

Analysis of the Influence of Pond Design on the Efficiency of Residual Feed Disposal in Inland Fisheries Farming Ponds

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Abstract - Failure in inland fisheries farming with artificial pond mechanisms made of tarpaulin is closely related to water quality issues. Water problems contaminated with dirt, temperature, and acidity levels trigger mass fish deaths. One source of water pollution is the sediment of uneaten feed by fish, which has been at the bottom of the pond for too long. Removing sediment periodically, accurately, and quickly can maintain water quality and reduce production costs for adding replacement water to the pond that is wasted with sediment. This study aims to determine the effect of variations in pond design on the hydrodynamic behaviour of pond flow, which affects the rate of disposal of uneaten feed by fish. The study used the Computational Fluid Dynamics (CFD) simulation method using ANSYS 2023 R2 software. The simulation used data of 20 grams, or 8186 pieces, of fish feed pellet particles injected through the water surface, and its movement was observed for 100 seconds. The slope of the pond bottom in this simulation was varied between 0°, 4°, 8°, and 12° with circular pond geometry. The simulation results show that the slope of the pond bottom affects the hydrodynamic behaviour of pond flow and the fish feed pellet particle removal rate, where a slope of 12° shows the best results.

Keywords: Inland fisheries, artificial pond, CFD, fish feed, water quality.

I. INTRODUCTION

Superior fish commodities are produced through a planned fish farming process that meets technical standards, taking into account internal factors, such as the origin and quality of seeds, as well as external factors such as water quality, type and technique of feeding, application of supporting technology, and pest and disease control. Optimal water quality is one of the key elements in the success of fish farming, especially in inland fisheries systems with artificial ponds. Fish feed is the largest cost component in inland fish farming, contributing up to 50–60% of the total production costs and significantly affecting water quality due to feed

residues left at the bottom of the pond [1, 2]. Therefore, feed needs to be developed at an affordable price, with complete nutrition, made from natural and local raw materials, and in accordance with the type of fish consumption being farmed [3]. Theremaining fish feed and fish waste will form cohesive particles called flocs, which settle in the tank or module in the recirculating fish farming system [4]. The combination of sediment or flocs has the potential to produce ammonia, a toxic compound that can have a significant negative impact on fish health, including poisoning that leads to mass death in farmed fish [5].

In well-managed fish ponds, ammonia accumulation to lethal concentrations is rare. However, ammonia can cause sub-lethal effects [6], which are toxic effects at low concentrations that do not immediately kill or have adverse effects in the short term but can damage the aquatic ecosystem or threaten the life of fish in the long term [7]. Sub-lethal effects include conditions such as growth inhibition, inefficient feed conversion, and decreased resistance to disease [6].

Fluctuations in ammonia levels in ponds are influenced by several factors, including the presence of residual feed that settles, fish excretion, the presence of pests, and plankton population explosions. One method commonly used to reduce ammonia levels is to periodically replace the pond water with clean water.

Periodic water changes, in addition to providing benefits, also have negative impacts, such as causing drastic changes in the pond ecosystem with the emergence of indications of disturbances in the algae and moss population, as well as changes in temperature and pH that can affect fish growth and development [8]. The method of periodic water changes also requires a large volume of water, thus increasing operational costs, including electricity consumption. This approach is certainly not suitable for fish farming areas with limited clean water sources or locations far from clean water sources. This is very uneconomical.

Based on these problems, it is necessary to conduct a study on the design of artificial fish farming ponds that have an optimal system for disposing of fish feed waste and fish waste (flocs). The application of appropriate technology is the key to efficient modern pond management, which not only maintains water quality but also maintains the stability of environmental parameters such as pH and temperature consistently [9,10].

This study uses Computational Fluid Dynamics (CFD) simulation software-based modelling on ANSYS 2023 R2 to analyze the flow velocity in the drain in a fish farming pond through a numerical approach. The purpose of this study is to evaluate the effect of changes in the geometry of the pond bottom by providing different slopes on the bottom floor of the pond on the flow velocity in the drain in an artificial fish farming pond so that a pond design can be proposed that can maximize the efficiency of disposing of fish feed waste and fish waste by minimizing the volume of water that is also wasted.

II. METHODOLOGY

This research uses the Computational Fluid Dynamics (CFD) approach. In CFD, numerical analysis uses volume control as an integration element in equations such as mass, momentum, and energy balance. CFD operations have three stages: pre-process, process, and post-process.

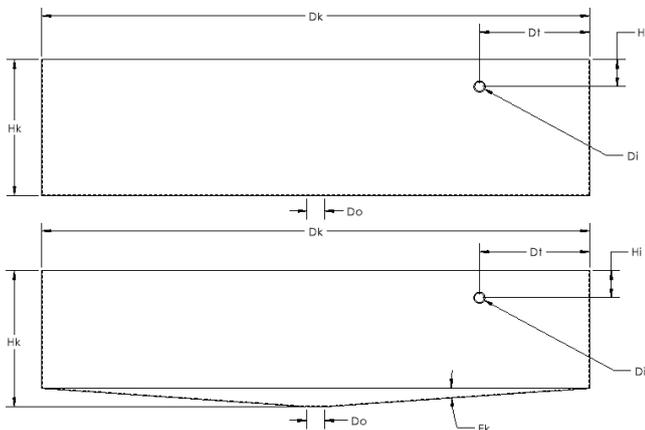


Figure 1: Geometric design of fish farming ponds

Table 1: Fish Farming Pond Dimensions

Description	Value
Dk-Pond Diameter (m)	2
Hk-pond Height (cm)	50
Di-Inlet Diameter (cm)	35
Do-Outlet Diameter (cm)	65
Dt-Distance from Inlet to Edge (cm)	400
Hi-InletHeight(cm)	100
Ek-Pond Slope (o)	0, 4, 8, 12

Pre-processing is the first step in analyzing a CFD model. The technique is to create a model in a CAD (computer-aided design) package, then generate a suitable and appropriate mesh, and continue by applying boundary conditions and fluid properties. The modelling of fish farming ponds in this study uses data from Table 1 and Figure 1. The meshing process in this simulation uses a tetrahedron meshing type with a total of 216901 elements. In the simulation setup, the turbulence model used will be determined by referring to several types of turbulence models provided by ANSYS. The model chosen is the K-Epsilon model. The K-Epsilon model used is standard with standard turbulence parameter values of $C_{\mu} = 0.090$, $C1\text{-epsilon} = 1.440$, $C2\text{-epsilon} = 1.920$, TKE Prandtl Number = 1, and TDR Prandtl Number = 1.300.

Particle discharge rate is the number of particles passing through the outlet or discharge side, per unit time. A thorough understanding of the discharge rate is crucial to evaluating the efficiency of the pond flow. We can visualize and optimize the flow pattern through the CFD approach to ensure optimal and sustainable pond performance. The calculation formulation of the particle discharge rate (K) can be seen in Equation 1 [11]. Where s is the total particles injected and s_p is the remaining particles in the fluid. Figure 1 shows a comparison of the particle release rate at each slope of the pool.

$$K = \frac{s - s_p}{s} \times 100\% \quad (1)$$

The diameter of the fish feed pellets was chosen to be 2 mm, which is the standard size for fish rearing with a density of 1300 kg/m^3 . The Particle Size Distribution (PSD) method used is uniform with the assumption that the injected particles are pellets with a uniform diameter and injected for 1 second. Particles are injected through the water surface with an area limit of 100 mm to 1500 mm to avoid pellets falling directly into the outlet hole and to ensure that the particles are affected by the flow from the inlet. Pellets are injected after the simulation has run for 600 seconds, after the flow is fully developed.

To evaluate the particle release rate, 20 g of particles with a density of 1300 kg/m^3 were injected in one second. The particles were injected through the water surface and their movement was observed for 100 seconds. In a pool without a slope, the particles tend not to move because the flow velocity from the inlet is very low so it is unable to move the particles strongly. However, at slopes of 4° , 8° , and 12° , the particle movement significantly increased because there was a gravity factor due to the slope of the pool.

In the simulation process, in addition to setting the mesh, it is also necessary to determine the computational domain. The computational domain acts as a boundary that allows a

model to function properly. In this study, the computational domain used includes the inlet, exit, and walls. Determining this computational domain is done by selecting a surface in the geometry and giving it a name that matches its boundary conditions during the meshing process. The appearance of the computational domain for this simulation can be seen in Figure 2.

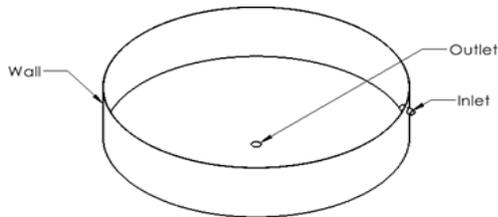


Figure 2: Computing domain

The process stage in simulation is the step where the basic equations are solved at each point in the fluid element using a predetermined method. The time required to solve these equations varies depending on the complexity of the case being studied. The process stage is considered complete when the desired minimum residual value at each iteration has reached the convergence level. The software will display a residual graph at each iteration for process monitoring and control.

The post-process stage is a step that is carried out after the solver process is complete. At this stage, the data is analyzed and presented in various forms, including graphs, vectors, and contours, which represent the parameters that have been tested, such as tangential and axial velocities in the pool, as well as particle analysis in the pool. Each type of data is presented for each variation that has been tested. Data from various variations are then analyzed to conclude from the results of the discussions that have been carried out.

The analysis was conducted to determine the effect of the slope on the pond floor on the velocity flow field and particle release performance in fish farming ponds. To facilitate the analysis of the simulation results, contour and vector retrieval were carried out on the XY axis. The data in the form of graphs were obtained radially when the Y value = 0 mm. Figure 3 shows a schematic of contour retrieval.

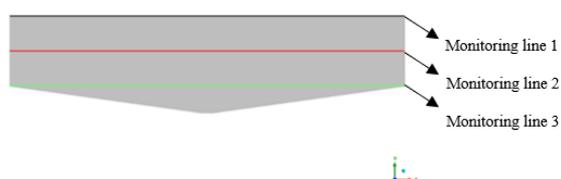


Figure 3: Schematic of contour capture area and simulation graph

III. RESULTS AND DISCUSSION

Velocity distribution is an important aspect in understanding the flow dynamics and fluid behaviour in a pond. Using CFD simulation, this analysis will reveal the flow patterns that occur, areas with high and low velocities, and factors that affect the velocity distribution. The results of this analysis are expected to provide deep insight into the flow characteristics in the pond and its implications for pond design and operation. Figure 4 shows the flow velocity vector in the pond, and Figure 5 shows the velocity contour on the XY axis monitoring plane.

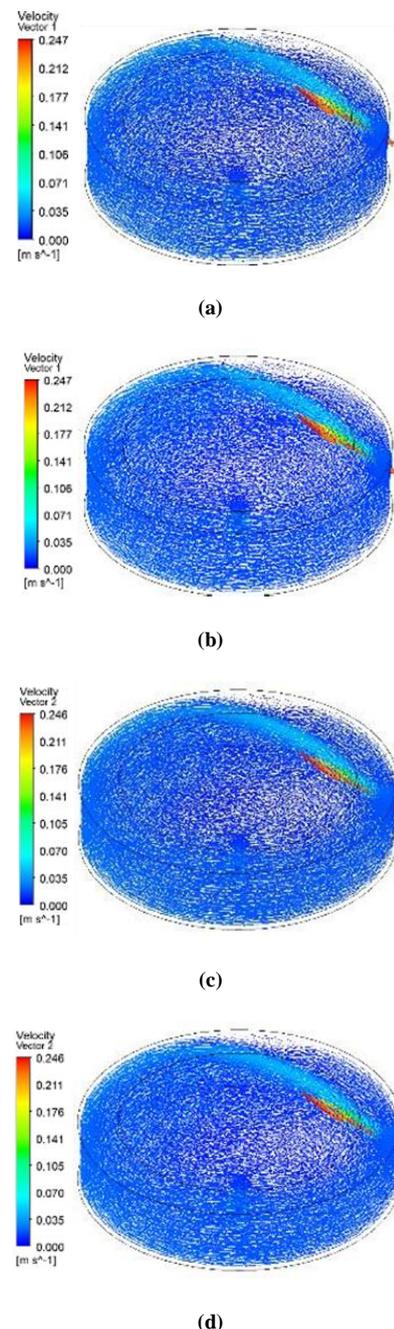


Figure 4: Velocity Vector in a fish pond with a slope angle at the bottom of the pond: (a) 0°, (b) 4°, (c) 8°, (d) 12°

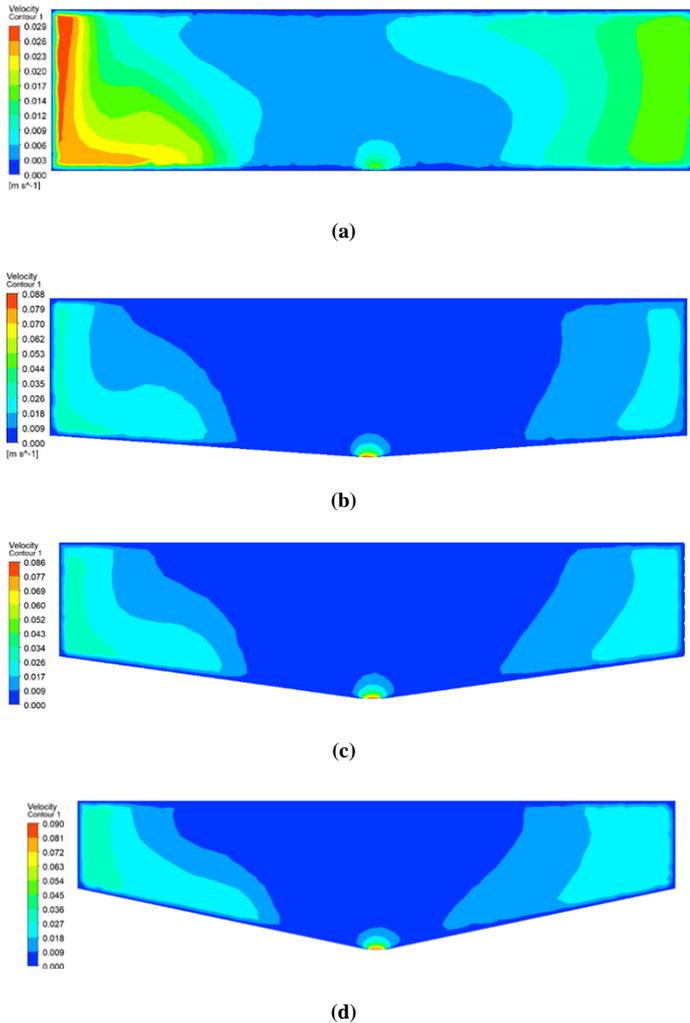


Figure 5: Velocity contours on the monitoring plane: (a) 0°, (b) 4°, (c) 8°, (d) 12°

The simulation results show that the flow velocity tends to be uniform at four variations of slope. In the fish farming pond, the flow velocity near the wall is higher and the lowest in the centre of the pond. The flow forms a vortex that leads to the centre of the pond with a lower flow velocity in the centre. The vortex flow becomes more clearly visible as the slope increases as seen in Figure 5, the formation of a higher flow zone on the wall and a lower flow zone in the center. In general, the formation of the flow zone will affect the sedimentation process and direct sediment particles closer to the outlet of the fish farming pond.

Figure 6 to Figure 9 show the flow velocity curves at different monitoring lines. The monitoring lines were taken at three different levels, namely the zone near the water surface (monitoring line 1), the zone in the middle of the pond (monitoring line 2), and the zone near the bottom of the pond (monitoring line 3). The flow velocity curve resulting from the simulation process at monitoring line 1 shows that the flow that occurs tends to be higher than the flow velocity at

monitoring line 2 and monitoring line 3. This is due to the influence of fluid flow from the inlet. From the surface to the bottom of the pond, the high-speed flow zone is getting wider, this is due to the influence of the slope of the pond, which means that the smaller the cross-section of the pond due to the angle of inclination at the bottom of the fish farming pond, the higher the flow velocity.

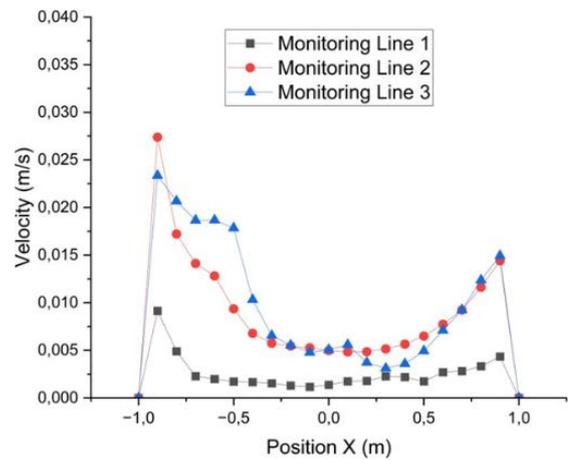


Figure 6: Velocity curve in a fish pond with a pond bottom slope 0°

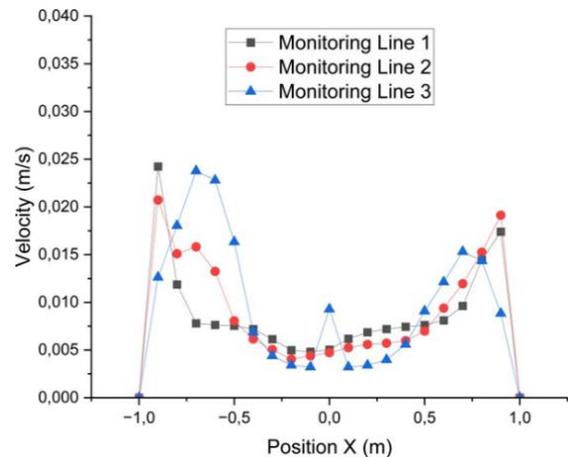


Figure 7: Velocity curve in a fish pond with a pond bottom slope 4°

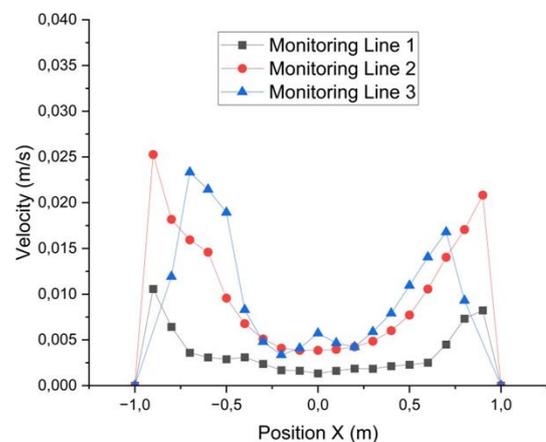


Figure 8: Velocity curve in a fish pond with a pond bottom slope 8°

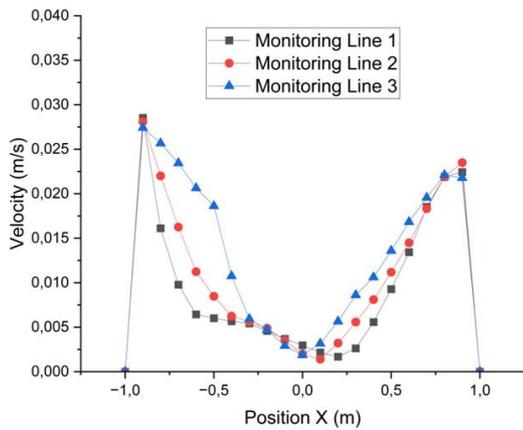


Figure 9: Velocity curve in a fish pond with a pond bottom slope 12°

Based on the analysis of the flow velocity on the monitoring line, it was found that the flow velocity on the monitoring line showed a uniform trend, namely the velocity distribution formed an “M-shaped” pattern and the flow velocity showed a low distribution trend in the middle and a high distribution on both sides of the edge. The flow velocity on the monitoring line was the same, which proved that the flow velocity was stable. However, the velocity in the middle area of the cultivation pond was still below 0.005 m/s. The “M-shaped” velocity distribution pattern is in line with the research conducted by [12,13].

Figure 10 shows a comparison of the particle release rate of the four slope variations. Based on the graph, the slope of 12° shows the fastest release rate with only 30 seconds needed to remove all injected particles. Meanwhile, the lowest particle release rate occurred in the fish farming pond without a slope on the bottom floor, which was only able to remove 49 particles from a total of 8186 injected particles. At a slope of 4°, the particles can be completely removed at 50 seconds and at a slope of 8°, the particles are completely removed at 40 seconds.

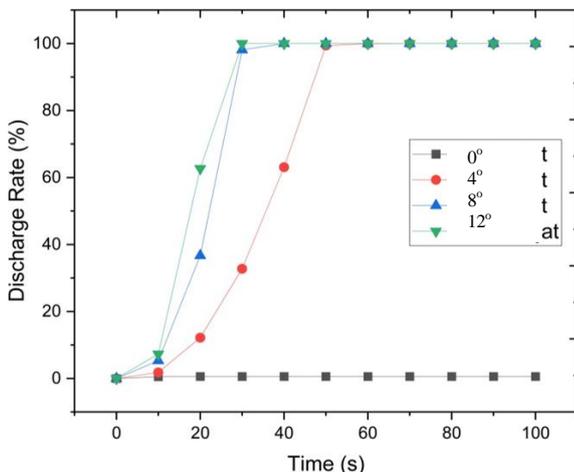


Figure 10: Particle discharge rate at varying pond bottom slopes

IV. CONCLUSION

Based on the CFD simulation results, it can be seen that the flow in the cultivation pond forms a vortex centred in the middle of the pond with a lower velocity value at the centre of the circle. The greater the slope of the pond, the more visible the vortex flow is marked by a lower velocity at the centre of the pond and a wider low-velocity zone. The flow forms an “M-shaped” pattern on the monitoring line with a velocity value at the centre of the pond below 0.005 m/s. These phenomena contribute to particle movement, thereby accelerating particle collection at the exit. Modification of the pond slope increases the particle release rate. The highest particle release rate occurs in a pond with a slope of 12° with a release time of all particles for 30 seconds. Meanwhile, the lowest particle release rate occurs in a pond with a slope of 0° only being able to remove 49 particles out of 8186 injected particles. At a slope of 4°, particles can be completely removed at 50 seconds and at a slope of 8°, particles are completely removed at 40 seconds.

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