Effect of Tank Shape on Performance of Aeration Tank in Sewage Treatment

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Abstract:This Study Was Made To Study The Use Of Circular Aeration Tanks Instead Of Rectangular One In Wastewater Treatment Plants. The Study Covered The Effect Of Tank Geometric Shape On Action Stability, Effective Parameters Homogeneity And Treatment Efficiency Inside The Aeration Tank And Its Reflection On The Final Sedimentation Tank Performance. A Pilot Scale Was Erected In Balaqs Wastewater Treatment Plant Pilot Consists From Two Lines One Circular Aeration Tank Followed By Final Settling Tank And Second Rectangular Aeration Tank Followed By Final Settling Tank For Comparison Purpose Under The Same Conditions. The Samples Were Taken Continuously For 5 Weeks From The Inlet, Outlet For (Bod, & Tss) To Measure The Aeration Removal Efficiency. Also Measurements Inside Both Types Of Aeration Tanks To Determine The Parameters Of Temperature & Do Distribution And Stability In Different Depths And Sides Of Tank. Also The Consumed Power Had Been Measured. The Results Shows That The Circular Aeration Tank Achieved Better Stability Inside The Tank With Minimal Variation In Both Of Do And Temperature That Varied Widely In The Rectangular Tank Between Different Depths And Also Longitudinally And In Cross Section Directions That Affects Mainly On The Tank Efficiency And The Consumed Power Needed For Surface Aerators Operation.The Circular Safe About 50% Of The Consumed Power That Also Safe In The Construction And Operation Costs For Such Treatment.

Key Words; Wastewater Treatment, Biological Treatment, Activated Sludge System, Aeration Tank, Factors Affecting Design, Tank Shape Effect.

I. INTRODUCTION &LITRATURE REVIEW

The activated sludge process has routinely been used for biological treatment of municipal wastewater for nearly a century. The invention of this process is connected with the efforts of British and American engineers at the end of the last century to intensify biological purification in fixed-film systems **[1]**.

During their experiments, Arden and Lockett found that sludge played an important role in the results obtained by aeration**.** The process was named activated sludge by Arden and Lockett because it involved the production of an activated mass of microorganisms capable of aerobic stabilization of the organic material in wastewater **[2].**

Numerous process configurations have evolved employing these components. An important feature of the activated sludge process is the formation of flocculent solids that can be removed by gravity settling.

In most cases, the activated sludge process is employed in conjunction with the physical and chemical processes that are used for the preliminary and primary treatment of wastewater and post treatment, including disinfection and possibly filtration.

Most activated sludge processes received primary effluents after removal of most settleable solids, whereas the biological processes are essential for removing soluble solids, colloidal substances, and particulate (suspended) organic substances; for biological nitrification and de-nitrification; and for biological phosphorus removal **[3].**

A number of activated sludge processes and design configurations have evolved since its early inception as a result of engineering innovation in response to the need for higher quality effluents from wastewater treatment plants, technological advances in equipment electronics and process control, increased understanding of microbial processes and fundamentals and the continual need to reduce capital and operating costs. With greater frequency the activated sludge processes used today may incorporate nitrification, biological nitrogen removal, and /or biological phosphorus removal. These designs employ reactors in series, operated under aerobic, anoxic, and anaerobic conditions, and may use internal recycle pumps and piping. Activated sludge processes are generally categorized into three major groups, i.e. plug flow, and complete mix and sequencing batch reactor. The most commonly used was the plug flow reactor with large length to width ratios. The complete mix reactor applied with industrial wastewater mainly to mitigate the effects of toxic discharges. In comparing the plug flow and complete mix activated sludge processes, the mixing regimes and tank geometry are quite different. In the CMAS process, the mixing of the tank contents is sufficient so that ideally the concentrations of the mixed-liquid constituents, soluble substances (i.e. COD, BOD, NH_4-N), and colloidal and suspended solids do not vary with location in the aeration basin. Although process configurations employing long, narrow tanks are commonly referred to as plug flow processes, in reality true plug flow does not exist. Depending on the type of aeration system, back mixing of the mixed liquor can occur and, depending on the layout of the reactor and the system reaction kinetics, nominal plug flow may be described more appropriately by a series of complete mix reactors.

Activated sludge process designs before and until the late 1970s generally involved the conventional plug flow and complete mix systems. However, with interest in biological nutrient removal, staged reactor designs consisting of complete mix reactors in series have been developed. Some of the stages are not aerated (anoxic or anaerobic) and internal recycle flows may be used to provide more efficient use of the total reactor volume than a single stage CMAS process.

The activated sludge process has been employed extensively throughout the world in its conventional form and modified forms, all of which are capable of meeting secondary treatment effluent limits. In the basic activated sludge process, the wastewater enters an aerated tank where previously developed biological floc particles are brought into contact with the organic matter of the wastewater. The organic matter, a carbon and energy source for the cell growth, is converted to cell tissue, water and oxidized products (mainly CO_2). The contents of the aeration tank are called mixed liquor. The biological mass, referred to as the mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS), consists mostly of microorganisms, inert suspended matter, and non-biodegradable suspended matter. The microorganisms are composed of 70-90% organic and 10-30% inorganic matter. The types of cells vary depending on the chemical composition of the wastewater, environmental conditions, and the specific characteristics of the organisms in the biological mass. After the mixed liquor is discharged from the aeration tank, a clarifier separates the suspended solids from the treated wastewater. A portion of biological solids are then recycled back to the aeration tank to maintain a concentrated population of microorganisms to treat the wastewater [1].

Temperature, dissolved oxygen, nutrients, toxic and inhibitory wastes, pH, and the inherent variability of wastewater flows and characteristics affect the performance and design of activated-sludge systems [4].

Dissolved oxygen concentration is an important control parameter. In systems designed for carbonaceous removal, a minimum average tank DO concentration of 0.5 mg/L is acceptable under peak loading conditions and 2.0 mg/L under average conditions. Using low values increases oxygen-transfer efficiency but can lead to filament formation and poor settleability. In nitrifying systems, engineers typically use minimum average tank DO concentrations of 2.0 mg/L under all conditions. The rate of BOD_5 removal in a plug flow system requires supply of most of the air to the first portion of the aeration tank. If air addition does not match the oxygen demand profile, the DO concentration may drop below a critical value and bulking organisms may form.

An adequate nutrient balance is necessary to ensure an active biomass that settles well. Typical nutrient requirements are based on a ratio of BOD_5 to nitrogen to phosphorus of approximately 100:5:1. Systems with higher values of SRT typically require fewer nutrients because of their recycle resulting from biomass autoxidation. Because nutrient requirements depend on SRT, some engineers calculate nutrient requirements based on waste VSS. The minimum nitrogen requirement should be 12% of the waste VSS mass/d, and the phosphorus requirement should be 2% of the waste VSS mass/d. Normal domestic wastewater typically contains amplnutrients. Wastes with substantial industrial compounds may require additional nutrient.

The presence of certain inorganic and organic constituents can inhibit or destroy suspended-growth system microorganisms. An excellent listing of many of these is presented elsewhere [8]. Nitrification processes are particularly sensitive to toxic inhibitions [4].

The pH of mixed liquor should range from 6.5 to 7.5 for optimum cell growth in carbonaceous BOD_5 removal systems. Nitrifying systems are more sensitive to system pH because the rate of growth of these organisms is a function of pH over the range 6.5 to 7.5 [4]. To avoid pH reduction, the designer should strive for a residual alkalinity of a least 60 mg/L (as calcium carbonate). Operating at even the 50 mg/L level is risky. A higher range of 80 to 100 mg/L gives more protection for operating over daily and diurnal load fluctuations.

The control of activated sludge process is very difficult, as there are too many parameters to be controlled, each one of those parameters have its effect on the other parameters beside the effect on the whole process. These parameters are Mixed liquor suspended solids, sludge age, Plant Loading includes Volumetric loading (Hydraulic loading, Organic loading (BOD loading with respect to tank capacity) and Sludge loading (BOD loading in relation to the total biomass of activated sludge), sludge settleability as sludge density index (SDI) & (ii) the sludge volumes index (SVI), returned sludge & Bulking Problems [5], [6] & [7].

II. MATERIALS & METHODS

The experimental works are executed in Balaqs Wastewater Treatment Plant in Shoubra El Khimah north of Cairo City.

The pilot plant consisted from two parallel lines one for circular aeration tank & another for rectangular aeration tank from steel. **Figure (1)** shows the pilot of circular aeration tank with 5.0 m diameter and 3.0 m water depth, the circular aeration tank has only one surface aerator of 1.0 m diameter. **Figure (2)** shows the pilot of rectangular aeration tank with 10.0 m length and 5.0 m width and 3.0 m water depth, the rectangular aeration tank has two surface aerators each of 1.0 m diameter.
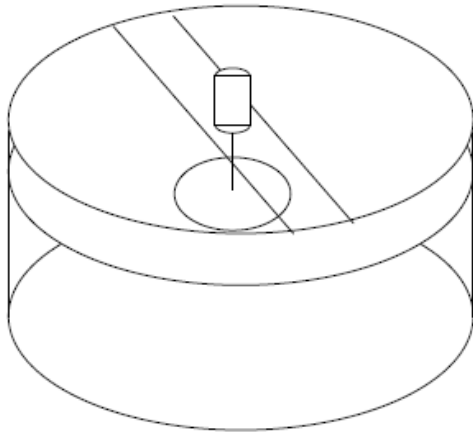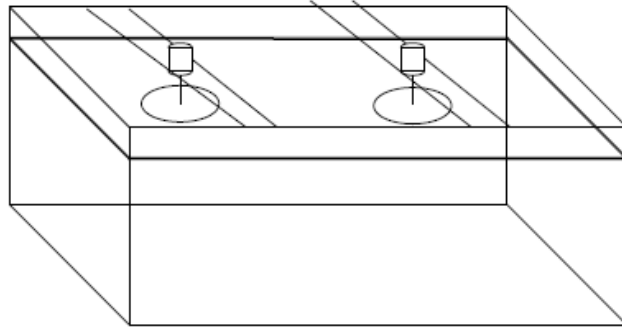
Fig (1) Pilot of circular aeration

Fig (2) Pilot of rectangular aeration

Both lines were fed from the plant primary sedimentation tank effluent channel and each one has final settling tank after it equipped with submersible pump for returned sludge and excess sludge.

Sampling was taken from pilot of circular aeration tank coming after primary sedimentation tank and after final sedimentation tank. There was three sampling in one point at three depths, first one under 10cm from surface, the second at 1.5m depth, and the third at 50cm above the bottom and all at 0.50m from wall. For the rectangular aeration tank, three sampling points were taken at longitudinal center line of tank (at 0.5 m from tank edge each side and at the mid of the tank) and other three sampling points on longitudinal line at 0.5m from tank edge were taken, in each point there are three samples, first one under 10cm from surface, second at 1.5m depth, and the

third at 50cm above the bottom. The samples were taken continuously for 5 weeks from the inlet, outlet for (BOD, & TSS) to measure the aeration removal efficiency.

A Comparison study between rectangular and circular aeration basins were implemented to determine the BOD & TSS removal efficiency, the amount of consumed power, the amount of needed air, the O & M Needs, the Area needed & the design parameters.

III. RESULTS & DISCUSSIONS

For circular tank pilot the Consumed power = 0.67 kw / kgO2 and the very little temperatures change the following had been found. Figures (3, 4, 5 & 6) illustrated the circular tank analysis for DO, temperature, BOD & TSS.
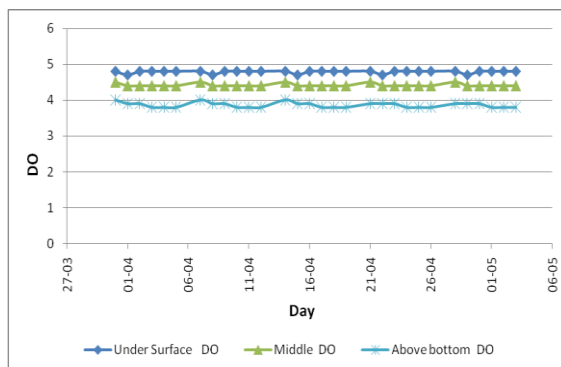

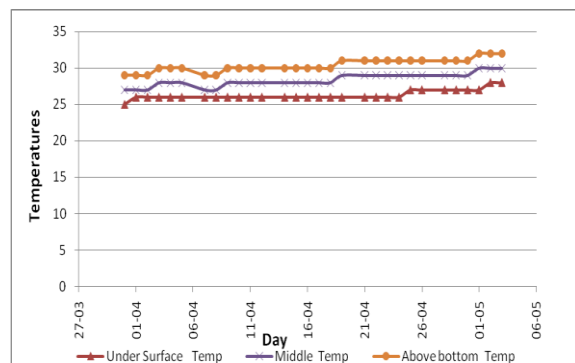**Fig. (3) Dissolved oxygen in circular tank**
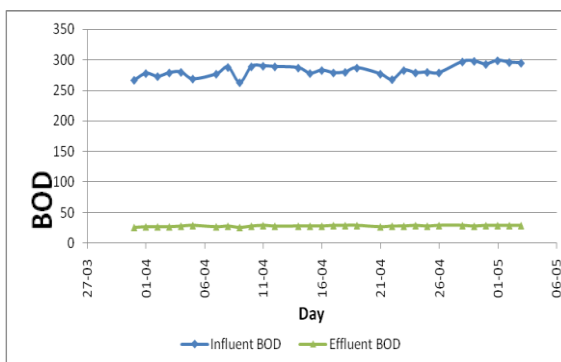

Fig.(4) temperatures in circular tank

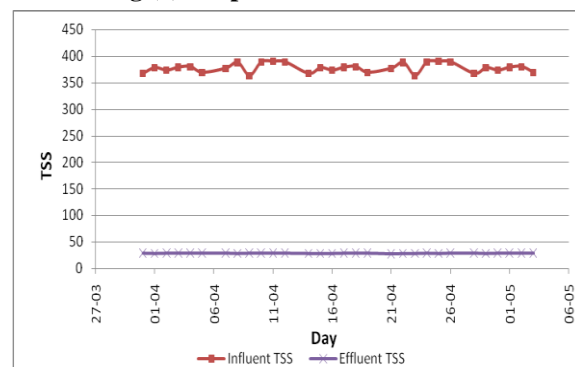**Fig.(5) Inf. & eff. BOD in circular aeration**

Fig.(6) Inf. & eff. TSS in circular aeration

The measured DO achieved its minimum level above the bottom of the tank, it is recorded 3.85mg/l which is the requirements for biological process, This was due to the aeration methodology depends on surface aerators. The DO increased gradually from bottom to surface to be 4.40 mg/l at the tank middle depth and the maximum value was 4.80 mg/l at the surface because it is nearest point to aerators.

So those DO at maximum near aerator under surface and minimum above bottom. Thus, we find that there is no significant variation in the dissolved oxygen in the circular tank with different depths and there is no dead zone.

Figure (5) illustrates the maximum, minimum values for BOD in both influent and effluent of the tank. The influent BOD was between 299 to 267 mg/l with average 283 mg/l. In the other hand the effluent BOD was varied between 29 to 26 mg/l with average 27.5 mg/l that achieved average removal ratio 90.28%.
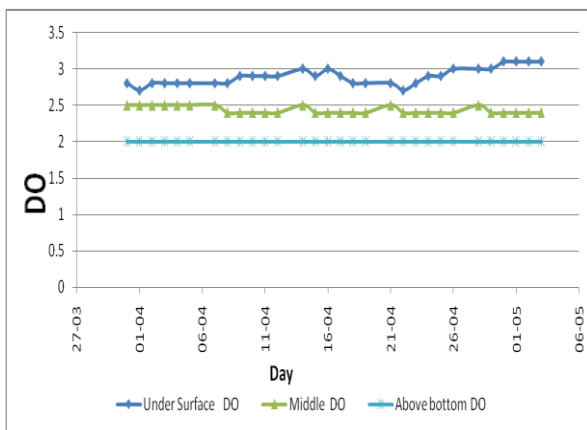
The tank removal efficiency is within the design efficiency range for such treatment type, because it has suitable design criteria, return sludge and no significant variation in the dissolved oxygen.

Figure (6) illustrates the maximum, minimum values for TSS in both influent and effluent of the tank. The influent TSS was between 390 to 363 mg/l with average 376.5 mg/l. In the other hand the effluent TSS was 28 mg/l with average 28 mg/l that achieved average removal ratio 92.56%.

The tank removal efficiency is within the design efficiency range for such type of treatment because it has suitable design criteria and absence of the effect of accidental of the water waves inside the tank with the flow and the aerators rotations.

For rectangular tank pilot the Consumed power = 1.34 kw / kg O2 and the very little temperatures change the following had been found. Table (1) and Figures (7& 8) illustrated the rectangular tank analysis for DO & temperature.
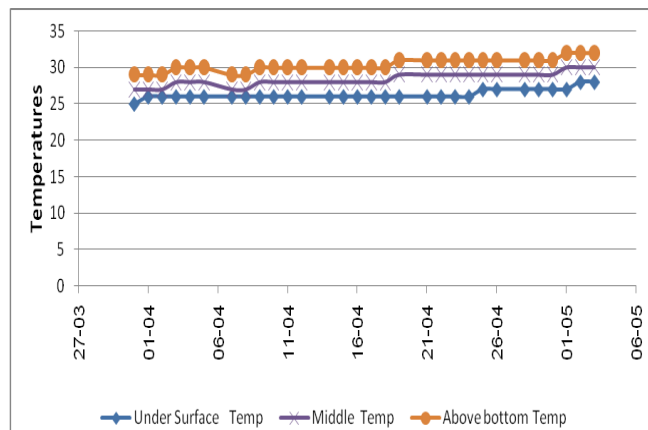

Fig.(7) DO in Rectangular aeration CL

Fig.(8)Temperatures in Rectangular aeration CL

Table (1) Average DO in Rectangular aeration at different depth in different location

LOCATION	Under Surface	Middle	Above bottom
Measured Parameters	Average DO	Average DO	Average DO
Start CL	2.99	2.53	2.3
Start edge 1	2.9	2.43	2
Middle CL	4.6	3.99	2.2
Middle edge 2	4.4	3.86	2
Effluent CL	3.96	2.58	2.1
effluent edge 3	3.86	2.43	2

The measured DO achieved its minimum level above the bottom of the tank, it is recorded 2mg/l which is the minimum requirements for biological process. This was due to the aeration methodology depends on surface aerators. The DO increased gradually from bottom to surface to be 3.86 mg/l at the tank middle depth and the maximum value was 4.4 mg/l at the surface because it is nearest point to aerators.

All these illustrate the bad distribution of air inside the tank between corners, edges and middle of the tank, the bad distribution of air through tank depth with weak points specially near the bottom, the weakness of air at corners specially near bottom that create dead zones and decrease the tank volume benefits.

Table (2) illustrates the maximum, minimum & average values for BOD in both influent and effluent of the tank and also presents the removal ratio for the BOD in the tank. The influent BOD was between 299 to 267 mg/l with average 283 mg/l. In the other hand the effluent BOD was varied between 29 to 26 mg/l with average 27.5 mg/l that achieved average removal ratio 90.28%.

Table (2) Averages BOD at Rectangular Aeration Tank

Parameter	Influent	Effluent	BOD removal ratio %
Max BOD mg/l	299	29	90.30
Mini BOD mg/l	267	26	90.26
Average BOD mg/l	283	27.5	90.28

The tank removal efficiency is with in the design efficiency range for such type of treatment but near the lower limit due to the effect of corners and the variation of air in the tank

Table (3) illustrates the maximum, minimum & average values for TSS in both influent and effluent of the tank and also presents the removal ratio for the TSS in the tank.

Table (3). Averages TSS at Rectangular Aeration Tank

Parameter	Influent	Effluent	TSS removal ratio %
Max TSS mg/l	390	28	92.82
Mini TSS mg/l	363	29	92.01
Average TSS mg/l	376.5	28.5	92.43

The influent TSS was between 390 to 363 mg/l with average 376.5 mg/l. In the other hand the effluent TSS was varied between 29 to 28 mg/l with average 28.5 mg/l that achieved average removal ratio 92.43%.

The tank removal efficiency is within the design efficiency range for such type of treatment, but near the lower limit due to the effect of corners and the bad distribution of air in the tank

IV. SHAPE EFFECTS

In circular DO varied between 3.85 to 4.8 ppm with depth variation and with no variation on the layer. While in the rectangular DO was varied in the longitudinal direction, in the vertical direction and also in the cross sectional direction between 2 and 3.99ppm. This shows that the circular achieved better aeration than the rectangular tank with more stability for DO concentration in the layer with minimum variations due to tank depth.

In circular BOD Removal ratio is 90.64 % with average value 90.28 %. In the other hand in the Rectangular BOD removal ratio was varied between 90.26and 90.30% with average value 90.26%. This shows that the circular achieved better BOD removal ratio than the rectangular tank with more stability for BOD removal ratio with the influent BOD variations.

In circular TSS Removal varied between 92.29 to 90.82 % with average value 92.56 %. In the other hand in the Rectangular TSS removal ratio was varied between 92.01 and 92.87% with average value92.43 %. This shows that the circular achieved better TSS removal ratio than the rectangular tank with more stability for TSS removal ratio with the influent TSS variations.

In circular the power consumption was 0.067 Kw / kgO2. In the other hand in the Rectangular the consumed power was 1.34 Kw/KgO2. This shows that the circular consumed less power to achieve better performance for the BOD & TSS removal by activated sludge system.

In circular the required amount of air is lower than the rectangular one due to the well distribution in the circular tank for the air that achieves homogeneity in DO inside it and minimizes the required power.

This shows that the circular need half of the air required in the rectangular one (about 70-80 m3air /kg BOD removed per day instead of 130-140 m3 air / kg BOD removed per day) to achieve same performance for the BOD & TSS removal by activated sludge system.

In circular the required area is lower due to the smaller volume needed to achieve the same quality for the well air distribution and minimum consumption of it in other purpose than oxidation.

The area of circular tank may be decreased about 30 - 50% for the same depths and may be more if depth increased. In circular for the lower of power consumption, minimizing the number of aerators the needed O&M works will also be decreased to about 50-60 % compared with that happened with rectangular one.

This shows that the circular tank needs lower O&M works to achieve better or same performance for the BOD & TSS removal by activated sludge system.

In general the circular achieved higher quality, lower power consumption, less area need, lower O&M works and best environment of action in the aeration tank due to the stability of the DO inside the tank with little effect for depth with the surface aeration system and the absence of dead zones for corners in the rectangular and the absence of the effect of accidental of the water waves inside the tank with the flow and the aerators rotations.

This achieved according to this work that the circular tank minimizes the construction cost by at least 20% than rectangular one due to the area decrease inspight of the cost of circular wall is higher than straight wall. Also the O&M needs will be lower by 50% .

V. CONCLUSION

This study was made in El-Gabal Al Asfar wastewater treatment plant to compare between the circular and rectangular aeration tanks in sewage treatment plant and to identify the impact of these two shapes of aeration tanks on the removal efficiency of the activated sludge process.

The study concluded that
- The circular aeration tank achieved higher removal efficiency compared with rectangular one.
- The circular aeration tank provides lower power consumption than rectangular one by 50%

- The circular aeration tank has best environment of action inside the tank with better homogeneity for DO in the tank.
- The circular aeration decreases the construction costs by about 20 % and running costs by about 50% that make it more effective in engineering manners.
- The use of circular aeration especially with surface aerators method of aeration is preferable.
- The canceling of corners in the rectangular tanks by adding concrete blocks make it half circle in the both side of rectangular

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