species in the solid phase.	[27]
Real urine wastewater	MPP	NaOH	MgSO ₄ Na ₂ HPO ₄ ·12H ₂ O	11.4	Mg:K:P = 3.3:1:3	42-68 % P	DTBR	Continuous	2.5 L ^c	2.5-12.5 h	-	HRT ≥ 7.5 h and mixing speed ≤ 200 rpm for good crystal settling characteristics. Excess slurry concentration blocks the fluid flow across the accumulated slurry.	[29]
SPU	MPP	NaOH	MgCL ₂ ·6H ₂ O NaH ₂ PO ₄ ·2H ₂ O	10.5	Mg:K:P= 1:1:1	99 % P 70 % K	FBHC column	Continuous	0.55 L	1.6h	-	Breakage of the precipitates under the intensive turbulence within the reactor. The up-flow velocity = 1.5 – 2.0 times the minimum fluidization velocity (MFV) for the effective fluidization.	[30]
SCWG liquid fraction	MPP	NaOH	MgCL ₂ ·6H ₂ O	11	Mg:P = 1:2	94 % P 42 % K	CSTR	Batch	-	-	-	The low K removal efficiency is attributable to the excess of potassium in the treating samples.	[31]
SPU	MPP	NaOH/ Aeration	MgCL ₂ ·6H ₂ O	12	Mg:K:P= 1:1:1	96 % P	CSTR	Batch	0.1 L		3.99 - 6.28 \$/m ³ of treated urine	pH and Na ⁺ concentration significantly affect the Na-struvite formation.	[32]
Landfill leachate	MAP	NaOH/ Aeration	MgCL ₂ ·6H ₂ O	9	Mg:N:P= 1.2:1:1.2	99 % P 96 % N	CSTR	Batch	0.2 L	30 min	-	Multiple recycling tests showed a progressive reduction of ammonium removal by exclusively exploiting struvite residues as a magnesium and phosphorus source for the treatment of raw leachate.	[44]

Livestock synthetic wastewater	MPP and MAP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$ $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$	10	Mg:K:P = 1:1:1	50-57 % P	BCRDT	Continuous	11.5 L	2.3	-	MPP yield was 36% for N concentrations below 1.1 mM.	[50]
Manure liquid fraction	MPP and MAP	-	KCl and $\text{Na}_3\text{PO}_4 \cdot \text{H}_2\text{O}$	10.3	Mg:K:P= 1:1:1	60-80 % P	CSTR	Batch	1 L	-	-	The best recovery performance was achieved at 38 °C.	[56]
Swine wastewater	MPP and MAP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	10	K:N= 6:1	>95 % P	CSTR	Batch	0.5 L	-	1.27 \$/kg PO_4^{3-} -P removed	When the K to TAN molar ratio was 6, the competition ratio between the K-struvite and struvite reached 93.7%.	[59]
Synthetic wastewater	MPP and MAP	KOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$ $\text{NH}_4\text{H}_2\text{PO}_4$	9	-	-	BSTR ^a	Batch	0.5 L	-	-	Temperature and stirring rate are significant factors in the mass yield of K-struvite crystals.	[62]
SPU	MPP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	10.5	Mg:P= 1:1	20 % K 80 % P	Pilot-scale FBR	Continuous	n.s.	n.s.	-	Small amount of fine crystals flowing out with the effluent, which was caused by the attrition and breakage of pellets during the stable operation of FBR	[67]
Source-separated urine	MPP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	10.7	MgO:K:P = 4:1:1.6	100 % P 70 % K	CSTR	Batch	1 L		2.79 - 5.42, \$/m ³ of treated urine	When the Na:K molar ratio was >10, the precipitation of Na was more than that of K.	[71]
SPS	MPP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	10	P:K = 1:4.9	-	DTBR	Continuous	0.25 L·h ⁻¹	-	-	Ammonia removal from urine is a crucial step to precipitate K-struvite	[75]
Manure effluent	MAP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	9	Mg:N:P = 1.5:1:1	86 % P 97 % N	CSTR	Batch	0.15 L	-	-	Presence of high concentrations of Ca led to complete PO_4^{3-} recovery in form of struvite.	[89]
Poultry manure	MPP and MAP	KOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$	8.5	-	90 % P	CSTR	Batch	1 L	1 h	-	-	[90]
Pumpkin waste	MPP	NaOH	$\text{MgCL}_2 \cdot 6\text{H}_2\text{O}$ $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$	9.5÷10	Mg:K:P= 1:2:2	80 % K	-	-	-	-	-	-	[91]

Anaerobically digested swine	MAP	NaOH	MgCL ₂ ·6H ₂ O	9.5	Mg:N:P = 1.5:1:2	99 % P 99 % N	CSTR	Batch	5 L	-	-	-	[94]
Cattle manure wastewater	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	10	Mg:P:N= 1.5:1.25:1	10 % K 77 % P	CSTR	Batch	0.250 L	1 h	-	Potassium removal efficiency was significantly lower than that of ammonium. The molar percentage of the removed K ⁺ over the total removed NH ₄ ⁺ was less than 10%.	[95]
Produced wastewater	MPP and MAP	NaOH	MgCL ₂ ·6H ₂ O	9.5	Mg:N:P = 1.5:1:1.5	85.9 % N 24.8 % K 96.8 % Mg	CSTR	Batch	0.15L	-	-	The precipitated struvite had high purity and showed the absence of heavy metals, indicating the sufficient quality for applications as fertilizers.	[99]
Landfill leachate	MPP and MAP	NaOH	MgSO ₄ Na ₂ HPO ₄ ·12H ₂ O	-	Mg:K:P= 3:1:3	53 % K	Cation-exchange membrane reactor	-	0.2 L	20 min	3.74\$/m ³ of treated landfill leachate	Combined electrochemical oxidation/magnesium potassium phosphate crystallization process is demonstrated to be an effective method for recycling of NF concentrates generated from a landfill plant.	[100]
Landfill leachate	MPP and MAP	-	-	9.5	Mg: P = 1:1.5	19.3 % Mg 29.8 % P	Membrane FO reactor	-	-	-	-	Calcium pretreatment improves the recovery of pure struvite.	[101]

^a Pyrex glass vessel mechanically agitated; ^b volume of struvite collected in settler plus the scaling removed; ^c reaction zone volume; n.s. not specified.