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Feasibility study and simulation of Mini-hydro power generation from greywater resources using computational fluid dynamics technique

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Abstract

The need to meet one of the United Nations sustainable development goals that centres on clean and affordable energy for all has been one of the major drivers pushing for alternative but viable means of generating electrical energy from diverse potential sources. In view of this global mandate, this study examines the feasibility of mini-hydro electrical power generation from greywater resources using computational fluid dynamics techniques. The approach proposed used SolidWorks for structural and component design, and mathematical modelling of the input and output parameters was done carefully, which was implemented through simulation in the MATLAB environment. Different scenarios were investigated through simulation, and the average flow rate at the site was obtained to be 0.0085 m^3/s. The optimal power output and volumetric flow rate were obtained to be 0.1100 m^3/s and 1079.1W at a fixed head of 1m, respectively. Also, with a varying water head and varying pipe diameter size, the power output generated from the setup showed an appreciable increase, ranging from thousands of watts. The outcome of the study showed that mini-power generation from the greywater is sustainable if the sited close to locations with an ample supply. Conclusively, the approach implemented is not only sustainable but also a good way to achieve energy security and water resource management in urban centres.

Nomenclature and units

Q	Volumetric flow rate
η	Turbine efficiency
P_{abs}	Absolute pressure at manometer location (Pa),
P_{atm}	Atmospheric pressure (Pa)
ρ	Density of water (kg/m^3)
g	Acceleration due to gravity (m/s^2),
z_{ref}	Elevation of pressure tap relative to turbine centerline (m)
T	Torque (Nm
P_{mech}	Mechanical power (W),
$T\omega$	Torque of the angular velocity (N-m),
n	Rotational speed (rpm),
ω	angular velocity (rad/s)

1.0 Introduction

The provision of sustainable and reliable electricity access remains a significant challenge in many developing countries around the globe (Olabode *et al.,* 2025). This challenge more often results in interruption of power supply, which has posed a significant negative effect on the production activities in industries and undermined the quality of life in modern residential buildings (Maika *et al.,* 2023). Recent advancements in home automation have transitioned many of the activities in modern houses to be exclusively dependent on energy supply, which barely exists in Sub-Saharan African countries (Maika *et al.,* 2023; Olabode *et al.,* 2025). Also, places like university communities known to be high-density micro-environments depend exclusively on energy supply for the smooth running of every bit of their arms, such as lighting systems, security systems, research activities, and teaching activities (Akinyele *et al.,* 2025).

This continual instability in energy supply in sub-Saharan African countries has led to exploring viable alternatives perceived to be sustainable and reliable in supply, with possibilities of triggering a paradigm shift from relying on conventional power generation sources (Akinyele and Olabode, 2025; Arif and Hasan, 2018). One of such viable alternatives is mini-hydropower systems generation from greywater resources, especially for university communities where such resources are continuously available in sustainable abundance from the students' dormitories (Arif and Hasan, 2018; Alvarado *et al.,*(2022). This option of power generation, when hybridised with seemingly steady and mature renewable energy sources such as photovoltaic energy systems, can sustainably power a section of the university community and, by extension, when deployed as an isolated microgrid system, several sections of the university community can be independently electrified sustainably (Shahzad *et al.,* 2023; Rashid *et al.,* 2023).

This line of thought agrees with the findings of authors in references (Rashid *et al.,* 2023; Nwagu *et al.,* 2025) that micro-grid systems comprise a variety of decentralised energy sources, which could be a wind energy system, solar photovoltaic system, or biomass-based energy system enhanced with energy management systems. This decentralised system of electrification signalled a positive approach in enhancing the energy generation efficiency in mega communities, such as the case of universities and research organisations (Olabode *et al.,* 2025).Several research papers have extensively explored the deployment of photovoltaic systems for sustainable energy supply for university communities; however, the deployment of greywater for university systems is under-researched despite the relatively abundant availability of greywater resources in such a mega community (Filali *et al.,*2022). According to Filali *et al.,*(2022) and Van de Walle *et al.,* (2023), greywater is the total domestic sewage, which has been separated from the faecal matter, mainly from sinks, baths, and laundry septic tanks. The outcome of their study also showed that grey water has been an under-researched energy resource, as green energy resources that need to be explored (Van de Walle *et al.,* (2023).

In a similar vein, Chitra and Muruganandam, (2019) opined that domestic wastewater, with the exclusion of toilet effluent, represents a massive and untapped resource, and its utilisation for energy generation aligns well with the concepts of circular economy and resource recovery. The outcome of this research, in conjunction with the international call of United Nations Sustainable Development Goals (UN-SDG-6 and 7), which emphasise energy use efficiency from water waste and green energy transition to provide affordable and green energy for all. This mandate, in no doubt, is opening researchers' eyes to the fact that power generation from wastewater in urban centres and mega communities, like that of residential campus communities, can be a sustainable paradigm shift in sewage management in mega communities.

Furthermore, greywater can sustainably act as a reusable water reservoir for micro-hydropower generation in such mega communities rather than making them to be great nuisance to the community. For instance, Asano (2005) and Alvarado *et al.,* (2022) reported that most of the urban houses release effluent greywater without treating or reclaiming it, which is a leading potential cause of loss of freshwater resources, pollution of waters, and loss of energy opportunity. The integration of advanced energy recovery systems and advanced greywater management infrastructure is therefore a primary strategy not only advancing the principles of the circular economy, whereby waste streams are redefined as resource streams, but also for global sustainability objectives (Van de Walle *et al.,* 2023; Asano, 2005).

Also, the growing resources for water recycling for hydro-power generation are another drive promoting harnessing sustainable energy from such sources. For instance, the Archimedes screw turbine, which has long been used for irrigation as well as fluid transport purposes, has recently been transformed into a low-head/low flow turbine suitable for use in grey water applications (Nuernbergk and Rorres, 2013; Yoosef and Lubitz, 2020). The suitability of the Archimedes screw turbine for hydropower generation from sewage is largely connected to its capability of being able to function even at a reduced head (Yoosef and Lubitz, 2020). In addition, Darries *et al.,* (2022) showed that the application of an Archimedes screw turbine at the point of discharge of the sewage treatment plant can generate electrical power in the range of 7.9-9.8 kW, which is comparatively massive relative to what can be obtained (approximately 4.5kW) with the use of a water wheel located at the river intake. In a similar vein, Weking and Sudarmojo, (2019) provided a useful insight into screw angle position relative to water pressures with a view to obtaining optimal hydro-power generation. Also, Hatziargyriou *et al.,* (2007) argued that the implementation of micro-hydro power generation systems in universities can be considered a shift for the future.

The underexploitation of greywater for micro-hydropower generation with the supporting water turbine informed this research, which investigates the feasibility of the usage of greywater resources in the university campus community. The choice of a university campus is unconnected to the fact that universities are major producers of greywater (Lanchipa-Ale *et al.,* 2024; Madhuranthakam *et al.,* 2023). This current research distinctively leverages holistic designs and simulations based on a computational fluid dynamics approach, in contrast to other hydropower generation systems based on the usage of virgin water resource reservoirs. The study supports increasing selfsufficiency pertaining to energy resources as well as increasing the environmental benefit to the community at a lower cost for the consumption of energy.

2. Methodology

2.1 Research Approach

This study designed and simulated a micro-hydropower system for the generation of electrical power from greywater produced within a university community. This current research leverages the advancement and suitability of the Archimedean screw turbine to achieve energy conversion, particularly from a low-head water pressure and fluctuating flows peculiar to greywater systems. The current research approach utilised site assessment, system design using SolidWorks, and simulations to demonstrate the feasibility of sustainable energy generation from greywater. The design is in line with the idea of greywater decentralised systems, which offer cost-efficient and environmentally sustainable solutions. In this study, SolidWorks was employed for the design, while a computational fluid dynamics approach was employed for the system performance. The method proposed in this research offers dual benefits to users by relieving the pressure off central wastewater treatment systems while simultaneously generating scalable alternative green energy.

2.2 Study Site and Greywater Assessment

The site's structural and environmental factors were one of the major points of concern during the site survey. This analysis revealed that this site had been abandoned and unused for quite a long period of time; consequently, there is little interaction with the existing structure and the installation processes. The water is supplied by two channels from the male dormitory of capacities of 1000 occupants each, with one nearly blocked; thus, the need for clearing and adjustment of the channels to ensure a constant supply of greywater. The water flows out of the raised ledge, ensuring a natural gravitational pull to accelerate the rate of water flow as well as increasing the pressure head necessary to optimise turbine performance. However, there is a presence of barriers and varied ground height that disrupts constant water flow.

Furthermore, the site data presented several critical parameters, like the width of the ledge of approximately 1.8 meters and the corresponding average depth of approximately 1.52 meters. These parameters form critical criteria for assessing the flow rate as well as designing the corresponding inlet and pipe size to facilitate the requisite rate. Also, during the preliminary investigation, direct assessment of the flow rate was conducted through measuring the time taken to fill a bucket of known capacity over a three-day duration in the morning and evening schedules to determine the requisite average rate of 0.0084697 m^3/s. This was used for the calculation of the optimal flow rate for the turbine, which was set to 0.025204 m^3/s. The variations in the rate measured emphasise site modifications to meet seasonal or daily variations in the water availability of the greywater. The conditions prevailing at the site not only affect the technology but are also influential in determining the functionality of the system. The continuous water flow from dusk to dawn offers a continuous supply of greywater. The availability offers a continuous potential for energy extraction. Problems arising from the existence of blockages in one of the waterways or ground level differences may pose problems that necessitate adjustments to the site infrastructure.

2.3 System Architecture

2.3.1 Design of reservoir assembly

Depicted in Figure 1 is the reservoir assembly designed to harvest and store the greywater at a level high enough to allow the force of gravity to be used for the production of energy. In the design proposed, a water intake inlet, walls, and an outlet conduit were carefully crafted to convey the water to the turbine. This was so designed in accordance with site parameters such as the rate of water flow and the head height for proper water supply and energy production.

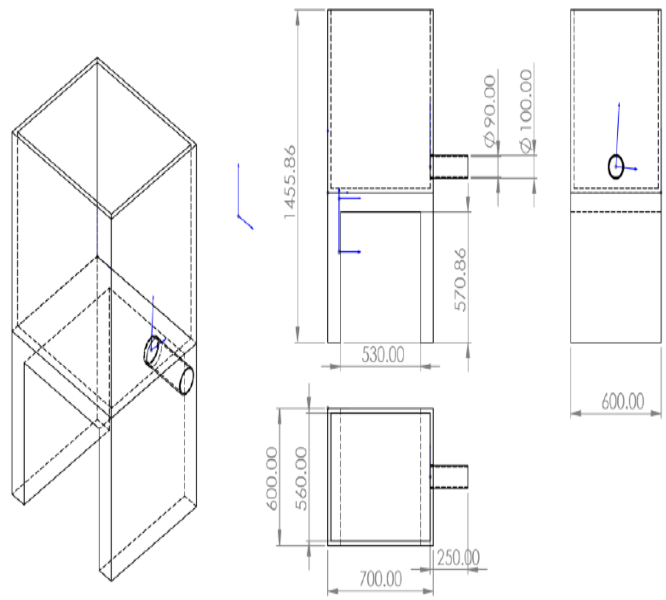

Figure 1: Reservoir assembly

2.3.2 Design of Archimedes' screw turbine (AST)

Figure 2 shows a schematic design of AST deployed for this research. The vital components of AST include Archimedes' Screw itself, the inlet part, the outlet part, and the support structure.

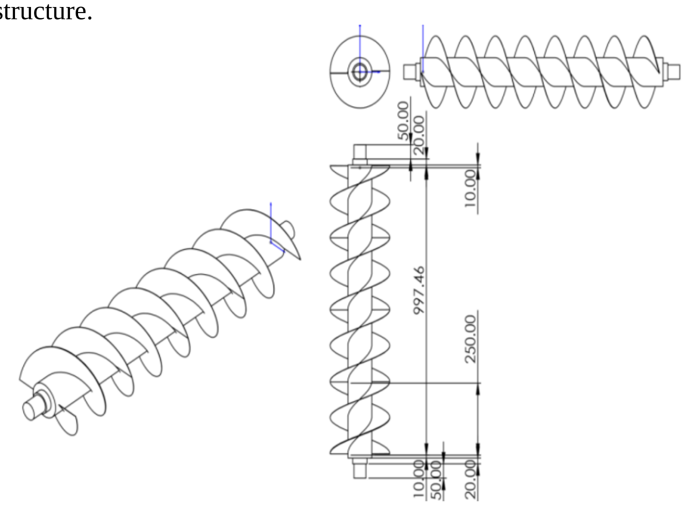

Figure 2: Designed AST components

2.3.3 Design of casing of the turbine

Figure 3 represents the proposed case of the turbine, designed to basically hold the element of Archimedes' screw. It is the component that ensures the flow of water for improved AST blade engagement. This design ensures the maintenance of hydraulic stability and facilitates the efficiency of the turbine system.

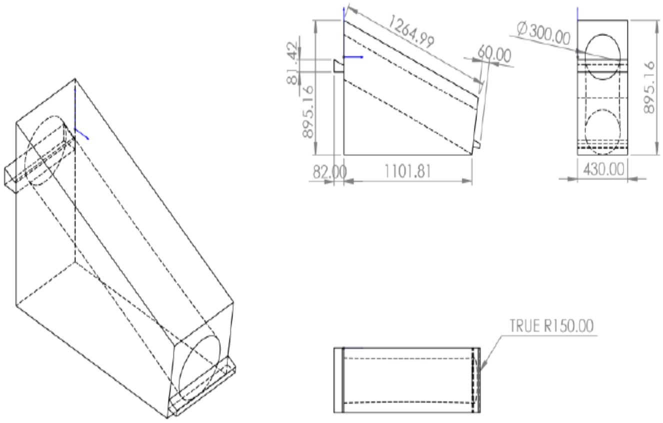

Figure 3: Casing of the turbine

2.3.4 Design of bearing assembly

Presented in Figure 4 is the proposed design of the bearing assembly of the turbine. It was so designed not only to facilitate easy rotation of the screw seamlessly but also to prevent friction and wear and tear during operations to ensure easy movement of the turbine shaft. Furthermore, it is one of the innovations incorporated to ensure that mechanical stability is achieved. The primary purpose of this design is to improve the durability of parts of the turbine and ensure proper functionality.

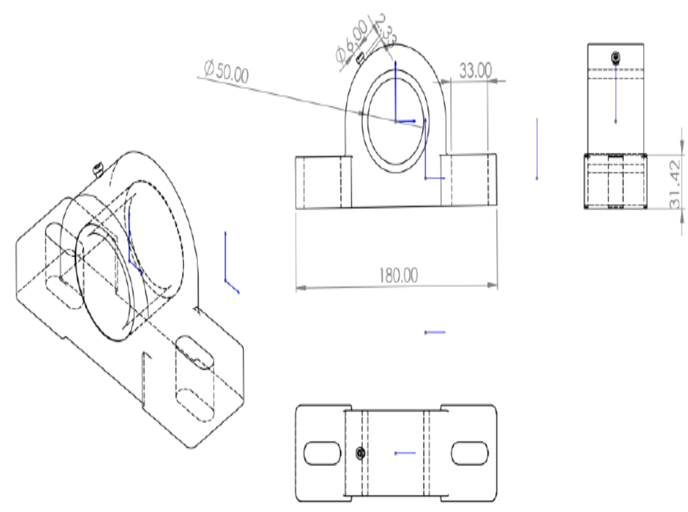

Figure 4: Bearing assembly

2.4 System Mathematical Modelling

For easy simulation implementation of the proposed approach, the following mathematical models are the relevant equations employed. The hydraulic head or static head of water at a specific point relative to a datum was computed using Eqn (1)(Yoosef and Lubitz, 2020);

$$H = \frac{P_{abs} - P_{atm}}{\rho g} + z_{ref} \quad (1)$$

Where; P_{abs}= absolute pressure at manometer location (Pa), P_{atm}= atmospheric pressure (Pa), ρ = density of water (kg/m^3), taken as at standard conditions,g = acceleration due to gravity (m/s^2), z_{ref}= elevation of pressure tap relative to turbine centerline (m)

Also, the gauge pressure deployed during the simulation was estimated using Eqn (2), which is given as follows;

$$H = \frac{p_{guage}}{\rho g} \quad (2)$$

Where; H = Pressure head (m), p_{guage} = guage pressure (Pa), ρ = density of water, taken as at standard conditions, g = acceleration due to gravity.

The torque produced by the turbine rotor was computed from the force imbalance on the calibrated brake system as given in Eqn(3), thus;

$$T = (F_1 - F_2)\frac{D_{shaft}}{2} \quad (3)$$

Where: T = torque (Nm), F_1, F_2= tangential forces measured on right and left brake arms, respectively (N), D_{shaft}= effective diameter of the torque measurement arm in the experimental setup

The output of the turbine shaft is the mechanical power, and it was computed using Eqn(4), which is the product of the torque and angular velocity, thus;

$$P_{mech} = T\omega = \frac{2\pi n T}{60} \quad (4)$$

Where; P_{mech}= mechanical power (W), $T\omega$ = Torque of the angular velocity (N-m), n = rotational speed (rpm), and ω = angular velocity (rad/s)

Similarly, the hydraulic power available in the fluid stream is the product of the pressure head and volumetric flow rate defined by Eqn (5), thus;

$$P_{hyd} = \rho g H Q \quad (5)$$

Where; Q = volumetric flow rate through the turbine(m^3/s), ρ = density of water, taken as at standard conditions (kg/m^3), g = acceleration due to gravity (m/s^2), H = Hydraulic head or static head of water at a specific point relative to a datum (m).

Furthermore, the hydraulic efficiency η_{turb} defined as the ratio of mechanical power output to hydraulic power input. This represents the turbine's effectiveness in converting fluid energy into rotational mechanical energy, excluding downsteam losses and computed using Eqn(6);

$$\eta_{turb} = \frac{P_{mech}}{P_{hyd}} = \frac{T\omega}{\rho g H Q} \quad (6)$$

Where; P_{mech} = Mechanical power output (W), P_{hyd} = Hydraulic power available (W).

The overall efficiency of the turbine generator set accounts for losses in transmission, generation, and power conditioning and was computed using Eqn(7), thus;

$$\eta_{system} = \eta_{turb} \times \eta_{trans} \times \eta_{gen} \times \eta_{conv} \quad (7)$$

Where; η_{trans}= mechanical transmission efficiency (%), η_{gen} = generator electrical efficiency (%), η_{conv}=power conditioning/inverter efficiency (%)

The expected electrical power output P_{elec} (W) was computed using Eqn (8a) and Eqn (8b) for the proposed site, given thus:

$$P_{elec} = \rho g H Q \eta_{system} \quad (8a)$$
$$P_{elec} = \rho g H Q \eta_{turb} \times 0.829 \quad (8b)$$

Similarly, the auxiliary power consumption and the net power consumption in the system designed were computed using Eqn (9) and (10) respectively, thus;

$$P_{net} = P_{elec} \times (1 - f_{aux}) \quad (9)$$
$$P_{net} = P_{elec} \times 0.98 \quad (10)$$

Where; f_{aux}= auxiliary power fraction

The annual energy yield E_{annual} (kWh) was obtained by integrating net power over time, considering flow duration given in Eqn (11), thus;

$$E_{annual} = \sum_{i=1}^{N} [P_{net,i} \times t_i] = P_{net}(Q_{avg}) \times T_{oper} \quad (11)$$

Where; $P_{net,i}$= net power corresponding to flow interval *i(W)*, t_i= duration of flow interval i (hours), N = number of flow intervals in the flow during curve, T_{oper}= annual operating hours (hours).

The flow of the fluid is governed by computational fluid dynamics, and for continuity, Eqn (12) must hold, which implies that the gradient of the fluid velocity must be equal to zero as given thus;

$$\nabla . U = 0 \quad (12)$$

Where; U (m/s), and ∇ = del operator

The Reynolds-Averaged Navier-Stokes equations of the momentum, which depict conservation of turbulent flow momentum in the case of instantaneous chaotic flow velocities, are averaged over time and are given with Eqn (13). Thus,

$$\rho \left(\frac{\partial U}{\partial t} + U . \nabla U \right) = -\nabla p + \nabla . \left[\mu_{eff} (\nabla U + \nabla U^T) \right] + \rho g \quad (13)$$

The approach of computational fluid dynamics can also be deployed to resolve the torque on the turbine rotor and was computed using Eqn (14), thus;

$$T_{CFD} = \int_A r \times (F_p + F_v) dA \quad (14a)$$
$$P_{CFD} = T_{CFD} \omega \quad (14b)$$

Where; T_{CFD} = torque computed from CFD results (N·m), r= position vector from axis of rotation (m), = pressure force per unit area (Pa N/m²), and F_v = viscous shear force per unit area (N/m²), P_{CFD}= mechanical power predicted from CFD (W), T_{CFD} = torque from CFD (N·m) and ω= angular velocity (rad/s)

Similarly, the variable Greywater Flow

$$\bar{P} = \frac{1}{T} \int_0^T \eta(t) \rho g Q(t) H_{net}(t) dt \quad (15)$$

Where; $\bar{P}$ =average power over time period T(W), T = total time interval (s).

2.6 The procedural flowchart

Presented in Figure 5 is the procedural flowchart for the implementation of the proposed strategies for micro-power generation via greywater.

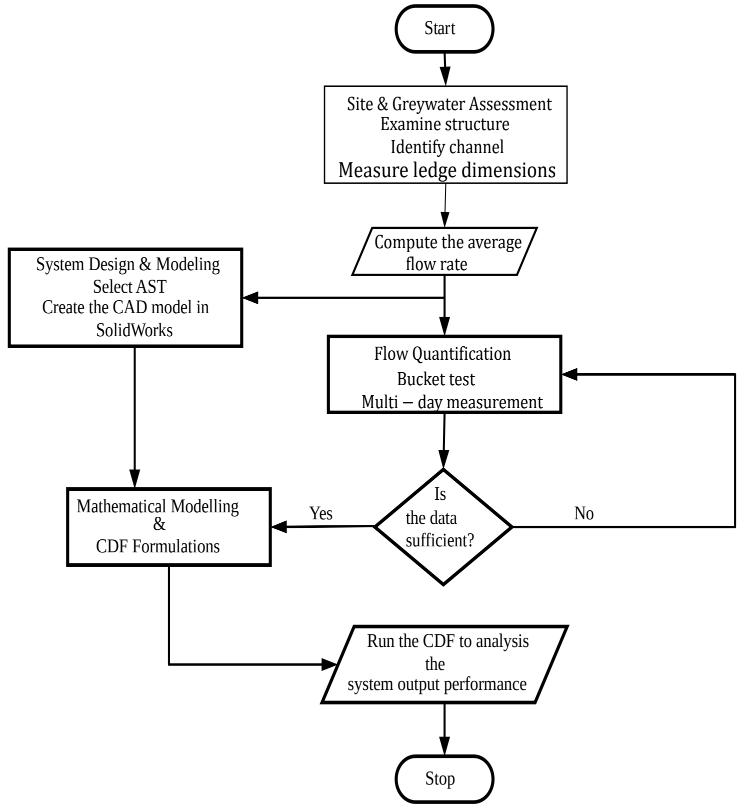

Figure 5: Procedural flow chart for the proposed technique

3.0 Results and Discussion

3.1 Effect of constant power at varying head and volumetric flow rate

This scenario was investigated to be able to determine pipe size, operational constraints and consequently influence the choice of turbine. The results presented in Figure 6 showed the effect of varying the water head on the volumetric flow at constant power (P (kW), acceleration due to gravity (g (m/s^2) and constant water density (ρ (kg/m^3). Furthermore, as the height of the head increases from 0.1 to 1.0 m in a uniform step of 0.1m, the volumetric rate of flow was observed to reduce from 0.1019 to 0.0102 m³/s. A direct relationship was observed between the height of the head and the volumetric rate of flow at a constant power. This agreed perfectly with the characteristics of hydropower resources because these resources display a typical behaviour where an increase in head leads accompany reduced volumetric flow so as to achieve a given level of power output. Furthermore, the results obtained indicated that with the increased head height, there is potential for efficient operation at low rates of volumetric flows. This is essential in the context of energy production to ensure proper utilisation of the availability of water.

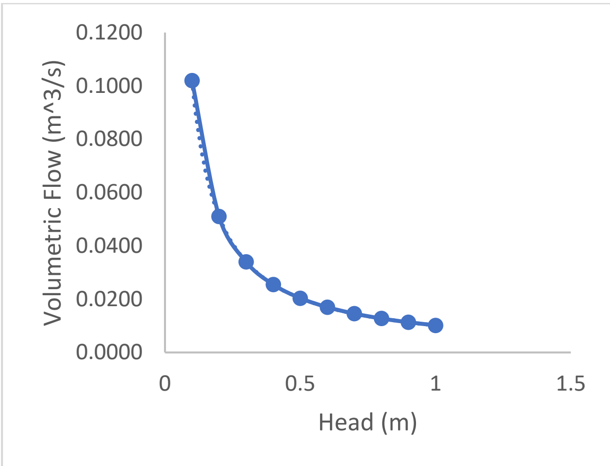

Figure 6: The behaviour of volumetric flow rate at varying values of water head

3.2 Effect of fixed water head on the volumetric flow rate and power out

Table 1 presents the effect of the power output and volumetric flow rate at a constant water head fixed at 1m. The simulation results showed that the rate of flow ranges from 0.0200 to 0.1100 m³/s. This translates to a proportional increase in output power that ranges from 196.2 to 539.5 kW. These results trends imply that when a higher flow rate is applied to the system, a higher power output emanates from the system, which is consonant with why the flow rate needs to be optimized in order to produce higher power in a hydropower system.

Table 1. Power and flow rate varied against a fixed head ((1m), constant water density (1,000 kg/m^3), acceleration due to gravity (9.81 m/s^2))

Volumetric Flow (Q) (m^3/s)	Power (P) (Watts)
0.0200	196.2
0.0300	294.3
0.0400	392.4
0.0500	490.5
0.0600	588.6
0.0700	686.7
0.0800	784.8
0.0900	882.9
0.1000	981
0.1100	1079.1

Leveraging the simulation results presented in Table 1, computational fluid dynamics was deployed to visualize the behavior of the volumetric flow rate to generate different output powers, as shown in Figure 7. An exponential increase in turbulent losses was observed as the turbine runners choked, and this indicates that a substantial kinetic energy was dissipated.

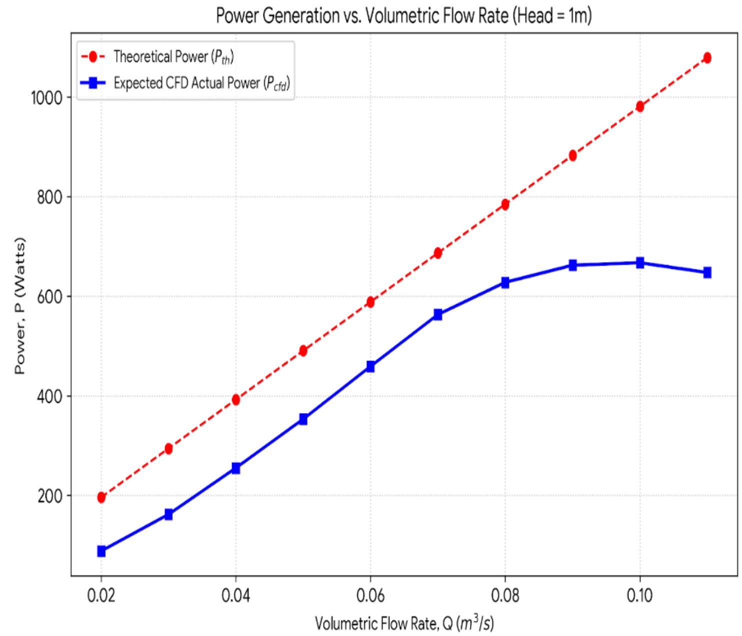

Figure 7: The volumetric flow rate at different computational fluid power outputs

Similarly, with the CFD analysis, the turbine efficiency, volumetric flow rate and the expected computational fluid power output are as shown in Figure 8. It can be deduced that the point of peak feasibility for the volumetric flow rate (Q) and turbine efficiency (η) is $0.0700m^3/s$ and 82, respectively. This shows that if the greywater runs beyond this peak feasible point, the power output diminishes appreciably.

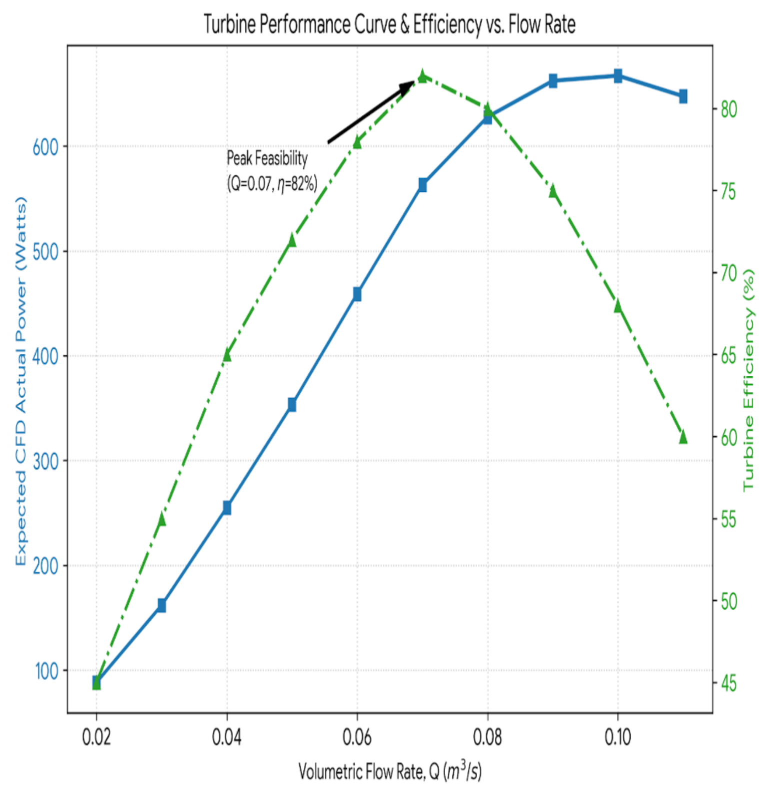

Figure 8. Peak feasible point for optimal energy yield from greywater using CFD

.3 Hydrodynamics and computational fluid power performance analysis

Figure 9 describes the relationship between the outlet pipe diameter and the volumetric flow rate. The graph indicates a relationship where, as the outlet pipe diameter increases, the volumetric flow rate also increases. This means that a larger diameter for the outlet pipe increases the water flow rate from the reservoir and consequently increases power output. This finding agrees with previous research outputs that higher turbine power output can be achieved. This means that a larger diameter for the outlet pipe increases the water flow rate from the reservoir and consequently increases power output. This finding agrees with previous research outputs that higher turbine power output can be achieved. This means that for optimal power output, it is necessary to optimise the outlet pipe while taking into account the cost of construction. Hence, the correct outlet pipe diameter ensures optimal water flow without creating issues such as turbulence.

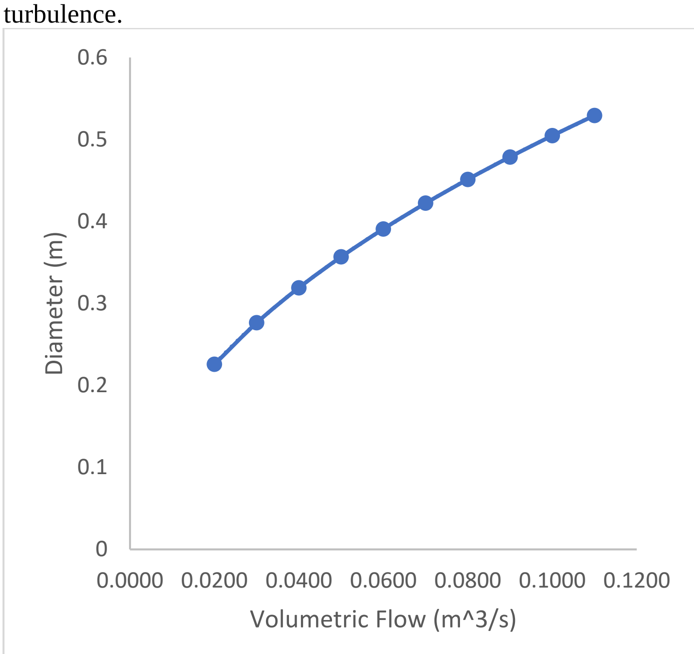

Figure 9: Relationship between the outlet pipe diameter and volumetric flow at 0.5m/s

Also, from the CDF analysis, the most stable design configuration for the greywater system under this study was obtained at a volumetric flow rate of 0.0700m^3/s. Figure 10 gives a visualisation of the interaction between the internal cross-sectional area, power output and volumetric flow rate. The dotted blue line showed the simulated computational fluid power at varying volumetric rate, internal cross-sectional area and constant velocity of 0.5 m/s. The rationale for maintaining a constant inlet fluid velocity of 0.5 m/s is to place a control on the kinetic energy flux that enters the turbine. Furthermore, the increase in hydraulic diameter relative to increases in internal cross-sectional area ensures that the greywater flow is shifted into deeper regimes of turbulence so as to obtain a corresponding increase in computational fluid power output.

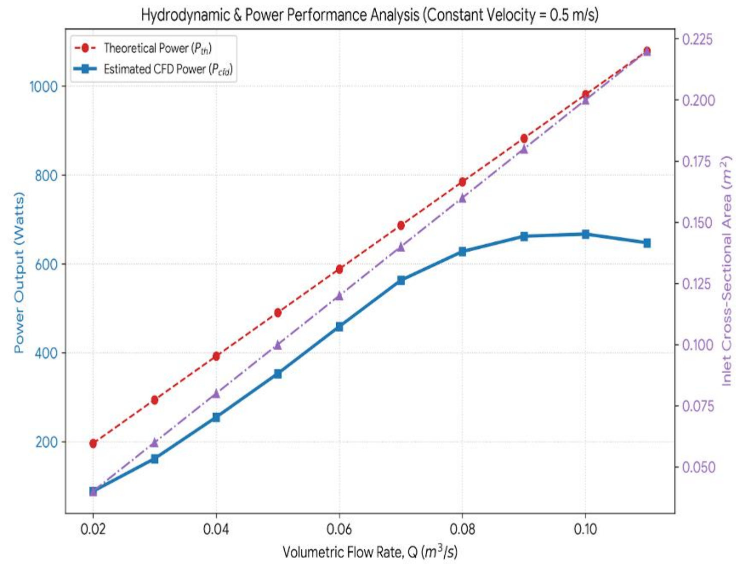

Figure 10: Hydrodynamic characteristics at constant velocity of 0.5 m/s

It is also necessary to point out that, at a fluid velocity of 0.02 to 0.04 m/s, a significant amount of total energy is consumed by the boundary layer friction along the small channel walls, while at the fluid velocity of 0.09 to 0.11 m/s calls for the need to use a larger turbine runner. However, the linear relationship observed has the tendency to upscale the secondary losses in addition to causing significant tip leakage vortices, which have the propensity to degrade the curve efficiency and consequently, the actual power does not experience a significant increase. Figure 11 shows the computed Reynold number at a constant fluid velocity of 0.5 m/s. Insight from Figure 11 revealed that the Reynolds number rises gradually from roughly 99,600 to 233,500 m, and this is because the physical space the fluid occupies expands significantly and also, research findings have shown that a larger hydraulic diameter often encourages increased inertial force relative to viscous force.

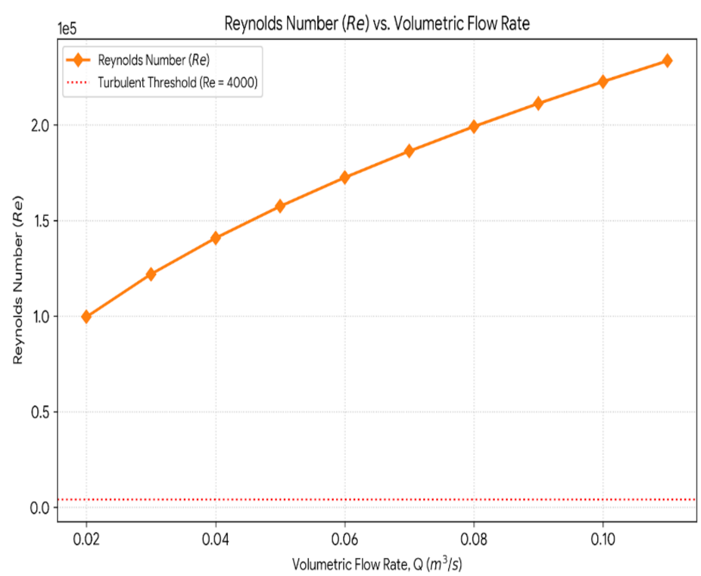

Figure 11: Relationship between the Reynold number and volumetric flow rate with computational fluid analysis

Figure 12 depicts the observed relationship between the output power generated and the outlet pipe's diameter. It can be observed from the graph that as the diameter increases, the power generated also increases proportionately. This means that the larger diameters of the outlet pipes can also facilitate the higher rates of flow, consequently leading to higher levels of power generation within the turbine system. In a hydropower system, the application of a larger diameter of the outlet pipe can be considered as one of the means of improving the power generation levels. Nevertheless, it is important to take into consideration some factors, for example, higher costs associated with the manufacture of larger pipes, as well as the levels of turbulence. The optimization of the outlet pipe is vital for maximizing power while maintaining the sustainability of the hydropower system.

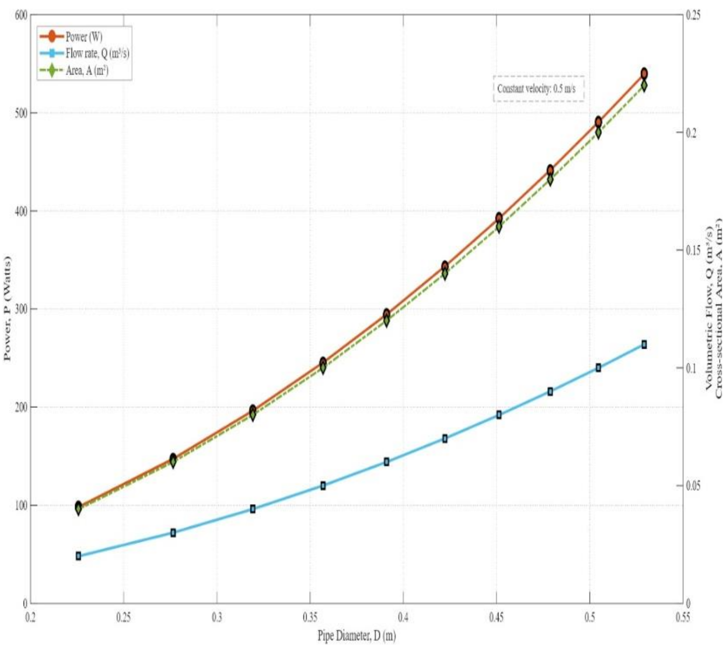

Figure 12. The relationship between the pipe diameter and power output, area and the volumetric flow rate

Furthermore, Figure 12 also depicts the variation in volumetric flow rate against cross-sectional outlet pipe area. This shows that with an increase in cross-sectional outlet pipe area, a corresponding increase in the volumetric flow rate, thus illustrating a direct proportionality interrelationship. From a practical point of view, building an outlet system with a well-proportionate diameter would ultimately improve its efficiency, which in turn affects the quantity of electricity generated. However, engineers are left to balance the cost factor and structural feasibility of using larger pipes, as well as complications such as increased flow velocity that can cause turbulence or mechanical tension. Successful optimization of the outlet pipe size according to this relationship can significantly increase the efficiency and viability of the hydropower system.

4.0. Conclusion

The study presented the feasibility of generating mini-hydropower from greywater accumulated in a septic tank located at the male dormitory of the university campus, considered to be a mega community. The choice of the location is largely connected to the continual availability of greywater from the student dormitory. The outcome of the study showed the technical feasibility of exploiting greywater resources in mini-hydropower plants with Archimedean screw turbines, as the simulation results obtained on low-head and fluctuating flow rates characteristic of greywater schemes showed a promising performance. The observed trends from the simulation results showed that pipe diameter exhibited a linear relationship with the volumetric flow rate and the power output from the system developed in SolidWorks. Also, at a fixed water head, varying the volumetric flow rate, the output power was observed to significantly increase appreciable sustainable energy for domestic applications. However, some of the major limitations encountered in this study include a lack of funding to implement the outcome of the simulation, which opens up a gap that further research should look into by creating a prototype to validate the findings obtained from this simulation study.

Declaration of conflict of interest

The authors have collectively contributed to the conceptualization, design, and execution of this journal. They have worked on drafting and critically revising the article to include significant intellectual content. This manuscript has not been previously submitted or reviewed by any other journal or publishing platform. Additionally, the authors do not have any affiliation with any organization that has a direct or indirect financial stake in the subject matter discussed in this manuscript.

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Appendix A: Power obtained at different values of pipe diameter

Volumetric Flow (Q) (m^3/s)	**Velocity (m/s)**	**Area (m^2)**	**Diameter (m)**	**Power (Watts)**
0.0200	0.5	0.04	0.225676	98.10
0.0300	0.5	0.06	0.276395	147.15
0.0400	0.5	0.08	0.319154	196.2
0.0500	0.5	0.1	0.356825	245.25
0.0600	0.5	0.12	0.390882	294.30
0.0700	0.5	0.14	0.422201	343.35
0.0800	0.5	0.16	0.451352	392.40
0.0900	0.5	0.18	0.478731	441.45
0.1000	0.5	0.2	0.504627	490.50
0.1100	0.5	0.22	0.529257	539.55