Design of Aerated Lagoon for Fish Pond Wastewater Treatment

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Abstract

A 16m by 10m aerated lagoon of depth 2.5m was designed for fish pond wastewater treatment. This was done to encourage the recycling aquaculture system of wastewater management. A sedimentation tank of 5.5m surface diameter with a total volume of 367.92m^3 and side slope of 2:1 was also designed to take care of settleable solids in the wastewater. These were done after biological analysis of wastewater from a commercial fish farm has been done. From the analysis, the average ratio of four-hour permanganate value and Biological Oxygen Demand (BOD) was 1:5 which rendered the wastewater treatable by biological method (aerated lagoon). A diffused unit aerator of 3 hp compressor over a 50mm diameter pipe was also recommended with a retention period few days.

Keywords: *Recycling, fish, water, sedimentation, aquaculture, settleable solids.*

Introduction

Fish make up a major part of human diet and some people eat fish to add variety to their meals. Fish rank among the most nourishing of all foods. The majority of freshwater fish are raised in ponds. Water is taken from a lake, bay, well or other natural source and is directed into the pond (Bucklin, *et al*. 1993). Fish pond ranges in size from a few square meters to several hectares. In general, small ponds are used for spawning and fingerling production. The water passes through the pond once and is discharged or it may be partially retained so that a certain percentage of the total water in a system is conserved (FAO 2005).

Agricultural wastewater may be defined as the combination of the liquid carried wastes from institutions, residences and commercial and industrial establishments. Untreated wastewater usually contains numerous pathogenic organisms that may be present in certain industrial waste (Akeredolu 1991). It also contains nutrients, which can stimulate the growth of aquatic plants and may also contain toxic substances. For these reasons, it is necessary to treat wastewater. Since water is also a basic need for human beings, more and more people compete for the same resource, which in turn creates problems for the fish farmers. These problems can then be tackled efficiently with the use of recycling aquaculture systems (Hochheimer 2005). Most fish production takes place in outdoor ponds where production success is often subjected to such natural occurrences as weather, the presence of aquatic weeds and predation by birds and other animals. The recycling aquaculture system removes some of the inefficiencies found in production systems. Water reuse reduces pumping costs and retains energy normally used to heat water. In addition, it enables production to occur in a controlled environment where losses to predators and seasonal drought do not influence production plans. It also permits a reduction in water consumption and the production of large quantities of fish in a small area (Bucklin, *et al*. 1993). It also maintains an excellent cultural environment while providing adequate feed for optimal growth. Maintaining good water quality is of primary importance in aquaculture. Critical water characteristics include concentrations of dissolved oxygen, un-ionized ammonia, nitrogen, nitrate concentration, pH, and chloride levels. The by-products of fish metabolism include carbon dioxide, ammonia-nitrogen, particulate and dissolved faecal solids. Water treatment components are designed to eliminate the adverse effects of these waste products. In wastewater treatment systems, proper water quality is maintained by pumping pond water through special filtration and aeration (oxidation) equipment. Each component is designed to work in conjunction with other components to carry out the reduction of toxic substances in the water before being discharged (Greenberg 1995).

The objectives of this study are to determine the physiochemical and bacteriological properties of wastewater from a fish farm, to establish the parameters that are detrimental to the environment from the wastewater and design a treatment system that will remove the harmful parameters from the fishpond wastewater.

Materials and Methods

The water samples used for this project were taken from Sheshi integrated farm located in Katcha town in Niger State. The farm is situated on the outskirts of the town and along the road that leads to Agae Town. It is located along Km. 2 Katcha-Bakeko-Badeggi road with a longitude of 6.4˚ East and latitude of 9.7˚ North.

Collection of water samples for examination was made in five clean bottled containers. Water samples were taken at two fishponds adjacent to each other; another sample was taken at the weir, one sample also taken at the central discharge point into the stream.

Before filling a container with water, some quantity of the sample was used to rinse the container then followed by the process of filling the containers themselves with their respective samples. The five bottles were labeled A, B, C, D and E, where A is the sample from weir, B is the sample from fishpond 1 (f.p.1), C is the sample from fishpond 2 (f.p.2), D is the sample from central discharge column (dis.1) and E is the sample from discharged water into the stream (dis.f). The samples collected were well covered and taken to the laboratory to be processed and analyzed.

Design of Sedimentation Tank

The parameters considered in designing a sedimentation tank are area, shape, depth and piping. Sedimentation tank is necessary to treat the effluents like total dissolved solids and bacteriological composition because from the result of the analysis it could be seen that there is quite high faecal contamination some of which can be removed through sedimentation since it possesses settling velocity.

The shape considered for this study was circular because any other shape used may cause sludge pockets to occur at its corners but with circular shape this will eliminated.

The surface diameter was 5.5 m. Therefore, the surface area of the sedimentation tank was:

$$A = \pi D^2 /4 = (\pi \text{ x } 5.5^2)/4 = 23.76\text{m}^2.$$

The depth of the sedimentation tank was 2.4 m. It was laid with concrete of high grade. This was done to prevent seepage and groundwater pollution. The side slope of 2:1 was suggested since the soil in the project site is clayey-loam, which makes it stable. The volume of the fish pond was 367.92m^3.

Lagoon Size Calculation

The size of the lagoon is based on the daily flow of effluent; the BOD of the effluent which was analyzed in the laboratory; the desired BOD percentage of 95% removal; the tropical climate of the area and finally on the type and size of the aerators.

In general, the capacity of the lagoon should be at least 4 times greater than the flow of effluent. The discharge flow of effluent when the tap is opened every 14 days is 100,000 L. Therefore, minimum capacity of the lagoon = 4 x 100,000 = 400,000 L.

The minimum area of the aerated lagoon surface is obtained accordingly:

since 1,000 L =1m^3,

400,000 L/1,000 L = 400m^3.

Assuming a depth of 2.5 m:

400m^3/2.5m = 160m^2,

proposed width = 10m,

proposed length = 160m/10m = 16m.

Selection of a Diffused Air Aerator Unit

Materials needed are 3 hp compressor, 50mm diameter pipe of length 30m and perforated ceramic plate. The aerated lagoon is a dilute, well stirred, with biological treatment operating without solids and having detention times in the order of 1-10 days depending upon loading and desired effluent quality. Stirring the water body is sufficient to distribute oxygen throughout the unit but may not be sufficient to keep all of the suspended solids in suspension. The diffused unit aerator is designed to deliver the required quantity of oxygen and to provide a minimum of solids deposition in the unit.

The values of 1hp/1,000 gals are only meaningful for a specific aeration unit since the pumping of liquids from various designs of surface aerators vary by factors of 2-10. The major factor that keeps solids in suspension is the pumping that an aerator produces per 1,000L of basin volume since this distributes the oxygen and keeps the solids in suspension. The transfer of oxygen is related to the quantity of fluid passing through the perforated ceramic plate.

In this aerated lagoon with 4 days retention time, the 3 hp value chosen for aeration is a function of the oxygen demand and the 4 days detention time. The 3 hp for mixing was picked as a result of the aerated lagoon volume and this horsepower varies directly with detention time.

Results and Discussions

Other physical characteristics are turbidity and taste. From Table 1, it was observed that the concentrations of most of the measured parameters increased from point of entry to f.p.1 and from there the concentration decreased at the point where it was discharged to the stream.

The water has a mild odor at the weir, but becomes objectionable as it gets to the pond and decreases at the point of discharge. The water has deep green colour at dis.1 and dis.f but it is a bit green at both fish ponds and colorless at the weir, its change in color is suspected to be a result of activities carried out on the pond and materials in solution.

Temperature of the wastewater ranges from 27.8^{o}C to 28.5^{o}C, which according to WHO (1995) standard is within tolerable limits if it doesn't exceed 29^{o}C. Turbidity of the water is very high at f.p.1, f.p.2, and dis.1, but its lower at the weir and dis.f due to high dissolved solid.

Other physical characteristic is the value of total dissolved solids which rises rapidly from 34mg/l to 156mg/l and then drops gradually. This is accounted for by the feeding rate of the fish and other remnants of feeds left in the water. It can also be seen that it has a smaller value at the weir and dis.f probably because there is no feeding activity taking place there.

From Table 2, it was observed that the wastewater is rich in potassium, sodium and nitrate, which are essential macro-elements for crop growth and therefore can be used for irrigation purposes. However, the presence of higher concentrations of magnesium, copper, iron, boron, calcium and chlorine ions will lead to salinity of the soil if used directly, therefore, the wastewater cannot be used for irrigation without proper treatment or dilution.

Also, the presence of nitrate and phosphate concentrations in the wastewater is suspected to having nitrates and phosphates being leached from the adjacent soil as a result of yearly application of nitrogen, phosphorous, and potassium (NPK) fertilizer on the surrounding farmland.

Table 1. Physical analysis of wastewater.

	A (weir)	B (f.p.1)	C (f.p.2)	D (dis.1)	E (dis.f)
Odor	Not objectionable	Highly objectionable	Highly objectionable	Not objectionable	Not objectionable
Color (HU)	20	28	29	23	21
Temperature (^{o}C)	27.8	32.1	30.2	28.0	28.5
TDS (mg/l)	34	156	130	110	47

Table 2. Chemical analysis of wastewater.

	A (weir)	B (f.p.1)	C (f.p.2)	D (dis.1)	E (dis.f)
Ph	6.7	7.1	6.9	7.0	7.4
Total hardness ($MgCaCo_3$)/L	13.2	8.7	9.3	11	9.8
Calcium, Ca (mg/L)	5.2	5.5	5.3	8.0	6.3
Sulphate,SO_4	23	31	27	26	25
Chloride, Cl^- (mg/L)	2.48	2.54	2.55	2.81	2.56
Iron, Fe^{2+} (mg/L)	0.11	0.00	0.00	0.30	0.12
Magnesium, Mg^{2+} (mg/L)	0.2	7.8	3.6	4.1	2.5
Phosphate,PO^-_4 (mg/L)	2.3	6.7	5.61	4.0	3.6
Nitrate,NO^-_3 (mg/L)	6.9	13.0	14.2	13.9	16.4
Sodium, Na^+ (mg/L)	0.12	2.8	6.0	5.3	3.9
$Potassium^+$ (mg/L)	1.3	1.8	2.6	2.81	1.9
Copper, Cu^+ (mg/L)	1.70	0.25	0.20	0.21	1.31
Manganese, Mn^+ (mg/L)	1.20	0.10	0.05	0.04	0.90
Chlorine, Cl (mg/L)	0.10	0.80	3.10	2.71	0.60
Boron, Br^+ (mg/L)	0.00	0.04	0.00	0.00	0.00
COD (mg/L)	0.97	4.50	9.00	10.60	9.60

Table 3. Biological analysis of wastewater.

	A (weir)	B (f.p.1)	C (f.p.2)	D (dis.1)	D (dis.f)
DO (mg/L)	2.5	1.8	1.99	0.96	0.91
Faecal coli form (cfu/ml)	0	127	189	120	10
Faecal streptococci (cfu/ml)	0	108	156	137	15
E. coli (cfu/ml)	2	56	23	45	45
Total plate count (cfu/ml)	2	76	45	170	23
PV_4 (mg/L)	2.7	7.4	6.2	32	29.3
BOD (mg/L)	19.2	36.7	37	220	120

The observed improvement in quality, also known as self purification, from dis.1 to dis.f has been attributed to oxidation of organic and nitrogenous materials, settling of heavy solids and coagulation of lighter ones.

Table 3 gives the results of biological analysis of the wastewater. There is high concentration of oxygen but it drops sharply as a result of increased fish activities and organic activities taking place in the pond. Also, lack of faecal coli form group parameters indicate the absence of human and livestock faeces but this changes as the water enters the pond and the discharged faeces of fish might have increased the concentration in the water.

Conclusion

The wastewater samples taken from the fishpond were analyzed and studied to determine their physical, chemical and biological parameters. Also, based on the result of the analysis, it was discovered that the water needs to be treated before it can be used for domestic purposes like washing, cooking, etc., and agricultural purposes like irrigation.

From the biological analysis comparison of BOD:PV_4 compounds, which was on the high side, therefore, biological treatment method was chosen. The farm has a large and available land of (10m x 16m) size was designed for the aerated lagoon on the farm after the water has been temporarily treated in the sedimentation tank. The dissolved solids, odor, color and toxic ions would then be diluted with water and discharged directly to the water course since the dissolved oxygen and BOD would have conformed to the 20/30 standard by Greenberg (1995).

Recommendations

It is recommended that further researches should be done to ascertain the extent of groundwater pollution by the fishpond wastewaters. The sedimentation tank and aerated lagoon should be constructed and performance evaluation done to ascertain the feasibility of the designed lagoon.

There should also be proper maintenance measure like sludge removal and proper aeration to prolong the lifespan of both the sedimentation tank and the aerated lagoon.

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