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# Greywater Flow Characteristics for Closed Channel Maintenance

Ratna Bachrun [1*], Santi [2], Surya Baskara [1]

[1] *Department of Civil Engineering, Faculty of Engineering, Muhammadiyah Kendari University, Kendari 93231, Indonesia.*

[2] *Department of Architectural Engineering, Faculty of Engineering, Haluoleo University, Kendari 93232, Indonesia.*

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**Abstract**

Knowing the characteristics of wastewater and its interaction with the channel is crucial to finding a suitable model and maintenance method to solve the closed channel problem. The purpose of this study is to find the relationship and how much it influences the characteristics of wastewater in closed channels and analyze the limit deposit velocity (LDV) of wastewater so that there is no deposition. The parameters used to analyze wastewater characteristics are density, oil and fat, specific gravity, total suspended solids, total dissolved solids, and kinematic viscosity. The parameters used to analyze the flow characteristics in closed channels are velocity, discharge, Reynolds number, friction coefficient, energy loss, and hydraulic gradient. The method used is experimental research by simulating a closed-channel model prototype. The closed channel model is made from an acrylic pipe with a length of 6 m and a pipe diameter of 0.064 m. Simulations on each wastewater sample and the discharge variations used were 0.005, 0.004, 0.003, and 0.0015 $m^3/s$. Velocity measurements at a 0.5 pipe water level height and distances of 0, 2, 4, and 6 m. The results showed that the nature and composition of the wastewater the flow velocity. The large value of wastewater parameters shows that the flow velocity is small. The wastewater content is considered a load that must be transported to the end of the closed channel. When the discharge increases, the velocity will increase, Reynolds number will increase, and the energy loss will be large, while the friction coefficient is inversely proportional to Reynolds number. The velocities of clean water samples are 2.90 - 1.07 m/s, tofu - making is 2.83 - 1.07 m/s, household is 2.74 - 0.85 m/s, laundry is 2.84 - 1.03 m/s, and the workshop is 2.54 - 0.66 m/s. The limit deposit velocity (LDV) for household wastewater is 1.49 m/s to prevent deposition in closed channels.

*Keywords:* Discharge; Velocity; Closed Channel; Wastewater; Greywater.

## 1. Introduction

Wastewater is the liquid residue of businesses or activities, and this wastewater can come from households and industries [1]. Wastewater containing polluting substances can cause water pollution, so it needs further handling so as not to pollute the environment. One of the methods of handling wastewater by treatment before disposal includes using activated charcoal, anaerobic treatment, or reuse after treatment [2–4]. Wastewater that is flowed into the channel must meet the quality standards for wastewater, especially those containing bacteria that endanger the environment and water bodies [5, 6]. The nature and composition of wastewater differ depending on the source, such as the kitchen, bathroom, or laundry [1, 3, 4, 7]. The characteristics of liquid waste are odor, temperature, density, color, turbidity, total suspended solids (TSS), total dissolved solids (TDS), kinematic viscosity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and so on [1]. The characteristics of greywater are uncertain because the activity influences them, the amount of water used, and the climate or weather in a country [7–11]. Because of this uncertainty, a country should have a database of greywater effluent characteristics in order to obtain the correct handling and processing methods [7, 8].

* Corresponding author: ratna.bachrun@umkendari.ac.id

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Research on the characteristics of wastewater from various sources has been done. Khotimah et al. (2021), in their research on the catheterization of household greywater, showed that for the TSS parameter, the trend of the highest value still comes from the kitchen, with a value of 202–620 mg/L compared to other sources [8]. Pambudi et al. (2022), in their research on the characteristics of tofu waste in Dele Emas, Surakarta. The results showed TSS 64 mg/L, BOD 150 mg/L, COD 7904 mg/L, PH 2.65, temperature of 36°C, and discharge of 18.8 $m^3$/ton [9]. Suryo Purnomo & Wijayanti (2021) show that the characteristics of workshop waste are oil and fat is 30.33 mg/L, COD is 956 mg/L, and BOD is 497.9 mg/L. These parameter values do not meet the quality standards [10].

The nature and composition of the wastewater impact the flow in a closed channel. The characteristics of liquid waste in the form of density, oil and grease, specific gravity, TSS, TDS, sediment grain size, BOD, COD, and other parameters will interact with the flow in a closed channel, and deposition is easier to occur [12, 13]. Research on other hydraulic channels has focused on velocity and flow discharge, where results show that velocity affects the flow pattern in pipes and open channels [13–17]. Channel pipe geometric research was done by Changhee et al., 2008 [16], which compared the transportation of a water-sand mixture in circular and square pipes. The experimental results show that the hydraulic gradient of water in the round pipe is more significant than that in the square pipe, and the hydraulic gradient of the water-sand mixture in the square pipe is more significant than that in the round pipe. This research is also the same as the results of Bachrun et al. (2019 and 2020) studied about the characteristics of slurry flow [18, 19].

Drainage problems in Kendari City are the same as drainage problems in general: garbage deposition, sediment accumulation, foul odor, and black drainage water. The deposition occurs due to the flow's inability to carry or transport the sediment. For this reason, it is necessary to have a maximum and minimum flow limit to continue transporting sediment to the end of the channel [20]. Research on the characteristics of wastewater from various sources has been done. However, research on flow characteristics in closed channels with wastewater samples in Kendari City has not been done. Different types and sources of waste will result in different flow characteristic values in closed channels. This research is to find the relationship and how much influence the characteristics of wastewater in Kendari City have on the flow in a closed channel, getting the limit deposit velocity of a flow so that no deposition occurs. For this purpose, it is necessary to research the flow in closed channels, analyze the characteristics of wastewater samples from Kendari City, and analyze the changes in velocity that occur in the flow of wastewater. The benefits of this research are: 1) to illustrate the effect of the nature and composition of wastewater on channel performance. 2) as a reference and information in the development of research related to the characteristics of wastewater and flow characteristics in closed channels. 3) As a reference for the government in planning closed channels in Kendari City.

## 2. Literature Review

In this study, the analysis of flow characteristics that are occurring in closed channels, using empirical equations, namely flow discharge ($Q$), Reynolds number ($Re$), friction coefficient ($f$), energy loss ($hf$), and hydraulic gradient ($hf/L$) [21, 22]. Measurement of flow velocity ($V$) using a pitot tube, calculated using the empirical equation:

$$V = \sqrt{2gh} \tag{1}$$

where, $V$ = flow velocity ($m^2$/s), $g$ = gravity ($m/s^2$), $h$ = height velocity (m). Reynolds number ($Re$) using the equation:

$$Re = \left(\frac{D.V}{v}\right) \tag{2}$$

where, $Re$ = Reynolds number, $D$ = pipe diameter (m), $V$ = velocity (m/s), $v$ = kinematic viscosity. Energy loss ($hf$) using the equation:

$$hf = \frac{f\ L\ v^2}{D\ 2g} \tag{3}$$

where, $hf$ = energy loss (m), $f$ = coefficient of friction, $L$ = pipe length (m), $V$ = velocity (m/s), $D$ = pipe diameter (m) and $g$ = gravity ($m/s^2$). The hydraulic gradient ($hf/L$) uses the Darcy-Weisbach equation:

$$I = \frac{hf}{L} \tag{4}$$

where, $hf$ = energy loss (m), $L$ = pipe length (m). The coefficient of friction ($f$) using the Moody diagram can show in Figure 1.

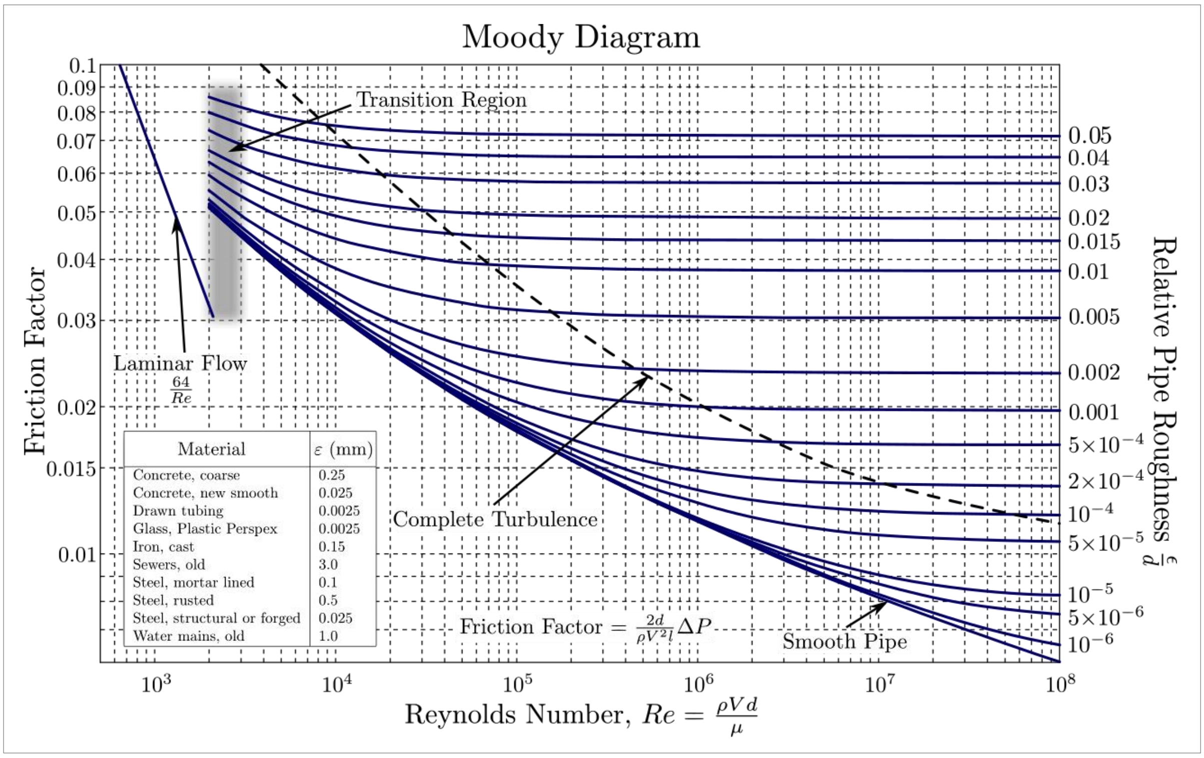


**Figure 1. Moody diagram**

Research on flow characteristics in pipes by Nosrati et al. (2017). In his research, he analyzed energy loss using ANSYS CFX software. The results show that the energy loss coefficient is not only related to the transition geometry but also depends on the Reynolds number, the relative roughness of the wall, and the Euler number. Increasing the Reynolds number and turbulence of the fluid flow in transition reduces the energy loss coefficient. In addition, by increasing the relative roughness of the transition wall, the energy loss coefficient is reduced. An increase in pressure causes an increase in the Euler number, which leads to an increase in energy loss [23]**.** Kumar et al. (2003), in their research using a mixture of fine and coarse particles, fly ash, and bottom ash in pipelines, the results showed that the transportation of a mixture of fine and coarse particles requires more energy or higher velocity. The maximum pressure drop occurs in a flash, and the minimum pressure occurs in bottom ash [24]. The increase in sample concentration in the flow also causes the pressure drop.

Bachrun et al. (2021), in research on slurry flow in pipes, used sand sizes 0.15 mm, 0.25 mm, and 0.42 mm, variations in the discharge of 0.005 $m^3/s$, 0.004 $m^3/s$, 0.003 $m^3/s$, and 0.002 $m^3/s$ and velocity measurements at a distance of 0 m, 2 m, 4 m, and 6 m. The results showed that the largest flow velocity was 0.15 mm particle size. The grain size and density of the sand influenced the flow velocity. Along the flow, there is also energy loss from a distance of 0 m to 6 m there is energy loss caused by friction on the channel walls [18]. In their research, Ting et al. (2021) used the CFD-DEM method, the velocity variation of 2 m/s, 5 m/s, 8 m/s, and 10 m/s, the coarse particle size of 10 mm and used a 0.1524 m diameter pipe. The results show that velocity greatly affects the flow regime in the pipe. Flow regime change is the change in particle movement because of different forces or velocities. A velocity of 2 m/s or a small velocity shows a tendency to be unsteady from time (Fixed-bed flow). In this case, the accumulation of particles continues to clog the pipe [25].

## 3. Research Methodology

This is experimental research, namely by simulating wastewater in a closed channel prototype to get the velocity value of each wastewater sample. The closed channel model is designed on a laboratory scale of 1:1. The wastewater samples used are PDAM clean water, tofu-making, household, laundry, and workshop. The parameters used to analyze the characteristics of wastewater are density ($\rho$), oil and fat, specific gravity ($y$), total suspended solids (TSS), total dissolved solids (TDS), and kinematic viscosity (v). Testing wastewater samples at the MIPA Laboratory of Haluoleo University Kendari. The parameters used to analyze flow characteristics in closed channels are discharge ($Q$) velocity ($V$), Reynolds number ($Re$), friction coefficient ($f$), energy loss ($hf$), and hydraulic gradient ($hf/L$). The closed-channel model can show in Figure 2.

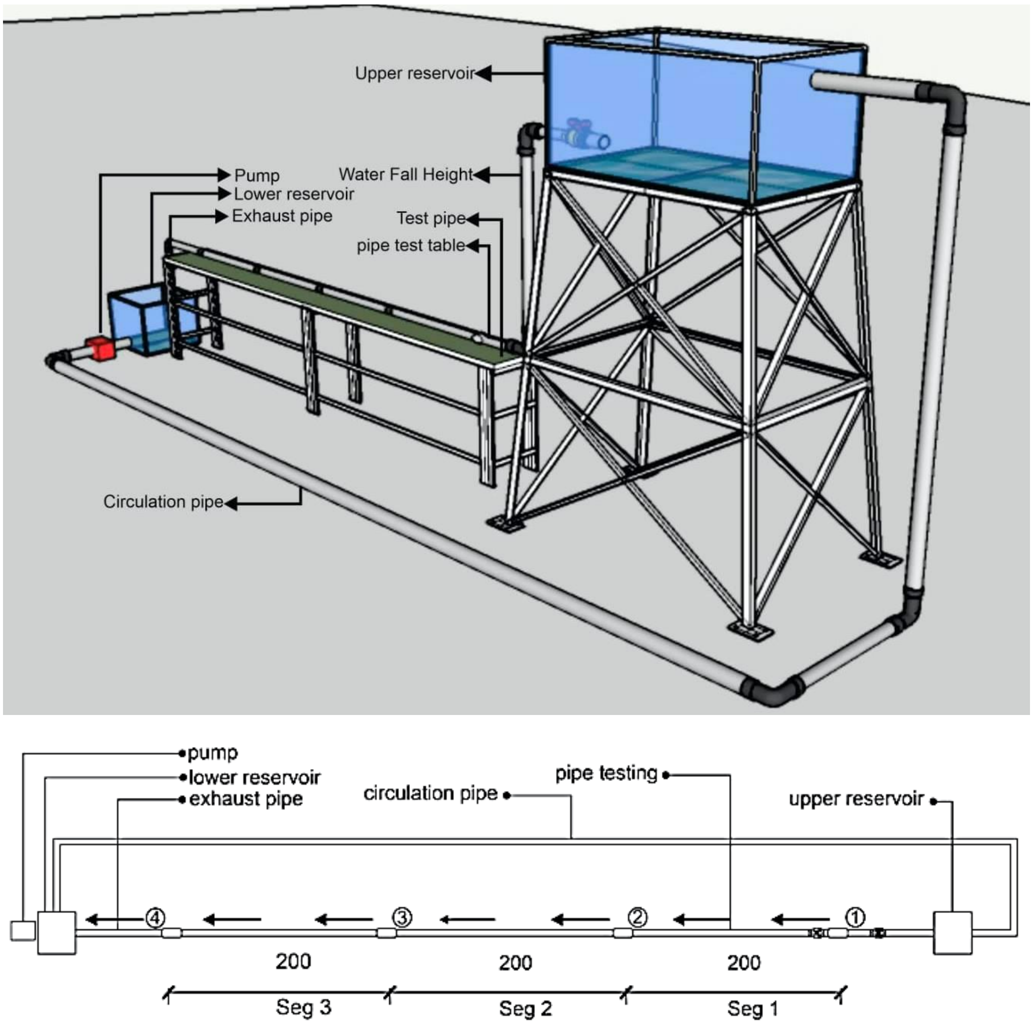


**Figure 2. Closed channel model**

Figure 3 shows the equipment used, discharge and sediment measurements, and velocity height measurements. The closed channel model has a length of 6 m and a pipe diameter of 0.064 m. Discharge variations are 0.005 $m^3/s$, 0.004 $m^3/s$, 0.003 $m^3/s$ and 0.0015 $m^3/s$. Simulations were done on each wastewater sample, variation of discharge, and measurement of velocity height at a distance of 0 m, 2 m, 4 m, and 6 m and the height of 0.5 water level in the pipe. The measurement results are calculated and analyzed using empirical equations.


**Figure 3. (a) Equipment, (b) discharge and sediment height measurement (c), velocity height measurement**

The stages of research and data analysis can be as shown in the following flow chart (Figure 4).

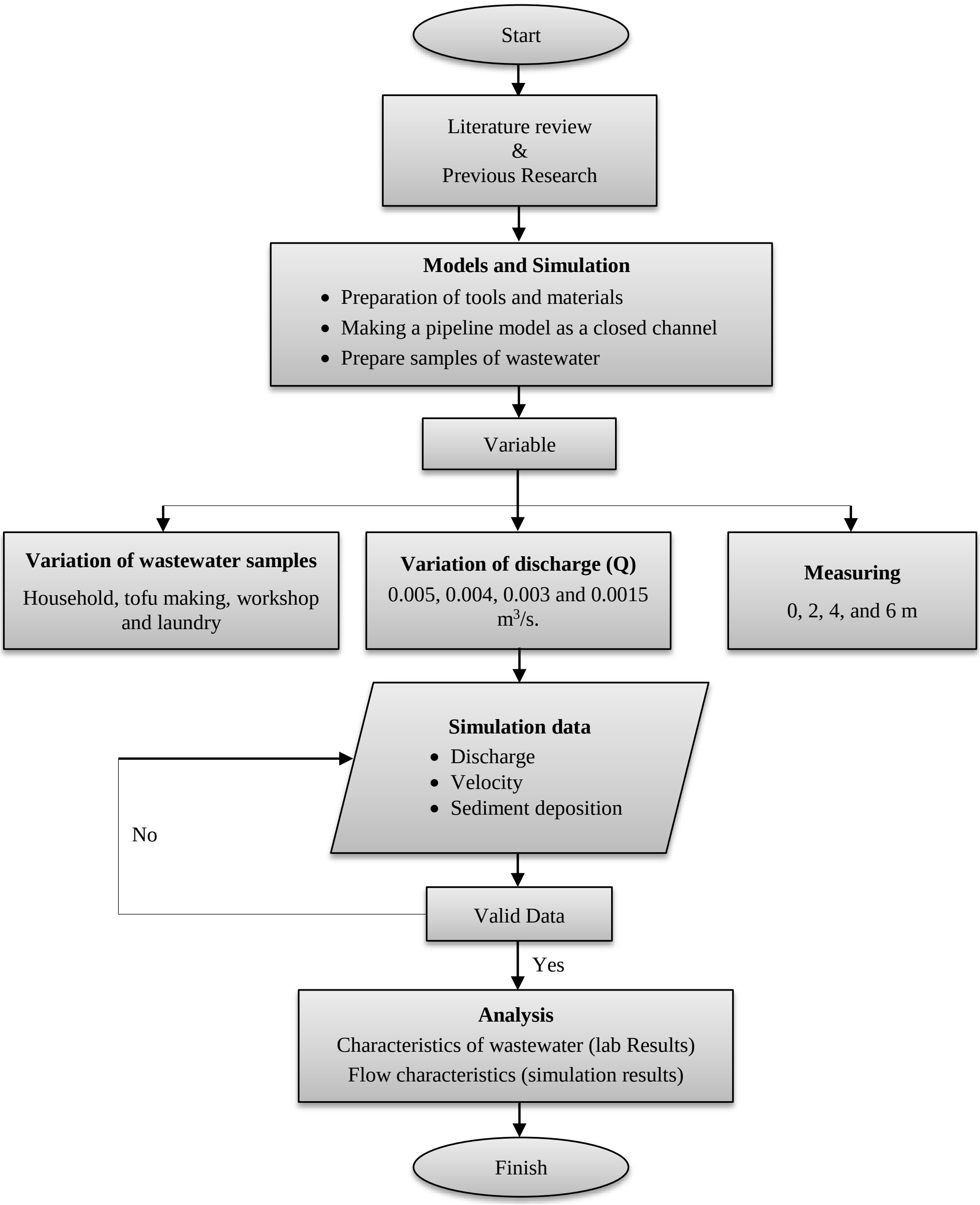


**Figure 4. Flowchart of the methodology**

# 4. Results and Discussion

Analysis of wastewater characteristics based on sample test results in the laboratory and flow characteristics in closed channels based on simulation results.

## 4.1. Characteristics of Wastewater

The parameters used to analyze the wastewater samples are density ($\rho$), oil and fat, specific gravity ($y$), total suspended solids (TSS), total dissolved solids (TDS), and kinematic viscosity ($v$). Testing of the wastewater samples at the MIPA Laboratory of Haluoleo University Kendari. The sample characteristics test results can show in Tables 1 to 5.

**Table 1. Recapitulation of clean water sample characteristics**

| Sample parameters | Unit | Clean water |
|---|---|---|
| Density ($\rho$) | kg/m$^3$ | 996.52 |
| Oil and Fat | mg/L | 0.017 |
| Specific gravity (y) | N/m$^3$ | 9772.45 |
| Total suspended solids (TSS) | mg/L | 64 |
| Total dissolved solids (TDS) | mg/L | 350 |
| Kinematic viscosity (v) | m$^2$/s | 8.175 x $10^{-7}$ |

**Table 2. Recapitulation of tofu-making wastewater characteristics**

| Sample parameters | Unit | Tofu-making | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Density ($\rho$) | kg/m$^3$ | 998.07 | 998.32 | 1017.24 |
| Oil dan Fat | mg/L | 0,475 | 0.738 | 0,843 |
| Specific gravity (y) | N/m$^3$ | 9787.70 | 9790.10 | 9970.66 |
| Total suspended solids (TSS) | mg/L | 388 | 410 | 712 |
| Total dissolved solids (TDS) | mg/L | 5970 | 5474 | 5178 |
| Kinematic viscosity (v) | m$^2$/s | 8.334 × $10^{-7}$ | 8.199 × $10^{-7}$ | 8.160 × $10^{-7}$ |

**Table 3. Recapitulation of household wastewater characteristics**

| Sample parameters | Unit | Household | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Density ($\rho$) | kg/m$^3$ | 996.72 | 994.39 | 996.55 | 996.41 |
| Oil dan Fat | mg/L | 0.028 | 0.029 | 0.027 | 0.029 |
| Specific gravity (y) | N/m$^3$ | 9774.47 | 9751.64 | 9772.73 | 9771.43 |
| Total suspended solids (TSS) | mg/L | 172 | 252 | 588 | 4180 |
| Total dissolved solids (TDS) | mg/L | 638 | 636 | 420 | 294 |
| Kinematic viscosity (v) | m$^2$/s | 8.266 × $10^{-7}$ | 8.230 × $10^{-7}$ | 8.240 × $10^{-7}$ | 8.257 × $10^{-7}$ |

**Table 4. Recapitulation of laundry wastewater characteristics**

| Sample parameters | Unit | Laundry | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Density ($\rho$) | kg/m$^3$ | 996.04 | 995.79 | 1017.03 |
| Oil dan Fat | mg/L | 0.017 | 0.035 | 0.013 |
| Specific gravity (y) | N/m$^3$ | 9767.75 | 9765.35 | 9997.64 |
| Total suspended solids (TSS) | mg/L | 190 | 172 | 1384 |
| Total dissolved solids (TDS) | mg/L | 420 | 638 | 1596 |
| Kinematic Viscosity (v) | m$^2$/s | 8.182 × $10^{-7}$ | 8.190 × $10^{-7}$ | 8.244 × $10^{-7}$ |

**Table 5. Recapitulation of workshop wastewater characteristic**

| Sample parameters | Unit | Workshop | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Density ($\rho$) | kg/m$^3$ | 996.78 | 996.28 | 997.39 |
| Oil and Fat | mg/L | 0.028 | 0.045 | 0.033 |
| Specific gravity (y) | N/m$^3$ | 9775.02 | 9770.12 | 9781.06 |
| Total suspended solids (TSS) | mg/L | 1426 | 482 | 1812 |
| Total dissolved solids (TDS) | mg/L | 512 | 520 | 454 |
| Kinematic Viscosity (v) | m$^2$/s | 8.181 × $10^{-7}$ | 8.178 × $10^{-7}$ | 8.144 × $10^{-7}$ |

Table 1 shows the characteristics of the clean water samples. The clean water source is the PDAM in Kendari City. The use of clean water samples as a comparison to wastewater samples because the characteristic values of clean water samples are lower. Clean water samples are assumed to represent safe flow characteristics for discharge into the channel.

Table 2 shows the sample characteristics at three sampling points of tofu-making wastewater in Kendari City. The parameter values of the sampling points show an insignificant difference in value. It shows that the content of wastewater in tofu-making is the same as others and has not mixed with others wastewater. The average value is density ($\rho$) parameter is 1004.54 kg/m$^3$, oil dan fat parameter is 0.69 mg/L, specific gravity ($y$) is 9849.49 N/m$^3$, total suspended solids (TSS) is 503.33 mg/L, total dissolved solids (TDS) is 5540.67 mg/L, and kinematic viscosity (v) is 8.23 × 10$^{-7}$ m$^2$/s..

Table 3 shows the sample characteristics at four household wastewater sampling points in Kendari City. These samples result from washing, bathing, cooking, and other activities. The total suspended solids (TSS) parameter shows significant values between sampling points. The average values are density ($\rho$) parameter 996.01 kg/m$^3$, oil dan fat is 0.028 mg/L, specific gravity ($y$) is 9767.56 N/m$^3$, total suspended solids (TSS) is 1298 mg/L, total dissolved solids (TDS) 497 mg/L and kinematic viscosity (v) is 8.248 × 10$^{-7}$ m$^2$/s.

Table 4 shows the sample characteristics at three sampling points of laundry wastewater in Kendari City. This sample results from washing clothes and has not been mixed with other wastes. Total suspended solids (TSS) and total dissolved solids (TDS) parameters show insignificant values with other sampling points. The average values are density ($\rho$) parameter 1002.95 kg/m$^3$, oil dan fat is 0.021 mg/L, specific gravity (y) is 9843.58 N/m$^3$, total suspended solids (TSS) is 582 mg/L, total dissolved solids (TDS) is 884.66 mg/L and kinematic viscosity (v) is 8.205 × 10$^{-7}$ m$^2$/s.

Table 5 shows the characteristics of the samples at the three sampling points of the workshop wastewater in Kendari City. The value of each parameter shows a significant value against other sampling points except the total suspended solids (TSS) parameters. The average values are density parameter 996.816 kg/m$^3$, oil and fat is 0.035 mg/L, specific gravity is 9775.4 N/m$^3$, total suspended solids (TSS) is 1240 mg/L, total dissolved solids (TDS) is 495.333 mg/L and kinematic viscosity (v) is 8.16 × 10$^{-7}$ m$^2$/s.

Tables 1 to 5 show the results of the characteristic, test showing different values between sampling points although the same sample source. These differences are caused by the nature and composition of the waste source, namely environmental conditions, climate, activities of the community, and other factors**.** The results of this study also show compatibility with previous research by Shaikh et al. (2020) [7], Khotimah et al. (2021) [8], Suryo Purnomo an Wijayanti (2021) [9], Pambudi et al. (2021) [9] and Nurhidayanti, et al. (2021) [11], where their research results show different parameter values for the same wastewater sample source.

The wastewater sample used in analyzing the flow characteristic in closed channels is the sample with the largest parameter value. The parameter values of clean water sample, tofu-making, household, laundry, and workshop can be shown in Figure 5.

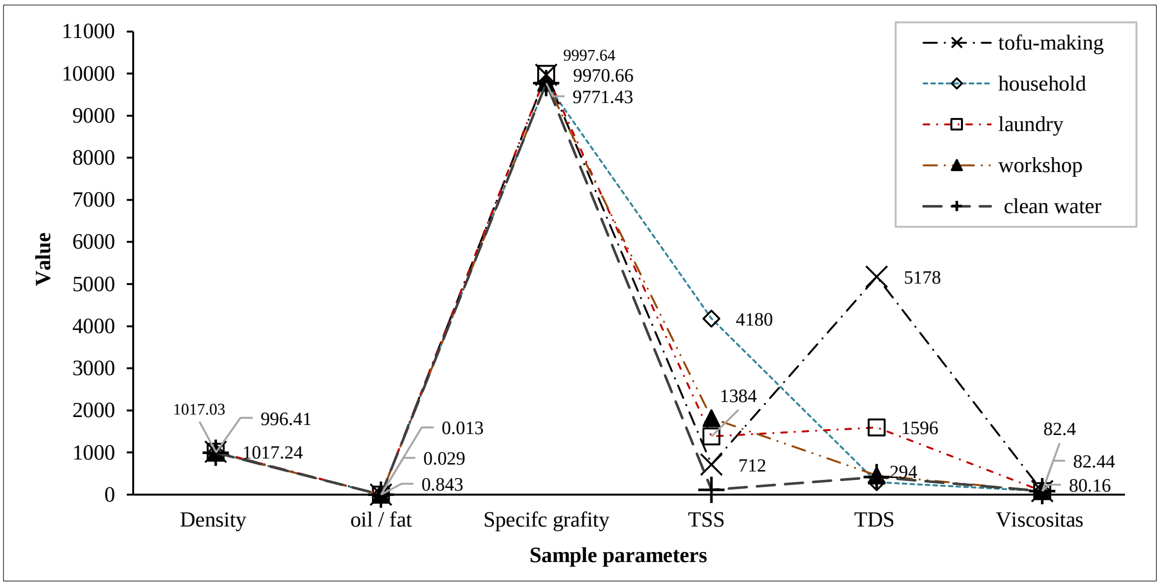


**Figure 5. Samp9le Parameter Values**

Figure 5 shows the parameter values of the wastewater samples used in the closed channel simulation. The nature and composition of the wastewater source influence the different parameter values. Tofu-making sample, largest density value is 1017.24 kg/m$^3$, laundry is 1027.03 kg/m$^3$, workshop is 997.39 kg/m$^3$, household is 996.41 kg/m$^3$, and clean water is 996.52 kg/m$^3$. The largest oil and grease values are tofu-making is 0.843 mg/L, household is 0.029 mg/L, laundry is 0.013 mg/L, workshop is 0.033 mg/L, and clean water is 0.01 mg/L. The specific gravity (γ) value, tofu-making is 9970.66 N/m$^3$, laundry is 9997.64 N/m$^3$, workshop is 9781 N/m$^3$, household is 9771.43 N/m$^3$, and clean water is 9772.45 N/m$^3$. Total suspended solid (TSS) values, tofu-making is 712 mg/L, household is 4180 mg/L, laundry is 1384 mg/L, workshop is 1812 mg/L and clean water is 116 mg/L. Total dissolved solids (TDS) values, tofu-making is 5178 mg/L, household is 294 mg/L, laundry is 1596 mg/L, workshop is 454 mg/L, and clean water is 414 mg/L. Kinematic viscosity ($\upsilon$) value, tofu-making is 8.16 × 10$^{-7}$ m$^2$/s, household is 8.24 × 10$^{-7}$ m$^2$/s, laundry 8.24 × 10$^{-7}$ m$^2$/s, workshop is 8.44 × 10$^{-7}$ m$^2$/s, and clean water is 8.175 × 10$^{-7}$ m$^2$/s.

## 4.2. Characteristics of Wastewater in Closed Channels

Parameters used to analyze flow characteristics in closed channels are discharge (Q), velocity (V), Reynolds number ($Re$), coefficient of friction ($f$), loss of energy ($hf$), and hydraulic gradient ($hf/L$). The variation of flow rate used is clean water discharge. Namely, Q1 is 0.005 m$^3$/s, Q2 is 0.004 m3/s, Q3 is 0.002 m3/s, and Q4 is 0.015 m$^3$/s. Velocity measurements at observation points 0 m, 2 m, 4 m, and 6 m to determine changes in velocity that occurred along the flow.

### *Relationship of Velocity (v) to Energy Loss ($hf$) and Hydraulic Gradient ($hf/L$)*

Discharge (Q) and velocity (V) are the essential factors in pipe flow. Discharge (Q) is used to measure the flow velocity magnitude (V). Velocity measurement results, calculated using empirical equations. The velocity (V) that occurs is influenced by the characteristics of the wastewater and variations in discharge (Q). The relationship between velocity (V) to energy loss (hf) can be shown in Figure 6.

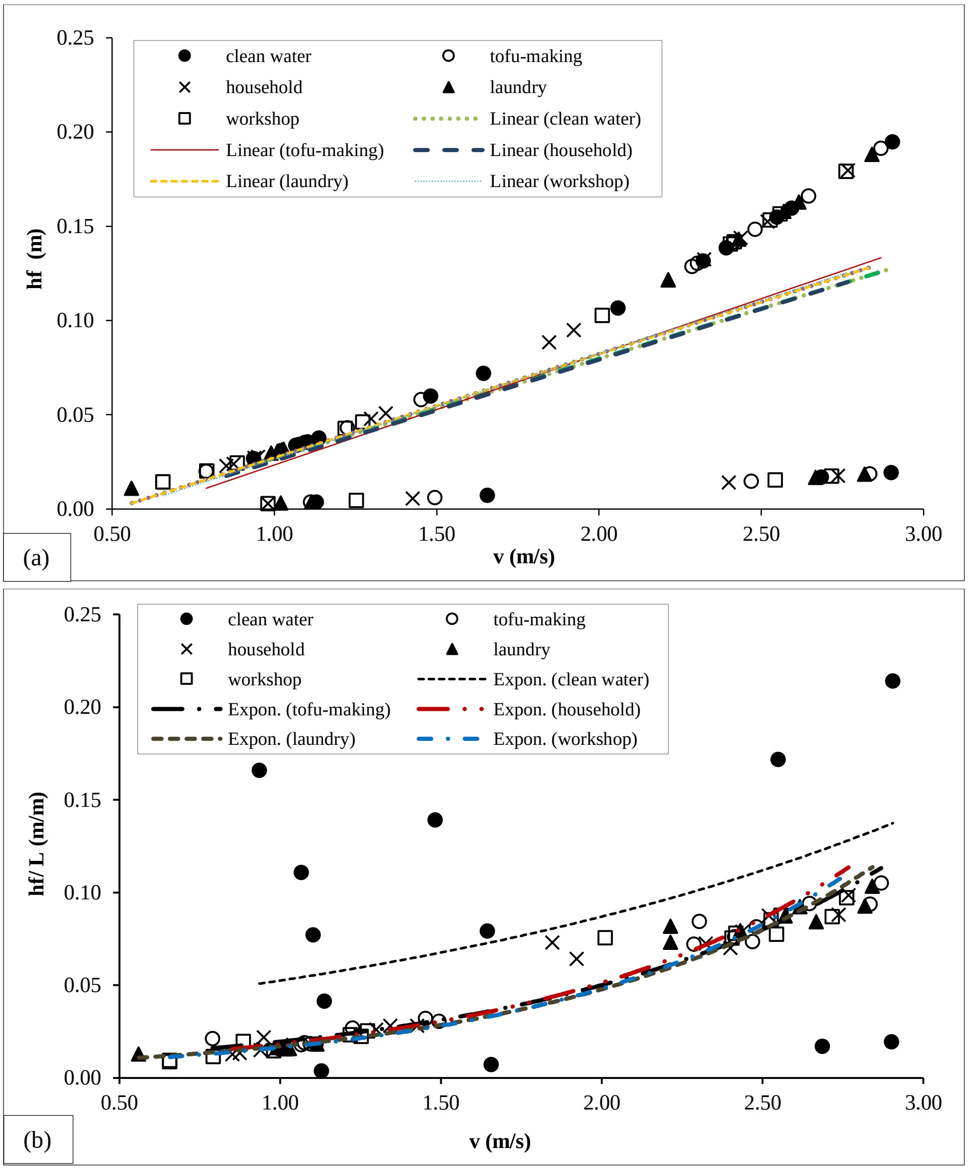


**Figure 6. Relationship of velocity to (a) energy loss and (b) Hydraulic gradient**

Figure 6 shows the relationship between flow velocity to energy loss and the relationship between velocity to the hydraulic gradient. Clean water sample, velocity (V) is 2.83 m/s - 1.07 m/s, energy loss (hf) is 0.0186 – 0.0336 m, and hydraulic gradient (hf/L) is 0.0194 m/m – 0.0185 m/m. Tofu-making sample, velocity (v) is 2.90 m/s – 1.07 m/s, energy loss (hf) is 0.0195 m – 0.0333 m, and hydraulic gradient (hf/L) is 0. 0937 m/m – 0.0179 m/m. Household sample, velocity (V) is 2.74 m/s – 0.85 m/s, energy loss is 0.017 m – 0.022 m, and hydraulic gradient (hf/L) is 0.0881 m/m – 0.0128 m /m. Laundry sample, velocity (v) is 2.84 m/s – 1.03 m/s, energy loss (hf) is 0.018 m – 0.021 m, and hydraulic gradient (hf/L) is 0.0928 m/m - 0.0159 m/m. Workshop sample, velocity (v) is 2.54 m/s – 0.66 m/s, energy loss (hf) is 0.015 m – 0.014 m, and hydraulic gradient (hf/L) is 0.0775 m/m – 0.0087 m/m. The discharge of the clean water sample is greater that of other wastewater samples because the parameter value of clean water is smaller. The greater the parameter value indicates the amount of material contained in the flow, both dissolved and non-dissolved, and makes the flow heavier. The value of this parameter will affect the flow velocity in the pipe.

The discharge (Q) increase is followed by an increase in velocity (V) in the pipe. The long flow distance (L) in the pipe causes a loss of energy (hf) and a decrease in velocity (V). The energy loss (hf) is mainly caused by the friction between the particles in the flow and the friction between the flow particles and the pipe wall (f). Linearly shows a large velocity (v), then the loss of energy is also large (hf) (Figure 6-a). This research is also in the same as the results of research by Nosrati et al. (2017), which showed that in pipes, there is energy loss that occurs not only due to geometric causes but also due to Reynolds number, relative wall roughness, and Euler number [23]. Bachrun et al. (2021) and Vlasak et al. (2011), the results of the research show that the hydraulic gradient (hf/L) affects flow velocity (v). The large hydraulic gradient (hf/L) at both points of the pipe causes the flow to be fast. The hydraulic gradient (hf/L) is affected by the loss of energy and the flow path length (L). Linearly increasing velocity (V) is followed by increasing hydraulic gradient (hf/L) [26, 27].

### *Relationship of Reynolds Number to Flow Velocity (V) and Coefficient of Friction (f)*

The Reynolds number indicates that the flow can be classified based on a certain number. Reynold determined that the Reynolds number below 2000 is laminar, and above 4000 is turbulent flow. Figure 7-a shows the relationship between the Reynolds number (Re) and the flow velocity (V). While, Figure 7-b shows the relationship between the Reynolds number (Re) and the friction coefficient (f).

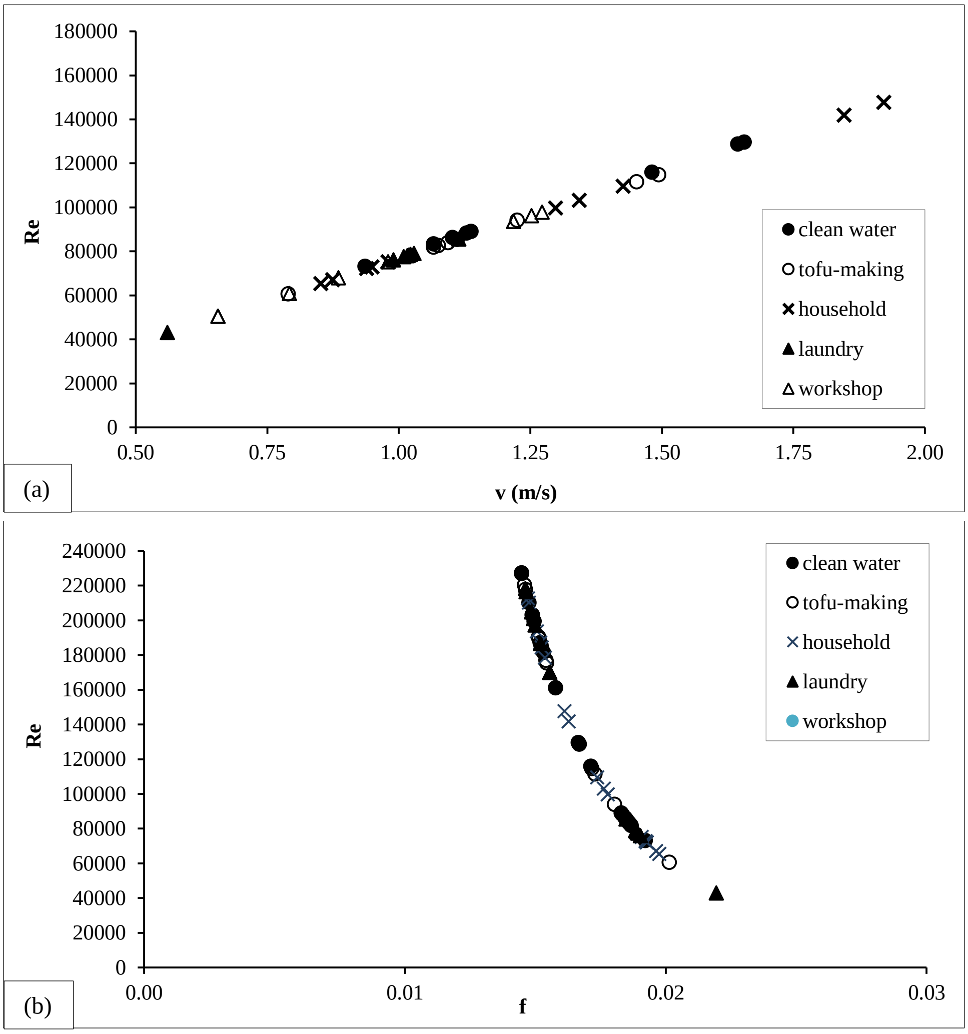


**Figure 7. Relationship of Velocity and (a) Friction Coefficient (b) to the Reynolds Number**

Figure 7 shows the relationship between the velocity and the Reynolds number and the relationship between the friction coefficient and the Reynolds number. For clean water samples, velocity (V) is 2.83 m/s - 1.07 m/s, Reynolds number (Re) is 225.654 – 84.872, and coefficient of friction (f) is 0.0145 – 0, 0185. Tofu-making sample, velocity (V) is 2.90 m/s – 1.07 m/s, Reynolds number (Re) is 222.883 – 81.917, and friction coefficient (f) is 0.0145 – 0.0185. For household samples, velocity (V) is 2.74 m/s – 0.85 m/s, Reynolds Number (Re) is 210.275 – 65.428, and Reynolds Friction coefficient (f) is 0.0148 – 0, 0198. Laundry sample, velocity (v) is 2.84 m/s – 1.03 m/d, Reynolds Number (Re) is 216.555 – 79.042 and Friction coefficient (f) is 0.0146 – 0.0188. Workshop sample, velocity (V) is 2.54 m/s – 0.66 m/s, Reynolds Number (Re) is 195.397 – 50.451, and friction coefficient (f) is 0.015 – 0.0211. The flow type in all samples of wastewater shows turbulent flow where the Reynolds number (Re) is above 4000. As the Reynolds number (Re) increases, the friction coefficient decreases (Figure 7-b). This shows the agreement with Darcy Weisbac's equation which shows an inverse comparison between Re and f [21, 22]. The friction coefficient (f) is influenced by the pipe diameter (D), the turbulent, transition, and laminar, Reynolds number (Re), and the pipe roughness (e).

Increasing the volume of water in the channel causes the velocity (V) to increase. Variation of discharge changes of 0.005 $m^3/s$ and 0.004 $m^3/s$, 0.003 $m^3/s$ and 0.0015 $m^3/s$, changes the flow characteristics in closed channels. At discharge, 0.005 $m^3/s$ and 0.004 $m^3/s$ did not show a change in the flow characteristics in the pipe. The pipe cross-section (A) is fixed, namely 0.064 m water level, and the volume of water is still large at discharges of 0.005 $m^3/s$ and 0.004 $m^3/s$, still showing the same characteristics between samples of wastewater, at discharges of 0.003 $m^3/s$ and 0.0015 $m^3/s$, where the volume of water in the cross-section of the pipe is reduced, and a free surface appears in the channel. While the discharge is 0.0015 $m^3/s$, the water level in the channel is at 0.062 – 0.060 m.

Samples of wastewater from laundry, tofu-making, and workshops are wastewater with almost no solid particles in their streams. Although this sample has no solid particles, the parameter values in oil and grease, total suspended solids (TSS), and total dissolved solids (TDS) are greater than samples of clean water and household wastewater. Parameter values indicate the presence of content contained in wastewater, both dissolved and insoluble. The content of the wastewater, in the form of chemicals and biology, can leave residual wastewater on the canal walls. Within a certain period, this can reduce channel performance (Figures 8b, 8c, and 8d). For samples of household wastewater, at discharges of 0.005 $m^3/s$ and 0.004 $m^3/s$, they can still transport solid particles in the stream up to a distance of 6 m. Changes in sediment movement begin to occur at a velocity of 1.49 m/s, where the sediment moves from the top and center of the pipe to the bottom. This velocity is called the limit deposit velocity (LDV), the minimum velocity needed to hold solid particles in the pipe [28]. When the velocity is less than this velocity, sedimentation begins to occur (Figure 8-a).

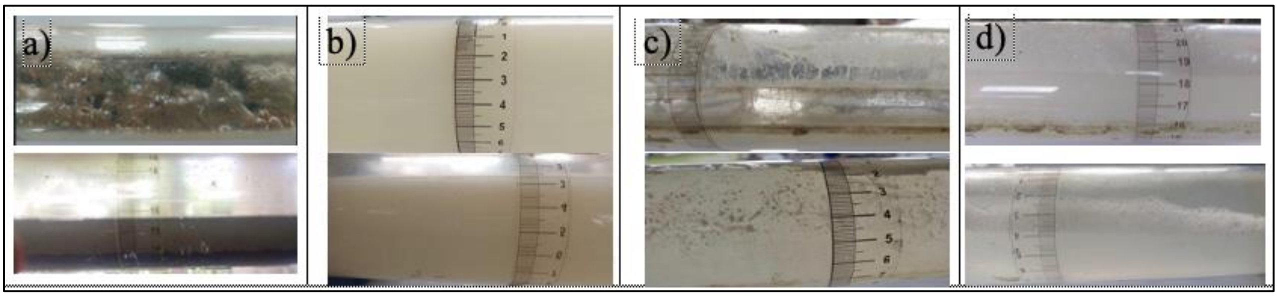


**Figure 8. Phenomenon of flow in pipes (a) households, (b) tofu-making, (c) household (d) laundry**

The characteristics of the sediment samples in household wastewater show that the sediment sizes are not uniform. Sediment size was at 0.15 mm and 0.29 mm (percentage passing the size above 50%), while the density for sediment samples was 2.62.

## 5. Conclusion

Velocity is the most important factor in pipe flow. The velocity is highly dependent on the wastewater type, source, and characteristics. In wastewater characteristics, important parameters are density, total suspended solids, and total dissolved solids. The larger the parameter value, the more concentrated the flow and the greater the velocity required. Clean water sample velocity is 2.90 – 1.07 m/s, tofu-making is 2.83 – 1.07 m/s, household is 2.74 – 0.85 m/s, laundry is 2.84 – 1.03 m/s, and workshop is 2.54 – 0.66 m/s. The long flow distance ($L$) in the pipe causes a loss of energy ($hf$) and a decrease in velocity ($V$). The energy loss ($hf$) is mainly caused by the friction between the particles in the flow and the friction between the flow particles and the pipe wall ($f$). The large value of the content in the wastewater will reduce the velocity because the content of the wastewater is considered a load that must be transported to the end of the channel. As the discharge increases, the velocity and Reynolds number will increase while the friction coefficient decreases. Energy loss occurs due to friction between the flow and the channel walls. The channel length will increase the energy loss and the greater the friction coefficient. To avoid settling in the closed channels, the limit deposit velocity (LDV) for household wastewater is 1.49 m/s. This research is very important to be applied to planning closed channels for wastewater, and more research is needed for different channel models and waste sources.

## 6. Declarations

### 6.1. Author Contributions

Conceptualization, R.B. and S.; methodology, R.B.; software, R.B.; validation, R.B., S.B. and S.; formal analysis, R.B., S., and S.B.; investigation, R.B.; resources, R.B.; data curation, R.B.; writing—original draft preparation, R.B.; writing—review and editing, R.B., S and S.B.; visualization, R.B.; supervision, R.B.; project administration, R.B. All authors have read and agreed to the published version of the manuscript.

### 6.2. Data Availability Statement

The data presented in this study are available in article.

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### 6.5. Conflicts of Interest

The authors declare no conflict of interest.

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