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Hydrodynamic analysis of different baffle layouts in a facultative pond to mitigate operational problems through computational fluidodynamics

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***Abstract*— *The main operational problems found in facultative ponds are the dead zones, short circuit zones of recirculation zones, caused mainly by the accumulation of solids in the bed. The use of baffles is one way of mitigating these problems. Thus, the objective of this work is to compare four baffle installation formats in an optional pond using computational fluid dynamics, and subsequently to identify the occurrence of the main operational problems in each model. For the development of the study, the software Ansys 14.5®was used, where the geometry of the analyzed pond was replicated, including in each model a different layout of the baffles. The use of deflectors allowed the mitigation of the main problems, such as the accumulation of sediments, and it was able to increase the flow velocity in all scenarios, as well as bringing the hydraulic retention time closer to that of the project. According to the data obtained, and the visual analysis of the simulations, it is possible to affirm that the baffle layouts assessed in scenario four would be more adequate to mitigate the operational problems found in the studied pond, as this arrangement conditions the flow of the piston type, which provides less sediment accumulation and the development of dead zones and short circuit zones in the bed. It was concluded that the installation of baffles could mitigate the operational problems of stabilization ponds by directing the flow. Likewise, there was a need for continuous studies to improve wastewater treatment systems.*

I. INTRODUCTION

Silva (2007) defines baffles, or deflectors, as transversal, vertical, or longitudinal barriers capable of altering the movement of a fluid within a pond by dividing it into several channels. The layout of the baffles is related to the intended purpose of the installation. According to Takeuti (2003), longitudinal baffles form parallel channels in the ponds, conditioning the flow to the piston flow, attributing greater efficiency to the treatment system than other hydraulic models, such as dispersed flow and complete mixing, in the case of facultative ponds.

Another way of arranging deflectors in ponds is in a transversal way, increasing the path taken by the fluid between the inlet and the outlet of the pond. This arrangement is indicated for cases where the operational hydraulic retention time is less than the theoretical HRT, because with the increase in the route, the longer the time necessary for the fluid to travel the entire length of the pond. This layout allows greater exposure of the effluent to UV rays, for example, helping to remove pathogenic organisms (Kellner; Pires, 1998)

The use of baffles aids in the removal of various classes of pollutants. The regulation of the sedimentation rate, the increase in HRT, the longer time of exposure to sunlight, are factors resulting from the use of baffles in ponds and they condition the improvement of the treatment system in the removal of organic pollutants such as BOD, from the remaining pathogenic organisms, in addition to nitrogen compounds that are not eliminated in the previous steps (Von Sperling, 2017)

Based on the change in flow caused by the installation of baffles and its influence on the deposition of solids in the pond beds, this study aims to compare four baffle installation layouts in a facultative pond in the city of Campo Mourão, then analyzing the main operational problems of each installation format.

II. MATERIAL AND METHODS

With the pond sizing information obtained from the analysis of the treatment plant implementation project, the facultative pond three-dimensional geometry was replicated on the solid creation platform available in the Ansys 14.5® *software*, a high-performance program used for computer simulation. It generated four models, all with dimensions equal to the original, but using baffles to direct the fluid in its path. The four models of baffles were:

1. Four lateral baffles, two-thirds the length of the pond, arranged as follows: the first baffle, parallel to the fluid inlet duct, the rest, parallel to the outlet ducts, having an equivalent distance of approximately 25m between them (Figure 1).

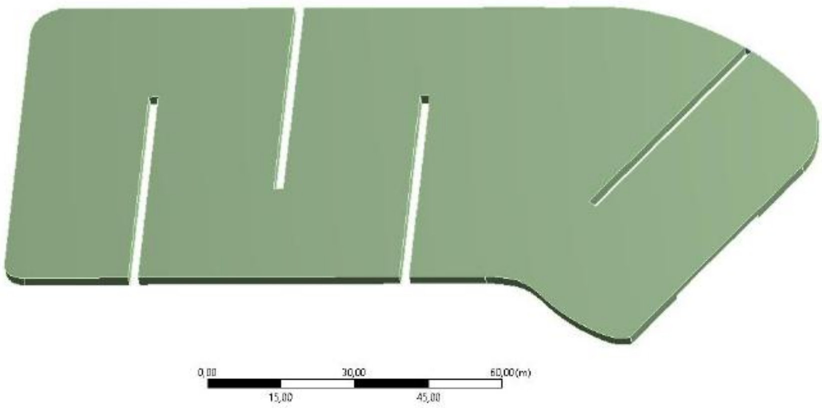

Figure 1 First layout model of the four baffles in the WWTP pond

2. Four lateral baffles, with dimensions and distances equal to the previous case. However, all arranged parallel to the outlet ducts (Figure 2).

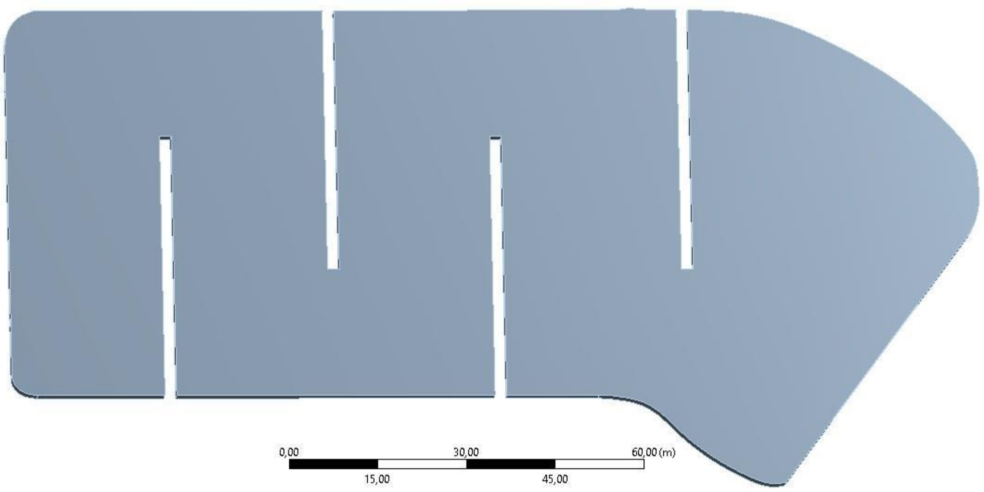

Fig.2 Second layout model of the four baffles in the WWTP pond

3. Two central baffles plus four lateral baffles. In this situation, the central baffles were two-thirds the width of the pond, and they were arranged alternately with the lateral baffles, which were one-third the length of the pond. The spacing remained equivalent between them. The first baffle was central and parallel to the inlet duct, and the others parallel to the outlet ducts (Figure 3).

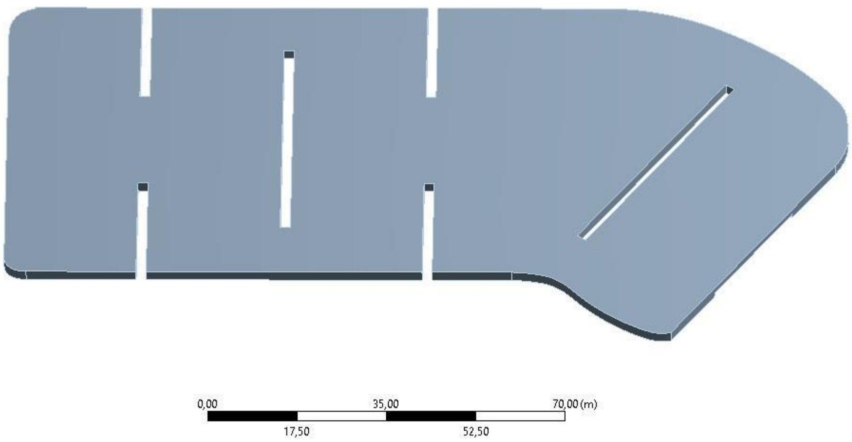

Fig.3 Model of central and lateral baffles at the WWTP

4. Three central baffles, longitudinally arranged, perpendicular to the inlet and outlet ducts, with a length of two-thirds of the total length of the pond and a distance of approximately 17m (Figure 4).

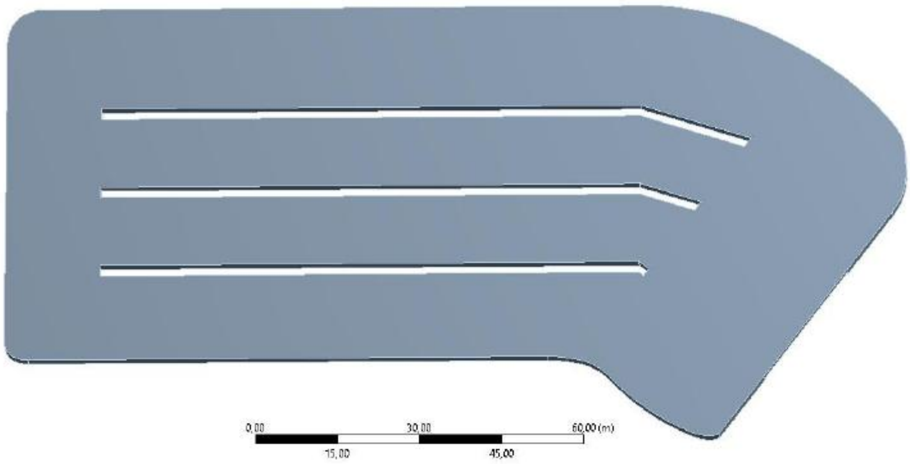

Fig.4 Longitudinal baffle layout model

The results were analyzed by comparing four different flow models with barriers (baffles). The function of this comparison was to verify the model that presented less operational problems, such as controlled flow velocity, generation of short-circuit zones, or dead zones, in addition to retromixing zones.

In addition to being able to find the best model for the disposition of baffles, the comparison also made it possible to justify the creation of the floating baffle model, which can be used in different formats and installed in ponds already in operation.

III. RESULTS AND DISCUSSION

To demonstrate the mitigation potential of the baffles for the operational problems already elucidated, four models of the layout of the barriers inside the pond are presented below, and the consequence of these different dispositions in the flow of the liquid mass in the bed.

Case 1: baffle arrangement on the sides and center of the pond, parallel to the inlet and outlet ducts (Figure 5).

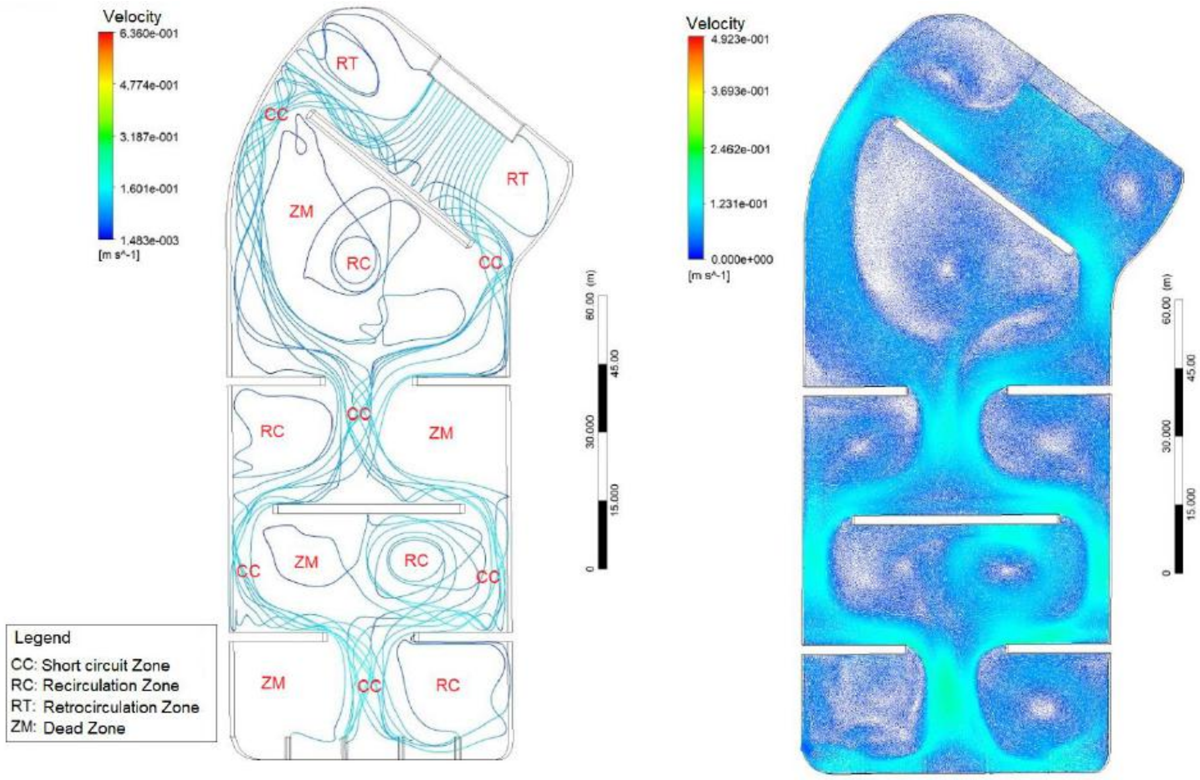

Fig.5 Scenario 1 - central and lateral baffles

The baffle located near the inletof the pond contributed to the dispersion of the liquid throughout the available area, preventing the fluid from being directed in the same direction. However, due to the proximity of the inlet duct and the velocity of the flow, there was the formation of recirculation zones on the sides of the pond, as well as the creation of a large dead zone after the baffle.

In the rectangular region, the fluid behaved uniformly, dispersing throughout the available area and no longer forming low-velocity regions. In this scenario, it is possible to predict the formation of a sediment bank in the region of the first baffle, close to the inlet, just as it happens in the original layout. The current lines show the formation of the recirculation zones and the large low-velocity region right after the first baffle.

The velocity in this scenario increases proportionally to the proximity of the outlet ducts, varying between 0.002 m/s and 0.221 m/s. This characteristic is because the flow is continuous, and the inlet volume is equal to that of the outlet, reducing, therefore, the possibility of significant dead zones. This fact is explained by the area of the outlet ducts being smaller than the area of the inlet duct, and for the flow to remain the same, the flow velocity must be greater.

Case 2: four lateral baffles, with the first parallel to the inlet duct and the others parallel to the outlet ducts (Figure 6).

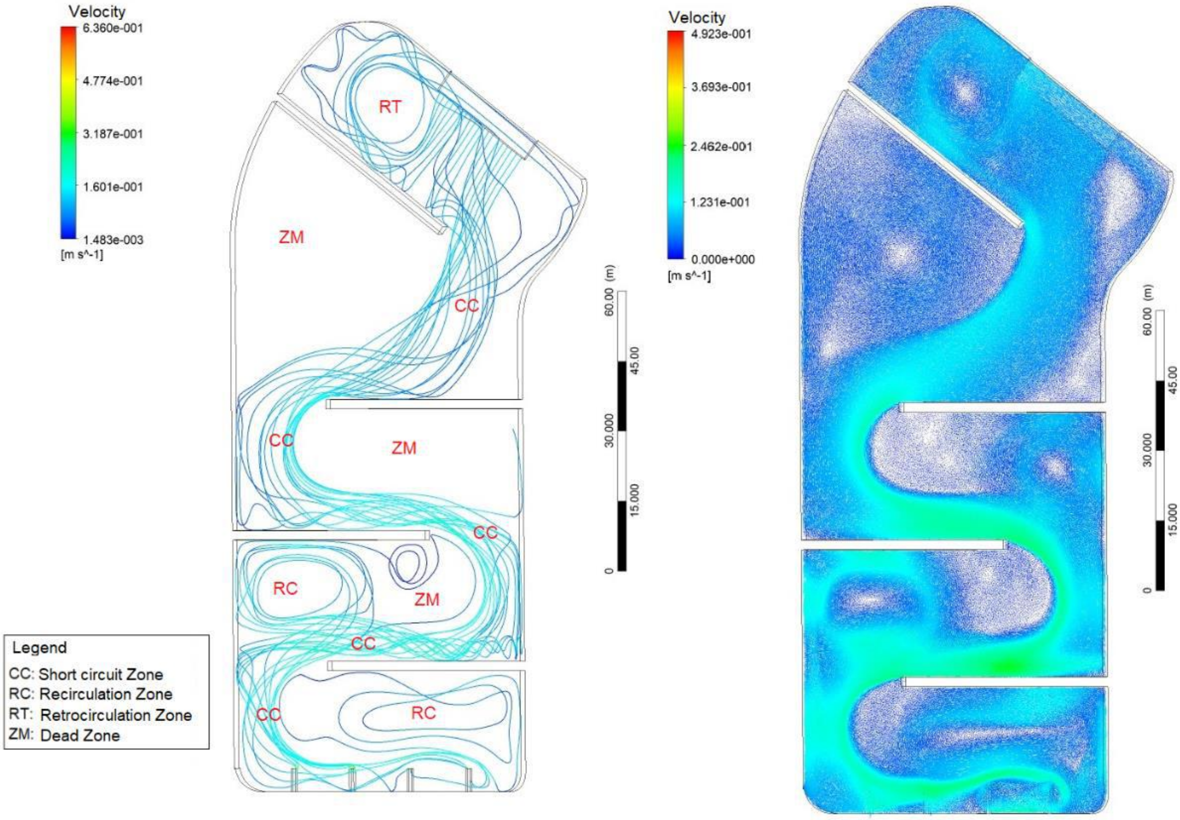

***Fig 6** Scenario 2 - lateral baffles, with the first parallel to the inlet*

As in the first case, there is the formation of several recirculation regions and a large dead zone after the first baffle. The fluid, in the rectangular area, is distributed in a way to form a channel, and the fluid starts to behave as in meandering natural water bodies, that is, it starts to drag sediments on the outside of the curves and to accumulate on the part internal. Thus, in this conception of barriers, the accumulation of sediments would happen mainly behind the baffles, increasing according to the proximity of the slopes.

The presence of a baffle parallel to the inlet duct induces the formation of dead zones, a fact related to the inlet velocity of the fluid into the pond and, therefore, dependent on the flow of the effluent. The velocity ranged between 0.002 m/s and 0.324 m/s. However, the images show that most of the flow presented an average velocity of around 0.121 m/s.

Case 3: four baffles arranged parallel to the outlet gates (Figure 7)

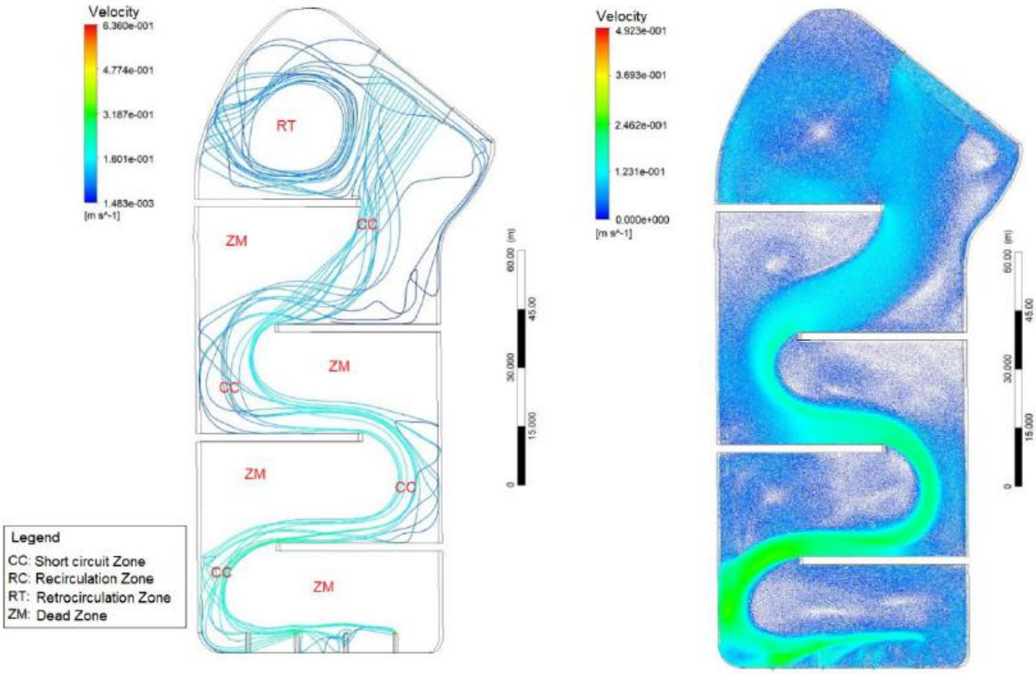

Fig.7 Scenario 03 - side baffles parallel to the outlet

This layout was adopted to verify if the change in the orientation of the first baffle would affect the formation of dead zones, reducing them, or even eliminating them.

What is observed is that the angulation of the first baffle interferes with the formation of dead zones, since it directs the flow to the curved margins of the pond, making the fluid that reaches the back of the baffle have a lower velocity than that of the flow.

When the orientation of the baffle is changed, a large recirculation zone is then observed. The fluid, when it encounters the barrier, still has a high-velocity variation due to the inlet conditions. When colliding, it separates into two currents: one follows the flow to the outlet. At the same time, the second is directed to the slope, then returns to the inlet region and follows the initial flow again.

In this layout, it was also noted the expressive increase in velocity at the end of the route, reaching 0.326 m/s. With the reduction of dead zones, the volume of sewage in circulation increases. Therefore, the velocity at the end of the path must be higher so that the flow inlet and outlet remain the same, as mentioned above.

The model presents dead and recirculation zones concentrated behind the baffles, increasing according to the proximity to the slope, as in the previous layout, showing that the length of the barriers needs to be shorter to avoid that the flow of the liquid mass does not reach the entire available pond area.

Case 4: three baffles perpendicular to the inlet and outlet ducts (Figure 8).

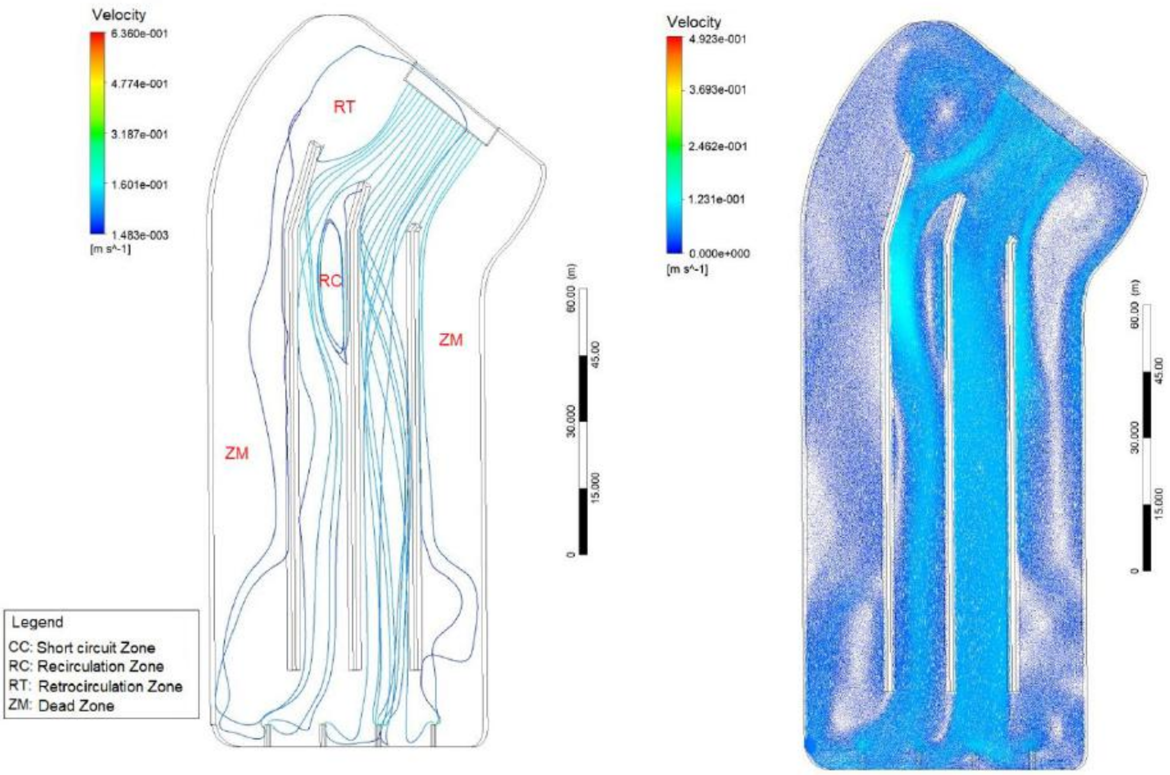

Fig.8 Scenario 4 - baffles perpendicular to the inlet and outlet

As the last proposal, a model was elaborated where the baffles were arranged perpendicularly to the inlet and outlet. This configuration replicates the geometry of the pond in smaller dimensions, forming a flow for each of the outlets, in the form of piston flow. The absence of parallel barriers prevents the formation of dead zones due to the inlet velocity and redirection of the flow. However, the irregular shape of the pond, once again, contributed to the development of some operational problems.

When entering the pond, the current goes mainly to the central channels formed by the baffle, forming a small recirculation zone, the only one developed in this model. This recirculation zone contributes to the flow not being able to travel through the last channel (above the recirculation zone) with a velocity equivalent to that of entering the pond. This layout denotes characteristics of decanters for this area, where the gravitational forces are greater than the drag forces, thus leading to the sedimentation of suspended solids. In this way, this region would be the one that would possibly suffer from the greatest accumulation of sediments.

A small part of the inlet flow goes to the first channel, and its movement follows the disposition of the baffle. In this situation, there will also be the formation of a denser sediment layer. However, the flow velocity close to the baffle will contribute to this accumulation being less than that of the last channel.

The two channels formed in the center of the pond receive most of the sewage flow that enters the pond. The fluid behaves evenly in these spaces, covering the entire area available for the flow, and there is no formation of recirculation zones or dead zones. The velocity varies between 0.002 m/s and 0.167 m/s, thus demonstrating that the distribution of liquid flow in the pond has not overloaded any circuit.

From the observation of the effects of the different baffle dispositions in the models presented, it is possible to propose some changes in the original pond to mitigate the problems found. The main source of such problems is, in fact, the shape of the pond, but the volume of operation also has a great influence. The original pond has very large dimensions, out of proportion to the sewage flow for which it is used. The fact of having a very large area provides the loss of fluid velocity, increasing the sedimentation rate and the hydraulic retention time, thus having a characteristic lentic environment, ideal for the development of algae.

Then considering the decrease in the sedimentation rate, the ideal scenario would be reached with the increase in the operation flow and installation of baffles perpendicular to the inlet and outlet ducts, as in the last case presented. If it is impossible to increase the operating flow, reducing the pond area would be another alternative. This new layout could be achieved by extending the first and last baffle to the inlet and outlet margins, and the new format would encompass only the central circuits presented in case 4.

IV. CONCLUSIONS

With the analysis of the hydrodynamic behavior in the different models of the baffle arrangement, it was clear that the movement of the fluid within the analyzed space can be reoriented, smoothing the accumulation of sediments at the beginning of the pond, passing to its uniform distribution along the bed. The scenarios showed that the longitudinal arrangement of the barriers presents less formation of dead zones, retromixing zones, and short-circuit zones, being, therefore, the indicated for the mitigation of problems through low investments.

It was also concluded with the analyses, that ponds with smaller dimensions and the choice of systems with piston flow are better adapted to the treatment of effluents, and prevent the accumulation of sludge in specific posts of the bed, leading to continuous and uniform sedimentation. The choice of units with capacity for lower volumes and smaller dimensions is justified by the fact that the largest volume of deposited sediments was found close to the margins, where the fluid did not have enough velocity to drag the particles through the bed. This accumulation was also greater in the regions where the geometry shows curvature, so rectangular geometries should be chosen in the dimensioning and elaboration of the pond projects for wastewater treatment.

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