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Article

Performance evaluation of dewatering systems for bio-digestate for developing countries

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Abstract: The performance evaluation of a screw type dewatering system for bio-digestate in Nepal demonstrates significant potential for improving the usability and efficiency of bio-digestate as a fertilizer. Remarkable modifications in the previous include a 5 HP motor running at 1440 RPM with a gear reduction ratio of 1:40, a spring assembly system at the outlet, and a fine sieve. Testing and performance analysis at different operating speeds using a variable frequency drive revealed an optimal performance at 8 RPM, where the system achieved a liquid yield of 92.02% and an extraction efficiency of 73.12%. The installation cost of the machine was NPR 384,000, with a payback period of 2 years, six months, and two days. The internal rate of return (IRR) was calculated at 28.53%, while the net present value (NPV) was NPR 179,006.35. This study indicates that operating the dewatering system at lower speeds may improve efficiency and effectiveness in the dewatering process. This makes the machine a viable option for producing organic fertilizer and addressing Nepal's significant need for fertilizer.

Keywords: screw type dewatering system; bio-digestate; performance evaluation; liquid yield; extraction efficiency

1. Introduction

Anaerobic digestion of organic waste results in the production of biogas. Anaerobic digestion is the treatment method in which the waste with high organic content is breakdown to produce biogas [1]. The biogas plants are based on the phenomenon of biological decomposition of organic materials in the absence of air. For biogas production, main inputs are manure and sew bio digestate from biogas plants, a nutrient-dense residue, often requires dewatering to enhance its usability as a fertilizer by reducing moisture content. This process ensures improved handling, transportation, and effective application in agricultural practices. The slurry from biogas plants, rich in moisture content, poses challenges in handling, management, and transportation. In this research, a SolidWorks-designed screw-type dewatering system is employed to extract liquid from the slurry, making it viable for commercial use. Testing and performance analysis are conducted at different operating speeds using a variable frequency drive. The evaluation indicates a production capacity of 79.9 kg/h for the dewatering system, with liquid yield, extraction efficiency, and extraction loss at 92.02%, 73.12%, and 27.60%, respectively age, straw, households and industrial organic waste, maize and grass silage. The byproduct of the biogas plant is called slurry which can be used as a high nutrient fertilizer [2]. Biogas slurry has high water content of almost 90%, which arises the concern of dewatering and drying before using in agriculture.

According to WECS 2021, Nepal has built 433,173 small-scale and 343 large-scale biogas plants across the nation [3]. The Terai region of Nepal has the largest share of 51.99% of the installed domestic biogas plant and Bagmati province has the highest installed share of 25.88%. The fifteen periodic plans of the Government of Nepal have targeted to install further 200,000 domestic biogas plants and 500 large size biogas plant [4]. These biogas systems have the potential to generate a significant amount of nutrient-rich slurry. The valuable nutrients in the slurry can greatly benefit crop growth without harming the environment [5]. Moreover, using slurry can reduce the need for costly imported fertilizers, contributing to the profitability of the agricultural sector. By incorporating slurry into farming practices, biogas technology becomes a sustainable source of rural energy. This not only saves traditional fuel resources but also decreases the reliance on chemical fertilizers, thereby having a positive impact on agriculture.

The application of biogas slurry as a fertilizer offers significant environmental benefits, particularly in reducing greenhouse gas emissions. By capturing methane during the anaerobic digestion process and converting it to biogas, the potential release of methane—a potent greenhouse gas—is significantly reduced. Additionally, biogas slurry reduces dependence on synthetic fertilizers, which are energy-intensive to produce and often result in the emission of nitrous oxide, another potent greenhouse gas. The organic matter in biogas slurry can also enhance soil carbon sequestration, further reducing atmospheric carbon dioxide levels. Beyond mitigating greenhouse gas emissions, biogas slurry improves soil health due to its rich content of essential nutrients such as nitrogen, phosphorus, and potassium, which are vital for crop growth. Its application enhances soil fertility, leading to better crop yields. The organic matter in the slurry improves soil structure, increasing its water retention capacity and reducing erosion. Moreover, the addition of organic material from the slurry stimulates microbial activity in the soil, promoting nutrient cycling and overall soil health.

Furthermore, using biogas slurry as a fertilizer can significantly reduce water pollution caused by runoff from synthetic fertilizers. The organic nature of the slurry ensures a slower release of nutrients, reducing the risk of nutrient leaching into water bodies and preventing eutrophication. This combination of environmental benefits makes biogas slurry an effective and sustainable alternative to synthetic fertilizers, supporting both agricultural productivity and environmental conservation [6].

Dewatering is the treatment process to reduce the moisture content in the slurry output [7]. Dewatered slurry can be handled as. a solid material, rather than as a liquid material, and hence can be easily transported, stored, managed and used. Among various dewatering technologies such as centrifugal press, belt filter, screw press dewatering technology is widely used for high and low concentration sludge. The dewatering technology separates the moisture content in the slurry and hence improves the utilization of the bio slurry along with making it commercially viable as the organic fertilizer. The advantages of dewatering of the slurry are: dewatering decreases the volume, lowers the storage and the transportation cost; produces a material which helps in composting; and removes ponding and runoff [8].

The slurry generated from biogas plants poses a formidable challenge due to its inherently high moisture content, complicating its handling, management, and transportation. The current limitations in dewatering technology constrain the utilization of slurry to the immediate vicinity of the biogas plant, contributing to a degradation in its overall quality even within this constrained scope. Notably, the absence of efficient dewatering methods necessitates resorting to traditional approaches, characterized by prolonged processing times and a demand for substantial storage space. Consequently, these drawbacks render the slurry impractical for commercial applications, underscoring the pressing need for advancements in dewatering technologies to enhance the viability and utility of biogas plant by-products. The aim of this research is to conduct performance evaluation of screw type dewatering system for bio-digestate.

Limitations

The study focuses on dewatering and slurry obtained from anaerobic digestion of organic waste. It does not consider the effect and segregation of inorganic waste like plastics, glass etc. in the biogas digester.

2. Literature review

2.1. Biogas slurry

Biogas slurry, the byproduct of anaerobic digestion in a biogas plant, is a nutrient-rich organic fertilizer with around 93% water and 7% dry matter. The dry matter consists of 4.5% organic and 2.5% inorganic content [9]. It contains phosphorus, potassium, zinc, iron, manganese, copper, 1.6% nitrogen,1.55% phosphorous, and 1.00% potassium [10]. When combined with organic fertilizers, the slurry enhances the carbon/nitrogen ratio, resulting in increased yields of cotton, wheat, maize, and rice by 6.5%, 8.9%, 15.2%, and 15.9%, respectively [9]. Biogas slurry serves as an environmentally safe organic fertilizer, producing macro and micro nutrients while having lower levels of heavy metals compared to synthetic fertilizers. It can reduce chemical fertilizer use by 15% to 25%, promoting bio-pesticide activities, beneficial microbe growth, biochemical levels in plants, and maintaining soil physio-chemical properties, ultimately improving plant health.

2.2. Dewatering technology

Dewatering technology is essential for enhancing the utility and commercial viability of bio slurry as organic fertilizer. By effectively reducing moisture content, it significantly decreases the volume of the slurry, leading to lowered storage and transportation costs. This process also facilitates composting, contributing to the organic fertilizer's effectiveness. Additionally, dewatering eliminates ponding and runoff issues, creating a more sustainable approach. It optimizes the air-drying process, ensuring the bio slurry achieves an ideal consistency for efficient utilization as organic fertilizer. These advantages highlight the importance of incorporating dewatering technology into our processes, aligning with our commitment to cost-effectiveness, environmental sustainability, and optimized resource utilization.

2.3. Types of dewatering technology [11]

Dewatering methods for slurry can be categorized into natural and mechanical approaches, each offering unique advantages. Natural dewatering relies on gravity settling and porous surfaces, as seen in sludge drying beds where liquid evaporates gradually. Mechanical dehydration, on the other hand, uses machinery and processes to remove moisture efficiently. This includes the use of centrifugal presses, which employ centrifugal force to separate moisture from the slurry, enhancing the drying process. Belt filter presses utilize continuous filtration with a belt, effectively removing moisture from the slurry. Rotary drum filters leverage rotation to separate moisture, setting the stage for subsequent drying processes. These methods improve the dewatering efficiency of slurry, leading to better drying outcomes and increased utility as organic fertilizer. **Table 1** shows the comparison of six different types of dewatering system based on various criteria.

Table 1. Comparison of different types of dewatering system [12].

Type	Cake dryness	Solid recovery	Process/drying time	Operating cost	Capital cost	Chemical
	% solid	% solid capture	Time (measurement)			Usage
Vacuum filters	16–45	85–95	Fast (minutes or hours)	High	Moderate	Moderate
Filter presses	40–60	80–95	Very fast (minutes or months)	High	High	High
Centrifugal press	20–35	85–90	Fast (minutes or hour)	Moderate	Low	High
Drying beds	25–60	90–100	Slow (weeks or months)	Very low	Low	Low
Sludge lagoons	20–40	90–100	Very slow (months or years)	None	Very low	None
Gravity/low pressure	10–50	90–96	Moderate (days or weeks)	Low	Moderate	

2.4. Selection of dewatering technology

The characteristics of the dewatering technology vary according to different attributes such as cake dryness, solid recovery, drying time, operating cost, maintenance required, and so on. The comparison of different dewatering technologies is mentioned in. **Figure 1** shows the comparison of various artificial technologies on the basis of total solid content.

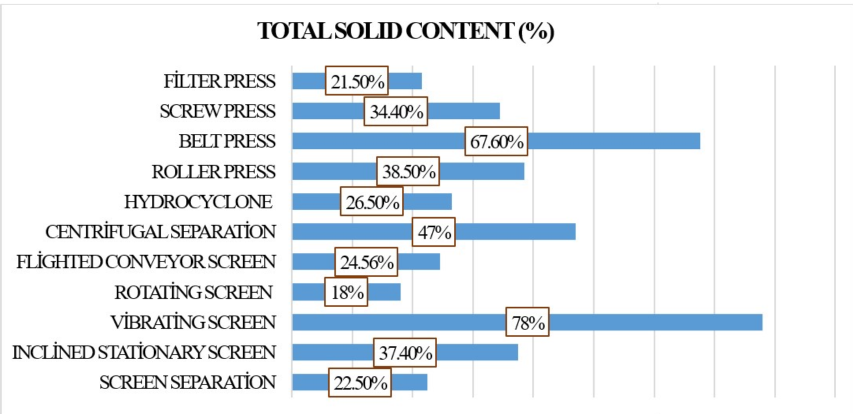


Figure 1. Comparison of different dewatering technologies.

Screw presses are adept at effective dewatering, making them suitable for a variety of production processes where the separation of particles from liquids is crucial [13]. These dewatering devices consume less energy compared to alternative types, resulting in reduced overall operating costs over their lifespan [14]. Screw press technology is advantageous for sludge dewatering in comparison with others for the following reasons**.** Recent advancements in screw press technology have significantly improved efficiency, surpassing their earlier counterparts. These modern screw presses excel in the dewatering of sludge with elevated solids content, leading to the formation of a more concentrated sludge cake and a substantial volume reduction. This heightened efficiency directly translates into cost savings for wastewater treatment plants. Moreover, the operational expenses associated with screw press technology are notably reduced compared to centrifuges, as it requires less energy and produces minimal noise and vibration. This diminished operational impact reduces the need for additional measures such as soundproofing and vibration isolation. Notably, screw presses can achieve higher solids content in dewatered sludge compared to centrifuges, resulting in a more concentrated sludge cake and a decreased volume of waste for disposal. Furthermore, the lower number of moving parts in screw presses translates to lower maintenance requirements compared to centrifuges [15].

Table 2 shows the performed structural and computational fluid dynamics simulation for different type of screws for screw press technology.

Table 2. Comparison of different types of screw.

Types of screw and shaft	Deformation (mm)	Equivalent stress (MPa)		Equivalent strain (mm/mm)	
	Max	Max	Min	Max	Min
Constant pitch screw with straight shaft	0.2129	46.19	0.0046493	0.00024385	3.6288×10^{-8}
Variable pitch screw with straight shaft	0.21344	45.035	0.0083044	0.00022607	7.1824×10^{-8}
Constant pitch screw with tapered shaft	0.17151	43.941	0.0259	0.00022244	4.1637×10^{-7}
Variable pitch screw with tapered shaft	0.17116	46.285	0.048465	0.00023649	3.1202×10^{-7}

According to the findings, the constant pitch screw with the tapered shaft shows the least amount of distortion, indicating that it has better structural integrity overall.

3. Materials and methodology

A comprehensive and well-structured methodology was developed, covering all essential steps for the study. The research commenced with a review of existing literature and assessments, followed by the design and modeling of the technology. The detailed sequence of the methodology is depicted with a **Figure 2**.

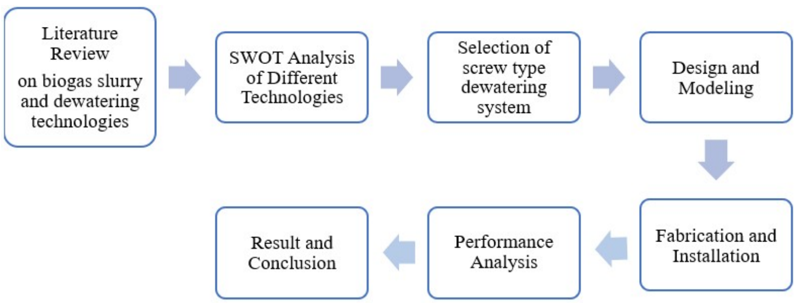


Figure 2. Methodological flowchart.

3.1. Design and modeling

Detail design and drawing of dewatering technology considering the size of the biogas plant, byproduct of the biogas plant, waste input in the biogas plant, proportion of organic waste, etc. was done in this phase. The drawing of plant layout and schematic drawing indicating different parts of the dewatering system and their specifications was developed in this phase. The rough specification for the dewatering technology for the biogas plant is indicated in **Table 3**.

Table 3. Rough specification for the dewatering system.

S.N.	Parameter	Specification
1	Name	Dewatering system
2	Application	Organic waste dewatering work
3	Feed capacity	0.5 to 1 ton/day
5	Mechanism	Belt filter press rotary drum filter, screw press
6	Electric motor	Chopper: 2 kW, squeezer: 5kW
7	Chopper type	Multi blade/double screw
8	Squeezer type	Single conical
9	Screen type	Perforated
10	Screen size	2 mm
11	Material used	Mild steel

The screw-type dewatering system was designed using SolidWorks, employing its advanced features for precise modeling. This facilitated the creation of a detailed and optimized representation of the machine's structure as shown in **Table 4**.

After the assembly simulation was performed to test the performance and reliability of the system in different load and performance conditions.

The **Figure 3** is the conceptual design of the dewatering system that was designed in SolidWorks software and **Figure 4** shows the detailed design of the system.

Table 4. Modelling of parts.

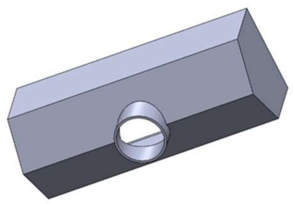
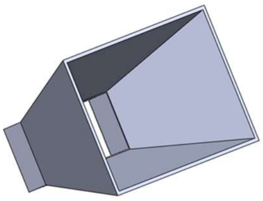
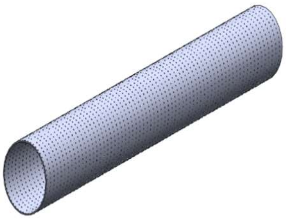
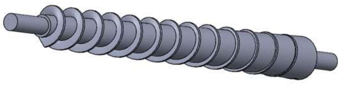
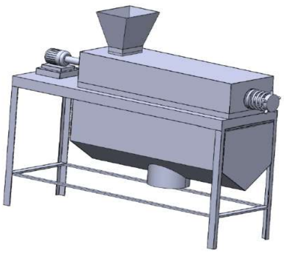
Modeled part	Description
	**Collector** After the water has been sorted from the solids that have been dried, it is collected by a collector. It guarantees effective drainage and makes water removal easier. Design and placement of the collector are essential for efficient water and output products management.

Table 4. (*Continued*).

Modeled part	Description
	**Hopper** A hopper is where material that is fed into a machine. Upon entering the hopper, the material is directed toward the machine's screw. It is an essential component since it makes loading efficient.
	**Sieve** A sieve or screen is used to separate the particles from the liquids during the dewatering stage of a screw press machine. With the help of a wire mesh, the sieve is designed to capture solid particles while allowing water to pass through it. The design of the model is presented here in the figure.
	**Frame** The frame of a screw press machine provides a sturdy structure to hold the numerous components of the machine and withstand the stresses generated during use. The frame is typically built out of steel or other robust materials that are strong, resilient, and deformation-resistant.
	**Screw** A screw featuring a constant pitch and a gradually tapering shaft ensures uniform thread spacing. With the capacity to handle fluctuating flow rates and efficiently transport materials from one end to the other, this design enhances the conveyance of materials.
	**Assembled final model** Figure here shows the final model with all the individual components assembled into a single and complete model. It mainly represents the visual form of real machine used as dewatering system.

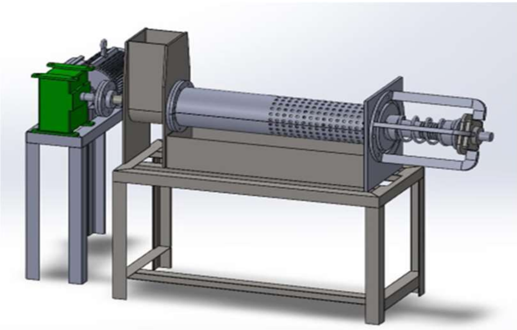


Figure 3. Conceptual model of the system.

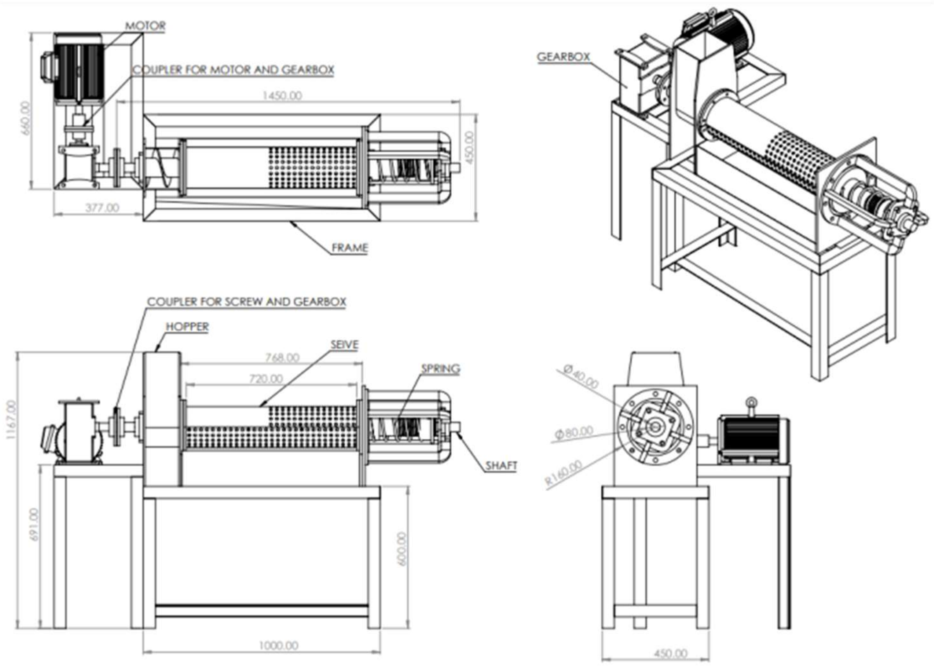


Figure 4. Detailed design of the system.

Table 5 shows the detailed design and formula for designing the system.

Table 5. Detailed design.

Power requirement	
To Overcome the inertia of shaft and screw	• The volume of hollow tapered cylinder section; volume, $V = \pi r^2 l$ • The net volume of flight $V_{\text{net}} = \text{volume of flights} - \text{Volume of hollow shaft}$ • Power to overcome this mass = Weight × Mean Peripheral velocity (v_m) • $v_m = T_m \times N/60$ where, T_m is the mean lead of the screw, and N is the rpm of the screw.
Convey the biogas effluent slurry	• capacity of the screw press is $Q\left(\frac{kg}{hr}\right) = 15\pi d^2 t_m N \psi \rho_{S1} c$ [16] D = screw diameter (160 mm) t_m = screw lead (69 mm) N = rotational speed (10 rpm) c = correction factor based on the angle of inclination (0.7), ψ = filling coefficient of the screw cross section (0.125 for high abrasive materials) ρ_{S1} = density of biogas slurry (1100 kg/m^3) Power required to convey the slurry is $P_2 = \frac{QL\rho_{S1}F_{mt}}{168547}$ [17] where, Q is the conveying capacity L is the projected length of the screw conveyor (0.92 m) F_{mt} is the material factor per Kw.
To press and separate slurry	• Power to separate slurry, $P = FV_m$ where, F = Force required to separate the slurry V_m = Mean velocity F = Pressure × Total surface area $V_m = t_m N/60$ where t_m is pitch of the screw
To overcome friction and other losses	• Frictional force, $F = \mu \times N_{fr} = 0.35 \times 31.0068 \times \cos 30 = 9.3984$ kN Considering other losses as 10% of frictional loss, then $P_4 = 0.10808 \times 1.1 = 0.11888$ kW
Overall power required	• $P = P_1 + P_2 + P_3 + P_4$ $P = 1.13128 hp$

3.1.1. Power required to overcome the inertia of the shaft and screw

The design of the shaft is tapered and it is a hollow shaft. The **Figure 5** is the drawing of the screw with dimensions.

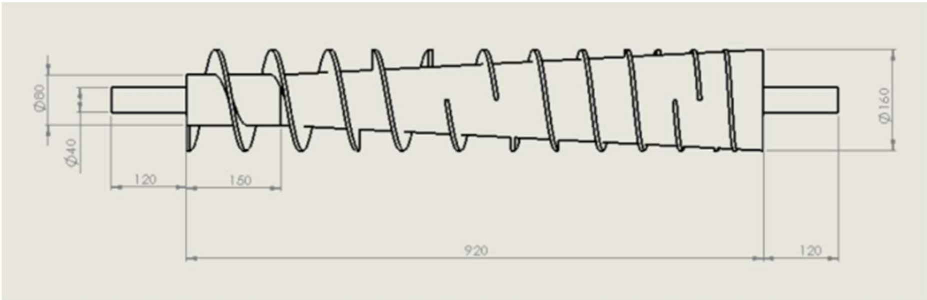


Figure 5. Dimension of screw press.

The assessment outlines the calculations for the mass and power requirements of a hollow tapered shaft within a screw press system. The total volume and mass of the shaft and flights were calculated to assess the system's weight. Combined, they amount to a total mass of approximately 34.526 kg. Using this mass, and accounting for the mean peripheral velocity, the power required to overcome the system's weight was estimated to be about 0.0039 kW. This power requirement is crucial for ensuring the efficient operation of the screw press.

3.1.2. Power required to convey the biogas effluent slurry

The analysis focuses on the power required to convey biogas effluent slurry using a screw press system. The throughput capacity of the screw press is determined by factors such as screw diameter, screw lead, rotational speed, and the density of the biogas slurry. The system's capacity was calculated to be approximately 79.9 kg/h. The power needed to convey the slurry is estimated based on the conveying capacity, the projected length of the screw conveyor, and other factors such as material factor and density. This leads to a calculated power requirement of around 0.29 kW. In summary, the analysis identifies the necessary power to effectively convey the biogas slurry through the screw press system, ensuring efficient operation. The low power requirement demonstrates the system's efficiency in managing the biogas effluent slurry.

3.1.3. Power required to press and separate slurry

The optimum pressure to separate biogas effluent slurry into solid and liquid constituents is approximately 1.74 MPa [18]. The examination focuses on the power required to press and separate biogas effluent slurry using a screw press system. The optimum pressure for separation is around 1.74 MPa, but the analysis uses 60% of the optimum, equating to 0.696 MPa. The force required to separate the slurry is calculated as the product of the compression pressure and the total effective area of 0.04455 m^2, resulting in a total force of approximately 31.01 kN. The mean velocity of the screw press is calculated using the screw pitch and rotational speed, resulting in a mean velocity of 0.0115 m/s. The power required to press and separate the slurry is then calculated as the product of the force and mean velocity, leading to a power requirement of approximately 0.36 kW. This power estimation is crucial for the efficient operation of the screw press in separating biogas effluent slurry into its solid and liquid constituents. Ensuring the system operates within this power range will facilitate the effective separation process and contribute to optimal system performance.

3.1.4. Overall power required

Therefore, the power of the motor shall be greater than 1.13128 hp i.e., 2 horsepower electric motor is considered. The evaluation assesses the power required to overcome friction and other losses in a screw press system. The frictional force is calculated using the friction coefficient, resulting in approximately 9.4 kN. The power needed to overcome this friction is calculated to be 0.10808 kW. Accounting for other losses (10% of frictional loss), the total power required increases to 0.11888 kW. The overall power required for the screw press operation is calculated as the sum of the power required for mass, slurry conveyance, pressing and separating slurry, and frictional losses, totaling 0.7672232 kW (1.02844 hp). Including a 10% additional compensation for safety, the final power requirement is approximately 1.13 hp. Therefore, a motor with a rating of at least 2 horsepower is recommended to ensure efficient and reliable operation of the screw press system.

3.2. Fabrication and installation

Based on the specifications developed, a bill of quantities of goods and accessories was prepared and hence goods available within the country and outside the country were procured by proper channels during this phase. While procuring the goods, the quality of the accessories was checked to verify that they match the specifications developed along with after-sales service of the accessories. **Table 6** shows the list of fabricated components that are used to fabricate dewatering system.

Table 6. List of fabricated components.

S.N.	Fabricated parts/components
1	Screw (Constant pitch, tapered shaft)
2	Sieve and cage
3	Covering
4	Stand/frame
5	Collector
6	Gearbox

The various technologies that were fabricated are dewatering technology as well as coupling system. The fabrication/installation was done with standard processes and procedures in the workshop at the Pulchowk campus, IOE, Nepal as shown in **Figure 6**.

Figure 6. Fabrication of system.

Some of the parts such as motor and pump required for the operation were purchased and integrated to the system. The system as a whole is integrated of different sub systems and components. Each system and component have their own function, so they were fabricated separately and assembled together.

The assembly of these part was carried out to get the fully functioning plant. The fabricated system is connected to a currently operating biogas plant. The outputs of the dewatering system i.e., dry slurry was evaluated. The dewatering technology was rigorously tested for strength and weakness in various parts. The weak part of the system had to be replaced so that the technology can perform reliably and durably throughout its lifetime.

3.3. Performance analysis

First the power requirement for the operation of the plant considering all the forces and inertia that come into play during operation was calculated. This included power required to overcome the inertia of the shaft and screw, power required to convey the biogas effluent slurry, power required to press and separate slurry, power required to overcome friction and other losses and overall power required.

Physical and chemical parameters associated with the dry, wet slurry, and liquid discharge have been evaluated, and based on that the effectiveness of the system has been determined. The various parameters associated with the dewatering plant such as liquid yield, liquid discharge, extraction efficiency, extraction loss, and liquid extracted was evaluated.

4. Results and discussion

The evaluation of the machine was carried out using the expression given below:

$$L_y = \frac{100 \times W_{le}\%}{W_{le} + W_{rw}}$$
$$L_e = \frac{100 \times W_{le}\%}{x\, W_{fs}}$$
$$E_1 = \frac{100 \times \left[W_{fs} - (W_{le} + W_{rw})\%\right]}{W_{fs}}$$

where,

W_{le} = liquid extracted (in kg)

W_{rw} = residual liquid in output cake (in kg)

W_{fs} = feed sample (in kg)

L_y = liquid yield (%)

L_e = extraction efficiency (%)

E_1 = extraction loss (%).

Table 7 shows the result of the test carried out on the dewatering system.

Table 7. Test results.

Test No.	Feed sample W_{fs} (kg)	RPM	Weight of cake W_c (kg)	Liquid extracted W_{le} (kg)	Weight of liquid in cake W_{rw} (kg)
1	10	36	1.82	6.1	1.14
2	10	25	1.76	6.37	0.92
3	10	18	1.61	6.48	0.84
4	10	12	1.38	6.61	0.74
5	10	10	1.25	6.69	0.68
6	10	8	1.12	6.8	0.59

4.1. Performance analysis

From the plant, the performance analysis was done by taking different parameters under consideration. At the different speed (RPM), liquid yield, extraction efficiency and extraction loss are calculated. The data of the weight of cake, weight of liquid in cake, and liquid extracted was taken from the table above. The biogas slurry samples, after undergoing a pre-treatment process of sun-drying for 24 h, have been subjected to dewatering, with an initial weight of 10 kg consistently maintained for feeding at machine. As the RPM settings decreases from 36 to 8, several key trends emerge which are listed in the **Table 8**.

Table 8. Performance analysis.

Test No.	RPM	Liquid yield, L_y (%)	Extraction efficiency, L_e (%)	Extraction loss E_1 (%)
1	36	84.25	65.59	27.60
2	25	87.38	68.49	27.10
3	18	88.52	69.68	26.80
4	12	89.93	71.08	26.50
5	10	90.77	71.94	26.30
6	8	92.02	73.12	26.10

It shows that as the speed decreases the Liquid yield percentage increases, along with the extraction efficiency. The value of extraction efficiency reaches a maximum value of 73.12% at 8 RPM. Further, the value of extraction loss decreases as we decrease the speed. This shows the lower RPM setting increases the overall efficiency of the plant.

4.1.1. Liquid yield

As shown in the **Figure 7**, the liquid yield decreased with the increase in the speed of the shaft. The highest liquid yield was observed to be 92.16% at 8 rpm whereas the lowest liquid yield was 87.02% at 36 rpm. The decrease in liquid yield with increase in rpm is due to the result of splashing liquid to the wall of the machine.

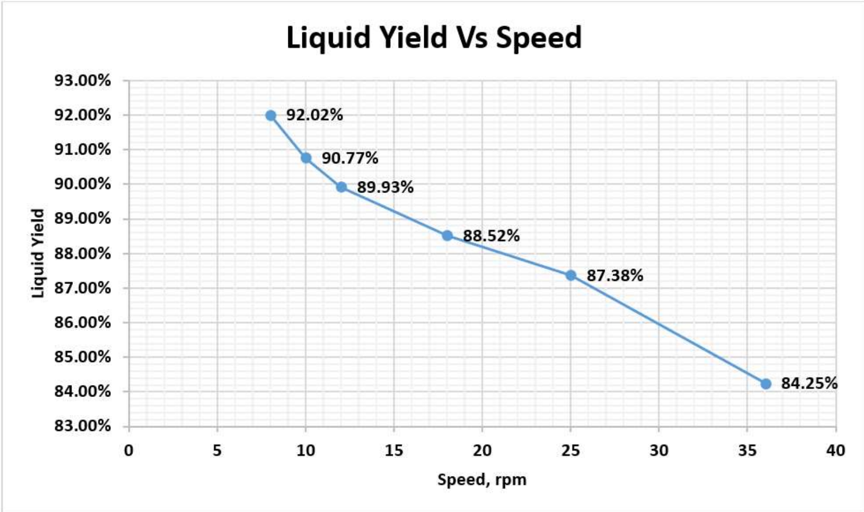


Figure 7. Liquid yield.

4.1.2. Extraction efficiency

The extraction efficiency of the dewatering system decreased with the increase in the speed of the shaft. The highest extraction efficiency was observed to be 73.12% at 8 rpm whereas the lowest 65.59% was observed at 36 rpm. As shown in **Figure 8.** It is evident that extraction efficiency is greater at a low RPM setting.

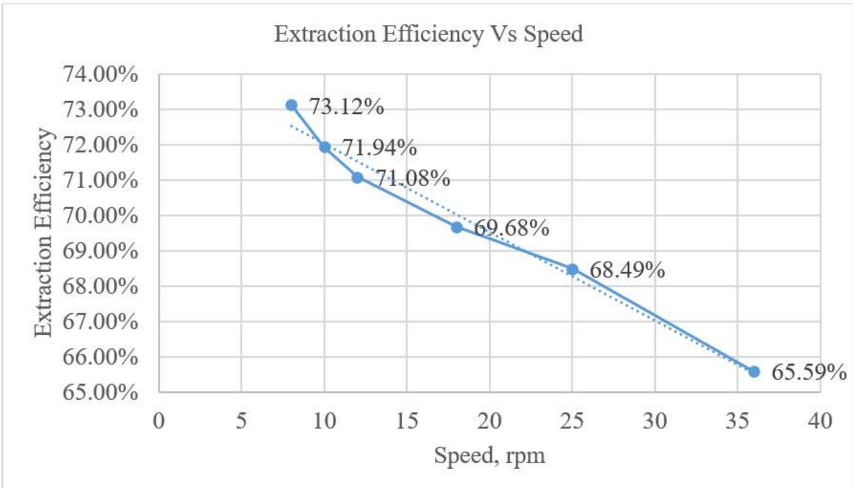


Figure 8. Extraction efficiency.

4.1.3. Extraction loss

The extraction loss has increased with the increase of speed. The highest loss was found to be 27.60% at 36 rpm whereas the lowest was 26.10% at 8 rpm as shown in **Figure 9**. The graph shows the trend between Extraction loss and speed (rpm). The extraction loss increased with the increase in speed, which indicates that once speed increases, the slurry moves fast and vibration occurs.

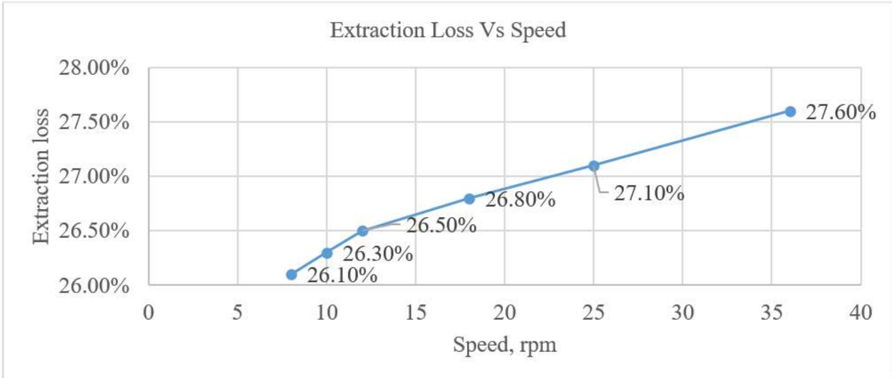


Figure 9. Extraction loss.

4.2. Financial analysis

The cost of the dewatering machine for the consumer will be NRs 384,000. Three laborers will be required for operating the machine and packing the fertilizer, with a monthly wage of NRs 19,000 per laborer, including salary and benefits. This sums up to a total annual labor cost of NRs 684,000. Assuming the dewatering machine operates for 300 days annually, the operation of the machine involves a 5 HP motor and a 1 HP slurry pump, running for 7 h per day. The cost of electricity for operating the machine is estimated to be NRs 93,958.2 annually. Additionally, the annual maintenance cost of the dewatering machine is assumed to be 10% of the total cost, amounting to NRs 38,400 as shown in **Table 9**.

Table 9. Cash flow.

S. No.	Cash flow (annual)	Amount (NRs)
1	Initial cost	384,000
2	Operating cost	93,958.2
3	Labor cost	684,000
4	Maintenance cost	38,400
5	Interest @ 10% annually	38,400
6	Income	1,008,000

If we consider a biogas plant of 30 m^3, then the output of the plant would be 1200 kg/day. The compression ratio of the machine by weight is 7, then the output will be 171 kg per day. With the efficiency of 70% the output per day will be 120 kg per day. Market value of 1 kg organic fertilizer is Rs 25.

The payback period is the required number of years to gain the original capital where annual income = 1,008,000.

Annual expenses = Operating cost + Labor cost + Maintenance cost + Annual interest on investment = 93,958.2 + 68,4000 + 38,400 + 38,400 = 854,758.2

Now,

Net annual profit = Net annual income − Annual expenses = 1,008,000 − 854,758.2 = 153,241.8

Therefore,

$$\text{Payback period} = \frac{\text{Investment}}{\text{Annual profit}} = \frac{384{,}000}{153{,}241.8} = 2.505844\ \text{years}$$
$$= 2\ \text{years}\ 6\ \text{month}\ 2\ \text{days}$$

5. Conclusion

The study assessed a screw-type dewatering system for biogas digestate to improve the commercial viability of bio slurry as an organic fertilizer. The system showed a production capacity of 79.9 kg/h, with a liquid yield of 92.02%, extraction efficiency of 73.12%, and extraction loss of 27.60%. Results from the study demonstrated that as the speed of the screw decreased, the overall efficiency of the dewatering system increased. Lower RPM settings resulted in higher liquid yield and extraction efficiency, while reducing extraction loss. The optimal performance was observed at 8 RPM, providing the highest extraction efficiency and lowest extraction loss.

In conclusion, the screw-type dewatering system shows promising potential for enhancing the utility and commercial viability of bio slurry as an organic fertilizer. By effectively reducing the moisture content in biogas digestate, the system can improve handling, storage, and transportation, making bio slurry more accessible for agricultural use. The study's findings suggest that implementing this technology in biogas plants could offer significant environmental and economic benefits, supporting sustainable energy and agricultural practices.

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Abbreviations

WECS	Water and Energy Commission Secretariat
CPS	Center for Pollution Studies
kW	Kilowatt

kN	Kilonewton
NPC	National Planning Commission
IOE	Institute of Engineering
RPM	Revolutions per minute

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