Jurnal Serambi Engineering JSE
Volume X, No.4, Oktober 2025 Hal 15886 - 15897
p-ISSN : 2528-3561
e-ISSN : 2541-1934

Potential Study of Hazardous Waste Sludge Recycle for Substituting the Supporting Raw Material in Fertilizer Manufacturing

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Received: September 15, 2025 Approved: September 20, 2025

Abstract
Waste water treatment facilities (WWTP) are producing a rising amount of sludge, which poses serious disposal and environmental issues. The purpose of this study is to investigate the possibility of using WWTP sludge in place of filler materials while making NPK fertilizer. Significant levels of vital elements, including nitrogen (N), phosphorous (P), and potassium (K), which are crucial for fertilizer quality, were found in the sludge after a thorough physical and chemical analysis. A comparative assessment was performed between the WWTP sludge and standard clay filler materials to evaluate compliance with Indonesian National Standard (SNI) 2803:2024 for solid NPK fertilizers. Experimental mixing trials identified the optimal sludge-to-clay ratio as 60:40, which produced fertilizer granules with acceptable physical properties, homogeneity, and nutrient content that met the SNI requirements. This study shows that using WWTP sludge as a filler in fertilizer manufacture has major financial advantages in addition to supporting resource recovery and sustainable waste management. The study promotes the use of sewage reuse in fertilizer production as a creative way to solve environmental issues and boost industrial productivity.
Keywords: *wwtp sludge; npk fertilizer; filler substitution; sludge characterization; cost saving*

Abstrak
Fasilitas pengolahan air limbah (IPAL) menghasilkan lumpur dalam jumlah yang terus meningkat, yang menimbulkan masalah pembuangan dan lingkungan yang serius. Tujuan dari penelitian ini adalah untuk mencari kemungkinan penggunaan lumpur IPAL sebagai pengganti bahan filler saat membuat pupuk NPK. Kadar unsur penting yang signifikan adalah nitrogen (N), fosfor (P), dan kalium (K), yang sangat penting untuk kualitas pupuk, ditemukan di dalam lumpur setelah dilakukan analisis fisik dan kimia secara menyeluruh. Penilaian komparatif dilakukan antara lumpur IPAL dan filler top soil standar untuk mengevaluasi kesesuaian dengan Standar Nasional Indonesia (SNI) 2803:2024 untuk pupuk NPK padat. Uji coba pencampuran secara eksperimental mengidentifikasi rasio lumpur dan tanah liat yang optimal adalah 60:40, yang menghasilkan butiran pupuk dengan sifat fisik, homogen, dan kandungan unsur hara yang sesuai dengan persyaratan SNI. Studi ini menunjukkan bahwa penggunaan lumpur IPAL sebagai bahan pengisi dalam pembuatan pupuk memiliki keuntungan finansial yang besar selain mendukung pemulihan sumber daya dan pengelolaan limbah yang berkelanjutan. Studi ini mempromosikan penggunaan kembali limbah dalam produksi pupuk sebagai cara kreatif untuk memecahkan masalah lingkungan dan meningkatkan produktivitas industri.
Kata Kunci: *lumpur ipal; pupuk npk; substitusi bahan pengisi; karakterisasi lumpur; penghematan biaya*

1. Introduction

National food security is supported by the fertilizer industry, which is a strategic sector. Fertilizer manufacturing remains critical in supporting global agriculture, often relying heavily on natural and synthetic raw materials [1]. One of the products produced by this fertilizer company is NPK Granule fertilizer with Urea, ZA, KCl, Phosphoric Acid, Ammonia, Sulfuric Acid, Filler, and Micronutrient. The production process is carried out using automatic machines and tools in a sequence that starts from the Scrubber System which cleans the exhaust gas, then the material is processed in the Pre-Neutralizer for the initial reaction. The mixture then enters the Granulator for granule formation, followed by the Dryer for drying. After that, the granules pass through the Screen for size screening, then cooled in the Cooler, and the quality is ensured in the Polishing Screen before finally coated in the Coater and ready for packaging [2].

Several processes for the production of NPK fertilizers that require water, such as scrubbers using water to capture exhaust gases and particulates, chemical reaction stages such as neutralization and granulators that use water in reactions or washing produce residual reaction water containing chemicals such as nitrogen, ammonia, phosphates, and heavy metals, wastewater is also generated from the use of cooling water, both as cooling water and from steam condensate in reactors and dryers, and the process of cleaning production facilities and equipment also produces wastewater containing raw material and product residues [2]. Due to the presence of wastewater in the production process, the fertilizer company built a special wastewater treatment plant (WWTP) for the NPK plant.

This research examines the utilization of sludge generated from the wastewater treatment process in the WWTP. This sludge comes from the process of settling and separating solids that occurs when the WWTP purifies factory wastewater to meet standards before being discharged or recycled. Thus, the focus of the research is to utilize sludge from WWTP wastewater treatment for potential recycling, for example as a substitute for supporting raw materials in the NPK fertilizer manufacturing process, thus supporting environmentally friendly and efficient waste management in fertilizer plants [3].

This study will characterize the content of the main nutrients, namely Nitrogen (N), Phosphorus (P), and Potassium (K), contained in sludge from wastewater treatment at the WTP of the NPK fertilizer plant to determine whether the NPK elements are still significantly contained in the sludge. If the NPK content is considered still sufficient, then the sludge has the potential to be used as raw material or supporting mixture (filler) in the production of NPK fertilizer. Furthermore, the research will compare the characterization of sludge with conventional fillers such as clay, to assess the suitability and potential of sludge as a filler substitute. In addition, the research aims to determine the optimum composition of sludge mixture as filler, i.e. the best percentage of sludge that can be mixed in fertilizer without reducing the quality of the final product. Finally, an economic analysis was also conducted to evaluate the feasibility of using sludge in terms of costs and benefits, so as to provide an overview of whether the use of sludge as a filler mixture in the fertilizer industry is economical and sustainable. Sludge from WWTP or industrial waste still contains nutrients that can improve fertilizer quality, but the dosage and composition of its use need to be determined appropriately to meet fertilizer quality standards and cost efficiency [4].

2. Material and Methods

2.1 Sample Collection

Hazardous waste sludge was collected from the final stage of the wastewater treatment process (screw press) at PT Petrokimia Gresik. From screw press the sludge will be goes to sludge disposal. This sludge originates from the industrial waste water treatment plant, which primarily treats effluents generated during fertilizer manufacturing processes.

2.2 Sludge Characterization

2.2.1 Moisture Content Analysis

The moisture content of the sludge was determined using the oven-drying method. A known amount of dewatered sludge was weighed using an analytical balance and placed into a clean, dry, heat-resistant crucible. The sample was then dried in a laboratory oven at a constant temperature of 105°C, repeated four times to ensure consistent and reliable drying. The drying process was continued until the sample reached a constant weight. The moisture content was calculated based on the weight loss before and after drying [4].

2.2.2 Chemical properties

Total nitrogen (N) content in the dried sludge sample was determined using the Kjeldahl method with the assistance of an automatic distillation unit (Vapodest). A 0.8-gram portion of dried sludge was placed in a digestion tube, followed by the addition of 10 mL of concentrated sulfuric acid (H_2SO_4) and a catalyst mixture, either boric acid or a combination of copper sulphate ($CuSO_4$) and potassium sulphate (K_2SO_4). The sample was then digested until the solution became clear, indicating the completion of organic nitrogen conversion into ammonium ions (NH_4^+). After digestion, the mixture was subjected to distillation using the Vapodest unit. The released ammonia was distilled into a boric acid solution and subsequently titrated with 0.5 N sulfuric acid (H_2SO_4) to determine the total nitrogen content. An indicator and blower were used to operate and monitor the distillation process. The nitrogen concentration was calculated based on the volume of titrant used [4].

Phosphorus content in the dried sludge sample was analyzed using a colorimetric method with a spectrophotometer. A total of 1-g of dried sludge was digested using concentrated nitric acid (HNO_3) to extract the phosphorus content. After digestion, the solution was diluted with distilled water (aquades) to a known volume and filtered if necessary to obtain a clear sample. A molybdate reagent was added to the digested solution to form a blue-coloured complex, which indicates the presence of phosphate ions. The mixture was homogenized using a fast mixer to ensure a uniform reaction. The absorbance of the resulting solution was measured using a spectrophotometer at the appropriate wavelength for phosphate determination. The phosphorus content was then calculated by comparing the absorbance value to a standard calibration curve [4].

For potassium analysis, a portion of the 50 mL phosphorus solution was further diluted to 100 mL (second dilution) to obtain a suitable concentration range. The potassium content was then measured using the spectrophotometer at a wavelength specific to potassium detection. Standard curves for both phosphorus and potassium were prepared using standard solutions of known concentrations [4].

2.3 Fertilizer Formulation Mixing

To simulate the potential replacement of conventional raw materials, the sludge was mixed with filler materials. Each fertilizer formulation was evaluated through a series of tests to assess its suitability and compliance with quality standards. The key parameters analyzed included nutrient content (total nitrogen, phosphorus as P_2O_5, and potassium as K_2O), heavy metal concentrations (such as Pb, Cd, Cr) to ensure safety within regulatory limits, and the solubility and stability of the final product to determine usability. The test results were compared against the Indonesian National Standard (SNI 2803:2020) and other relevant international guidelines for fertilizer quality.

2.4 Data Analysis

Data analysis was conducted to evaluate the utilizing hazardous waste sludge as a substitute for supporting raw materials in fertilizer manufacturing. First, the chemical characterization results of the dried sludge were analyzed, focusing on macro-nutrient content (N, P_2O_5, K_2O) and heavy metal concentrations to assess its potential as a nutrient source and its compliance with safety standards. The characterization of the filler materials was also assessed to determine their compatibility with the sludge in terms of physical and chemical properties [5].

Based on the nutrient content, each formulation's performance was compared to identify the most suitable sludge-to-filler ratio. The formulation that exhibited the best balance between nutrient availability, safety (within regulatory limits), and physical stability was considered the optimal composition. Additionally, a simple economic analysis was conducted to compare the cost-effectiveness of using sludge-based formulations versus conventional raw materials, taking into account material availability, potential treatment costs, and production efficiency [6].

3. Results and Discussion

3.1 Total Solid Waste Production

This section begins with an analysis of the total waste production from January to April 2025, which consists of three types of waste: solid, liquid and gas. Based on the data obtained, solid waste has a total production of:

Data source : Department Enviro & K3 PT Petrokimia Gresik
Periode : January – April 2025

Table 1. Identification type and quantity of waste generated by WWTP facility

No	Type of waste	Jan-25	Feb-25	Mar-25	Apr-25	Total (ton)	Average (ton/month)
1	**Solid**	**19**	**18**	**20**	**728**	**785**	**196**
2	Liquid	48	33	40	25	16	36
3	Gas	10	9	11	9	39	10
	Total	78	59	70	762	969	242

Based on the data above, the type of waste generated in the largest amount is solid waste, so the cluster determines the main priority of solid waste management issues.

From the average solid waste generated of 196 tons/month, the accumulated amount of solid waste sent to disposal is as follows:
Data source : Dep Enviro & K3 PT Petrokimia Gresik
Periode : January – April 2025

Table 2. Accumulated amount of solid waste sent to the third parties

Solid waste		Jan-25	Feb-25	Mar-25	Apr-25	Total (ton)	Average (ton/bulan)
1.A	**WWTP Sludge**	**0**	**100**	**210**	**400**	**710**	**178**
1.B	Sludge Cushion Pond	18	17	19	17	70	17
1.C	Celaning area	2	1	1	1	5	1
	Total	19	18	20	728	785	196

The waste data above shows that the most abundant solid waste is WWTP Sludge at an average of 178 tons/month. This shows that **WWTP Sludge** is the main focus in the management and potential re-utilization of solid waste in the company.

3.2 Sludge Characterization
3.2.1 Moisture Content Test

A total of 10 grams of dry WWTP Sludge was taken as a sample for the drying process. This sample was then put into a previously weighed empty porcelain dish, recording the initial mass of the porcelain dish as W_0. After that, the initial weighing was carried out to obtain the total mass of the porcelain dish along with the sludge, which was recorded as W_1.

Next, the porcelain dish containing the sludge was placed in an oven at 105°C. The drying process was carried out in stages, each for ±1 hour, and repeated up to four times (±4 hours in total), or until the weight obtained did not change significantly, indicating that a constant mass condition had been reached. Moisture content is calculated using the formula:

$$\frac{W_1 - W_2}{W_1 - W_0} \tag{1}$$

Where :
- W_0 = Weight of empty porcelain dish
- W_1 = Weight of porcelain + sludge before oven
- W_2 = Weight of porcelain + sludge after oven

a. Test result 1

$$\frac{60\text{ g} - 59.75\text{ g}}{60\text{ g} - 50\text{ g}} \text{ x } 100 = 2.5\ \%$$

b. Test result 2

$$\frac{60\text{ g} - 59.70\text{ g}}{60\text{ g} - 50\text{ g}} \text{ x } 100 = 3.0\ \%$$

$$\text{Average} = \frac{2.5 - 3.0}{2} \text{ x } 100 = 2.75\ \%$$

Based on the results of testing the moisture content of the dewatered sludge, an average moisture content value of 2.75% was obtained. This value shows that the tested sludge has a very low moisture content, indicating that the dewatering process has run effectively and optimally. With a moisture content of 2.75%, this sludge has met SNI 2803: 2024 as one of the raw materials for making fertilizer.

3.2.2 Sludge Characterization Test
3.2.2.1 Nitrogen Content Test

Total nitrogen content was determined using the Kjeldahl method, as much as 800 grams of sludge was put into a deconstruction tube, then 10 mL of H_2SO_4 was added and heated until the solution became clear. After cooling using a fan, the solution was transferred to a Vapodest device for the distillation process. Ammonia from distillation is collected with borax solution, then the distillate is titrated using 0.5 N H_2SO_4 to determine nitrogen levels [4]. The percentage of nitrogen content test results can be calculated using the following formula:

$$\frac{(V_{H2SO4} - V_{blank})\ x\ N_{H2SO4}\ x\ 14}{sample\ (g)}\ x\ 100 \quad (2)$$

Where :
- V_{H2SO4} = volume of H_2SO_4 titrant used for the sample (mL)
- V_{blank} = volume of H_2SO_4 titrant for blank (mL)
- N_{H2SO4} = normality of sulfuric acid (N)
- 14 = atomic weight of nitrogen (g/mol)
- Sample weight = weight of sludge tested (in grams)

a. Test result 1

$$\frac{(1.68\ mL - 0.4)\ x\ 0.5\ N\ x\ 14\ g/mol}{800\ gr}\ x\ 100 = 1.12\%$$

b. Test result 2

$$\frac{(1.74\ mL - 0.4)\ x\ 0.5\ N\ x\ 14\ g/mol}{800\ gr}\ x\ 100 = 1.17\%$$

$$\text{Average} = \frac{1.12\% - 1.17\%}{2}\ x\ 100 = 1.14\ \%$$

From the calculations, the nitrogen (N) content in the sludge is still present, around **1.1% - 1.2%.** This means that the sludge does contain measurable nitrogen and is not zero.

3.2.2.2 Phosphorus Content Test

Analysis of phosphorus levels in sludge samples was carried out using the spectrophotometric method with molybdate reagent. A total of 1 gram of sludge was weighed and put into a beaker, then HNO_3 solution was added to dissolve the phosphorus contained in the sample. The solution was left for 15 minutes at room temperature so that the dissolution process runs optimally [4]. After that, the solution was diluted using distilled water until it reached a volume of 100 mL to obtain a homogeneous solution. Then, molybdate reagent was added to the solution and stirred evenly using a fast mixer for 2 minutes to accelerate the formation of a colored phosphomolybdate complex. The solution was then cooled using a fan to stabilize the color of the reaction [4].

Measurements were taken using a spectrophotometer at a specific wavelength, and the absorbance values obtained were compared with a phosphorus standard curve to determine the concentration of phosphorus in the solution. Phosphorus content in sludge was calculated based on the concentration in the extracted solution and converted to the initial sample weight (mg/g) [4]. The percentage of phosphorus content test results can be calculated using the formula:

$$\frac{C\ x\ P}{W} x100 \quad (3)$$

Where :
- C = mg P2O5 from standard curve (mg/L)
- P = volume of solution after dilution extraction (L)
- W = sample weight (g)

a. Test result 1

$$P = \frac{46.29\ \text{mg/L x } 100\ \text{mL}}{1\ \text{gr}}\ \text{x } 100 = 0.469\%$$

P2O5 = 0.469% x 2.29 = 1.06%

b. Test result 2

$$P = \frac{44.98\ \text{mg/L x } 100\ \text{mL}}{1\ \text{gr}}\ \text{x } 100 = 0.4498\%$$

P2O5 = 0.4498% x 2.29 = 1.03%

$$\text{Average} = \frac{1.06 - 1.03}{2}\ \text{x } 100 = 1.05\%$$

From the test results and calculations, the P_2O_5 content is around **1.05%**, meaning that there is still a significant phosphorus content in the sludge sample.

3.2.2.3 Potassium Content Test

1 gram sample was weighed and put into a 100 mL glass breaker. Then, 10 mL of perchloric acid and 6 mL of nitric acid were added, then heated until white smoke appeared for 5 minutes to dissolve the potassium element. After cooling, the solution was transferred to a 500 mL volumetric flask and diluted with demineralized water to the mark, then shaken until homogeneous [4].

The solution was filtered using ash-free filter paper and a number of sample solutions were taken as needed to a 100 mL volumetric flask. Added 5 mL of suppressor solution to eliminate interference and diluted again to the line mark. Potassium concentration in the solution was measured using Atomic Absorption Spectrophotometer (SSA) or Flame Photometer. Dilution was done twice to ensure the concentration was within the range of the device. The potassium oxide (K_2O) content in the sample is

Jurnal Serambi Engineering JSE
Volume X, No.4, Oktober 2025 Hal 15886 - 15897
p-ISSN : 2528-3561
e-ISSN : 2541-1934

calculated by taking into account the measured potassium concentration, dilution factor, sample weight, moisture content, and conversion factor from potassium-to-potassium oxide [4]. The percentage of potassium test results can be calculated using the following formula:

$$\frac{C \; x \; P \; x \; 1.2046}{W} x100 \qquad (4)$$

Where :
- C = Potassium concentration (mg/L) from spectrophotometer reading
- P = Final volume of solution after extraction or dilution (in mL or L, depending on context)
- 1.2046= Conversion factor from Potassium (K) to Potassium Oxide (K_2O)
- W = Sample weight (in grams)
- 100 = Conversion to percent (%)

a. Test result 1

$$\frac{8.3 \text{ mg/L x } 100 \text{ mL x } 1.2046}{1 \text{ gr}} \text{ x } 100 = 0.1 \%$$

b. Test result 2

$$\frac{7.47 \text{ mg/L x } 100 \text{ mL x } 1.2046}{1 \text{ gr}} \text{ x } 100 = 0.09 \%$$

$$\text{Average} = \frac{0.1 - 0.09}{2} \text{ x } 100 = 0.95\% \approx 0.1 \%$$

Average K_2O content ≈ **0.1%** → Potassium element is still present and significantly detected.

Based on the results of laboratory analysis, the sludge tested still contains the main nutrients of Nitrogen (N), Phosphorus (P), and Potassium (K). The detected Nitrogen levels indicate the presence of nitrogen content although in relatively small amounts. Phosphorus was measured in the form of P_2O_5 with levels of just over 1%, while Potassium, converted to K_2O, was in the range of 0.1%.

3.3 Formulation of NPK Fertilizer in PT Petrokimia Gresik

Table 3. Data Production Formula T/T Pabrik NPK PT Petrokimia Gresik

FORMULA NPK FERTILIZER						
Seting formulation NPK (+)			N	P	K	Mg
			15,00%	15,00%	15,00%	0,00%
Materials	Component		Consumption	%	Set Rate	
	Substance	%	T/T		10	100
UREA	N	46,0%	**0,2616**	26,16%	0,2616	26,16
Phospate Rock	P2O5	30,0%	**0,2473**	24,73%	0,2473	24,73
ZA	N	21,0%	**0,1648**	16,48%	0,1648	16,48
KCL	K2O	60%	**0,2500**	25,00%	0,2500	25,00
Filler	Clay	-	**0,0762**	7,62%	0,0762	7,62
	WWTP Sludge	0	**0**	0	0	0

The data above is the NPK fertilizer formula commonly used by PT Petrokimia Gresik. The target of this research is tried to use as much as possible replace filler materials with WWTP sludge. Sludge and filler will be mixed with the following percentage:

Table 4. Experimental mixture presentage

Mixture	1	2	3	4	5	6	7	8	9	Percentage
WWTP Sludge	90	80	70	60	50	40	30	20	10	(%)
Filler	10	20	30	40	50	60	70	80	90	(%)

The composition of the WWTP sludge and filler mixture was selected gradually from 90:10 to 10:90 to ensure a clear and structured. This approach facilitates statistical analysis, enables the identification of consistent relationship patterns, and helps to find the optimal composition. Random or irregular composition selection can complicate the interpretation of results, obscure trends, and reduce the likelihood of obtaining representative and scientifically valid conclusions.

The mixing test was conducted twice to ensure the consistency of results. This repetition was important to minimize experimental errors, identify variations that might occur during the mixing process, and improve the reliability of the data obtained before further characterization.

1. Application test of mixture material no. 1 (90% WWTP Sludge with 10% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 5. Mixture 90% sludge and 10% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,2	1,03	1,11
Nitrogen	(adbk) %	**13,8-16,2**	15,11	15,02	15,06
P_2O_5	(adbk) %	**13,8-16,2**	15,1	16,2	15,65
K_2O	(adbk) %	**13,8-16,2**	16,9	15,30	16,1
MgO	(adbk) %	**-**	6,7	6,63	6,65
Mesh -4+10	%	**Min. 80**	84,50	87,50	86
Mesh +4	%	**-**	12,20	11,20	11,7
Homogenitas	%	**Min. 90**	**65**	**60**	**62,5**
Granule condition	% Humidity	**Max. 60**	**80**	**82**	**81**
Barriers	Frequently	**Max. 1**	**3**	**5**	**4**

2. Application test of mixture material no. 2 (80% WWTP Sludge with 20% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 6. Mixture 80% sludge and 20% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,10	1,27	1,18
Nitrogen	(adbk) %	**13,8-16,2**	14,30	15,77	15,03
P_2O_5	(adbk) %	**13,8-16,2**	14,40	14,77	14,58
K_2O	(adbk) %	**13,8-16,2**	15,40	14,47	14,93
MgO	(adbk) %	**-**	6,80	5,17	5,9
Mesh -4+10	%	**Min. 80**	88,40	84,68	86,54
Mesh +4	%	**-**	11,10	11,00	11,05
Homogenitas	%	**Min. 90**	**85**	**70**	**77,7**
Granule condition	% Humidity	**Max. 60**	**70**	**72**	**71**
Barriers	Frequently	**Max. 1**	**2**	**2**	**2**

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3. Test application of mixture material no. 3 (70% WWTP Sludge with 30% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 7. Mixture 70% sludge and 30% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,10	1,04	1,07
Nitrogen	(adbk) %	**13,8-16,2**	15,86	14,42	15,14
P_2O_5	(adbk) %	**13,8-16,2**	16,18	16,08	16,13
K_2O	(adbk) %	**13,8-16,2**	14,14	16,04	15,09
MgO	(adbk) %	-	6,00	2,44	4,22
Mesh -4+10	%	**Min. 80**	85.80	86.60	86,2
Mesh +4	%	-	12,10	13,20	12,65
Homogenitas	%	**Min. 90**	**80**	**85**	**82,5**
Granul condition	% Humidity	**Max. 60**	**65**	55	60
Barriers	Frequently	**Max. 1**	**1**	0	0,5

4. Test application of mixture material no. 4 (60% WWTP Sludge with 40% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 8. Mixture 60% sludge and 40% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,28	1,06	1,17
Nitrogen	(adbk) %	**13,8-16,2**	15,46	15,48	15,47
P_2O_5	(adbk) %	**13,8-16,2**	14,18	14,58	14,38
K_2O	(adbk) %	**13,8-16,2**	15,78	15,46	15,62
MgO	(adbk) %	-	2,57	3,26	2,91
Mesh -4+10	%	**Min. 80**	87,20	96.40	91,8
Mesh +4	%	-	8,10	3,20	5,65
Homogenitas	%	**Min. 90**	90	95	92,5
Granule condition	% Humidity	**Max. 60**	55	60	57,5
Barriers	Frequently	**Max. 1**	0	0	0

5. Application test of mixture material no. 5 (50% WWTP Sludge with 50% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 9. Mixture 50% sludge and 50% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Maxs. 3**	0,77	0,73	0,77
Nitrogen	(adbk) %	**13,8-16,2**	15,23	15,15	15,19
P_2O_5	(adbk) %	**13,8-16,2**	14,72	14,62	14,67
K_2O	(adbk) %	**13,8-16,2**	15,98	16,03	16,0
MgO	(adbk) %	**-**	1,37	3,38	2,37
Mesh -4+10	%	**Min. 80**	98,02	94,50	96,26
Mesh +4	%	**-**	0,20	1,50	0,85
Homogenitas	%	**Min. 90**	92	95	93,5
Granule condition	% Humidity	**Max. 60**	55	42	48,5
Barriers	Frequently	**Max. 1**	0	0	0

6. Application test of mixture material no. 6 (40% WWTP Sludge with 60% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 10. Mixture 40% sludge and 60% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,30	1,38	1,34
Nitrogen	(adbk) %	**13,8-16,2**	15,23	15,17	15,2
P_2O_5	(adbk) %	**13,8-16,2**	15,67	16,20	15,9
K_2O	(adbk) %	**13,8-16,2**	15,25	14,80	15,02
MgO	(adbk) %	**-**	4,98	2,77	3,87
Mesh -4+10	%	**Min. 80**	97,60	97,10	97,35
Mesh +4	%	-	3,00	2,80	2,9
Homogenitas	%	**Min. 90**	95	95	95
Granule condition	% Humidity	**Max. 60**	55	40	47,5
Barriers	Frequently	**Max. 1**	0	0	0

7. Application test of mixture material no. 7 (30% WWTP Sludge with 70% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows:

Table 11. Mixture 30% sludge and 70% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,10	1,43	1,2
Nitrogen	(adbk) %	**13,8-16,2**	14,07	15,17	14,62
P_2O_5	(adbk) %	**13,8-16,2**	14,83	14,95	14,89
K_2O	(adbk) %	**13,8-16,2**	14,07	15,90	14,9

Parameter	Unit	Standard	Result		
			1	2	avg
MgO	(adbk) %	**-**	3,89	1,52	2,7
Mesh -4+10	%	**Min. 80**	95,38	96,20	95,79
Mesh +4	%	**-**	2,20	1,00	1,6
Homogenitas	%	**Min. 90**	95	90	92,5
Granule condition	% Humidity	**Max. 60**	55	50	52,5
Barriers	Frequently	**Max. 1**	0	0	0

8. Application test of mixture material no. 8 (20% WWTP Sludge and 80% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows :

Table 12. Mixture 20% sludge and 80% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,22	1,20	1,21
Nitrogen	(adbk) %	**13,8-16,2**	15,00	15,40	15,2
P_2O_5	(adbk) %	**13,8-16,2**	15,50	16,20	15,85
K_2O	(adbk) %	**13,8-16,2**	15,23	15,70	15,46
MgO	(adbk) %	**-**	2,78	8,40	5,59
Mesh -4+10	%	**Min. 80**	96,23	94,60	95,41
Mesh +4	%	**-**	0,70	0,80	0,75
Homogenitas	%	**Min. 90**	98	95	96,5
Granule condition	% Humidity	**Max. 60**	55	55	55
Barriers	Frequently	**Max. 1**	0	0	0

9. Application test of mixture material no. 9 (10% WWTP Sludge and 90% clay material). Application test of mixed materials as filler material in the production process of NPK fertilizer formula 15-15-15. The observation results of the filler material application test are as follows :

Table 13. Mixture 10% sludge and 90% filler

Parameter	Unit	Standard	Result		
			1	2	avg
H_2O	(adbk) %	**Max. 3**	1,25	1,38	1,31
Nitrogen	(adbk) %	**13,8-16,2**	15,63	15,83	15,73
P_2O_5	(adbk) %	**13,8-16,2**	15,43	16,20	15,81
K_2O	(adbk) %	**13,8-16,2**	15,05	16,12	15,58
MgO	(adbk) %	**-**	3,95	3,33	3,64
Mesh -4+10	%	**Min. 80**	95,65	95,80	95,72
Mesh +4		**-**	1,08	2,42	1,75
Homogenitas	%	**Min. 90**	95	95	95
Granule condition	% Humidity	**Max. 60**	55	60	57,5
Barriers	Frequently	**Max. 1**	0	0	0

3.4 Evaluation of Monitoring Results of WWTP Sludge Utilization Application Test

The most optimal application of WWTP Sludge utilization is mixture number 4, namely the ratio between WWTP Sludge 60% and clay 40%, because it can utilize the most WWTP Sludge, good granulation homogeneity, good granule condition, no barriers and from the on size fertilizer grain size above 80% and the results of product analysis meet the specifications according to SNI Solid NPK Fertilizer 2803: 2024.

The calculation of filler material consumption in the NPK fertilizer formula is 0.0763 tons/ton of product, while the most optimal utilization of WWTP Sludge in the mixture is 60% of the total filler material consumption. So, the use of WWTP Sludge material is 0.0457 tons/ton of product.

Calculation and Evaluation of the utilization of WWTP Sludge as a filler material for NPK fertilizer is:

Calculation of filler material consumption	: 0.0744 tons/ton of product
Filler requirements	: 648 tons/month
Total sludge production	: 178 tons/month

With the need for filler is 648 tons/month, and WWTP sludge that can be utilized is entirely 178 tons/month, then the sludge in WWTP is used up 100%.

4. Conclusion

Strategic preparation made up of five aspects such as legal foundation, institutional, funding, community participation, and operational technique has the ability to significantly reduce household waste. Therefore, it is recommended that they are applied simultaneously due to their interrelation. This is because if only a few aspects are applied, there will only be a very low chance of achieving significant waste reduction. Moreover, none of them enjoys special priority, since the implementation is often adjusted by the conditions of municipal household waste. However, it is important for the city to provide waste infrastructure and facilities prior to implementing these five aspects, especially in order to achieve the target of 30% waste reduction by 2025. Notably, the biggest waste reduction was observed to be in the TPS3R and the 3R Community Center.

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