Treatment of Dairy Effluent using Rotating Biological Contactors (RBC)

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Abstract - *Safe disposal of waste water either on land or water is most challenging task before the engineers. For medium and small scale industries, it is a burden to treat the effluent if the cost involvement is high. There are many waste water treatment technologies in use today. Rotating biological contactors (RBC) is most popular due to its simplicity, low energy, and less area requirement. RBC is an aerobic treatment process. It serves as a superior alternative for biodegradable material, biological oxygen demand (BOD) and chemical oxygen demand (COD) removal rate. RBC consists of parallel circular disc attached perpendicular to a horizontal shaft. For better results, RBC is adopted in series of 3 to 6 to reduce waste water to nitrate level. RBC is utilized in several industries namely textile, dying, dairy etc. for treatment of effluent before disposal. This paper deals with application of RBC in dairy industry. The study area taken is Mahanand Dairy, which lies in suburbs of Mumbai, Goregaon. In this paper various treatment plants like screening, grit chamber, primary sedimentation tank, rotating biological contactor, secondary sedimentation tank and sludge digestion tank are designed. The treatment plant currently consists of traditional method of activated sludge process, this paper deals with design of entire treatment plant using rotating biological contactor.*

Key Words: Aerobic, ASP, Biodegradable, BOD, COD, Nitrate, RBC, Sludge, Treatment

1. INTRODUCTION

Waste-water from dairy industry mainly consists of biodegradable and organic matter which disrupts the marine life. Due to the high pollution load of dairy wastewater, the milk-processing industries discharges untreated/partially treated wastewater causing serious environmental problems. Hence, it is important to carry out a treatment as a starting point in order to optimize a simple and economic method to treat the whole dairy effluent. Appropriate treatment processes are required so as to meet the effluent discharge standards specified by the government.

The wastewater treatment does not offer any financial profit to the dairy industry owners therefore they unleash it directly to nearby water streams or ashore (i.e. in nature) by giving just some of the primary treatment that maybe due to lack of awareness in this regard or lack of funds.

1.1 Treatment using RBC

In our study, to minimize the cost of the treatment plant the use of RBC (rotating biological contactors) is being suggested, which is an attached growth system and is able to sustain the shock loadings. Moreover it does not require recirculation of secondary sludge and also hydraulic retention time is low.

The treatment of effluent is done by passing it through the primary and secondary treatment process and thereby reducing physical and chemical characteristics to safe permissible limits. The wastewater is passed through fine screens to remove large particles from the wastewater. The second stage is Primary Sedimentation Tank, in this all the organic as well inorganic matter is allowed to settle. Settled sludge is directly taken in sludge digester. The liquid waste is then passed to Biological treatment process for stabilization. In the biological treatment process the organic matter present in the wastewater gets in contact with the micro-organism present in the biomass layer on the discs of RBC resulting in its decomposition that leads to the formation of biomass again and when the disc dips in the wastewater, it is removed from the disc and get submerged in the wastewater, the suspended biomass as well as the liquid passes through 3-4 disc's, thus reducing the Nitrate level of effluent. After this, the waste effluent is passed through secondary sedimentation tank, where the sludge is settled and passed to sludge digester where the effluent is reduced to gases and water and the digested sludge is dried and used as fertilizer. The supernatant liquid is again passed to primary treatment process and likewise the treatment process is continued.

2. LITERATURE REVIEW

Prashant. A. Kadu et al. explained the use of RBC (Rotating Biological Contractor) and stated the benefit for small scale industry for them who cannot afford costly treatment plant. The reduction in Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) value of effluent water after the treatment process using RBC was done experimentally.

Manoj.R.Tonde, et al performed an experimental study on the treatment of municipal waste water at a temperature of 12-24°C in an RBC system. In this, RBC system is divided in to two similar stages connected in series to optimize the performance of RBC system; this system of stages was operated at different organic loading rates and hydraulic detention time. They carried out the study to evaluate the effectiveness of supplemental aeration for improving the performance of RBC treatment system.

Mr. K Stalin investigated the removal of COD from dairy industry effluent using three stage batch modes rotating biological contactor (RBC). The experiments were conducted at different influent COD and rotational speeds. The author stated that the effluent of the RBC can be used for irrigation and gardening without any risk.

Prashant.A.Kadu, Rajshree.B.Landge, Dr.Y.R.M.Rao, gave a rough estimate of amount of waste water generated per liter of milk processed. Also they have classified various dairy waste effluents depending on the type of systems and methods of operation used. The samples were collected from dairy industry and after treatment were analyzed for pH, TSS, BOD_5 and COD by using standards methods. The following parameters were measured Five Days Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand, COD and Total Suspended Solids, TSS using Dilution Method, Open Reflux Method and Gravimetric after filtration respectively. The author also stated the advantages of RBC and also did a comparative study with Activated Sludge Plants.

Steven.E.Williams, et al. explained the utilization of RBC for Municipal wastewater treatment, its upsides and downsides, and explained whether or not RBC provides nutrient removal just like that provided by ASP and also the design of RBC process.

A.S. Kolhe, V.P. Pawar performed the experiments on the treated and untreated effluents samples from dairy industry for studying & analysis of physicochemical parameters like pH, temperature, colour, DO, BOD, COD, TDS, TSS, TS, Chlorides, Sulphates, Oil & grease. It was concluded that the treated water can be used for gardening purpose. After analysis made by MPCB, of effluent sample, they suggested some repair and maintenance work of treatment plant, unit which is necessary. As far as the treatment plant is concerned, they concluded that the treatment plant is working with satisfactory efficiency.

Riyaj K.Mulla, Azim S.Sutar, Anil C. Ranveer studied about various technologies available for the treatment of dairy effluent. It also gives information about combination of conventional effluent treatment plant with tertiary treatment. Various technologies like activated carbon, packed bed filters, electro-coagulation, and reverse osmosis techniques are explained.

3. STUDY AREA

The area extends for about 60 hectares of land while treatment plant situated over an area of about 3 hectares situated in Goregaon a suburb in the Mumbai city, in the Mumbai Suburban district of India.

The area has following geographic features having an elevation of 14.7 meters (48.23 feet). The district has latitude of 19.1551° N and longitude of 72.8679° E. There are number of dairy plants in the vicinity namely Mother dairy, Dynamix dairy industries limited, Maharashta Shasan Aarey milk centre, Unit no. 10 (Central Dairy), Shree Thakkar dairy farm, Azam dairy, Aarey colony and Shree Jain dairy farm.

Mahanand dairy has milk procurement system which spreads over the district of Maharashtra. Mahanand dairy is distributing 30 lakhs liters milk per day in Mumbai with the help of one packing depot strategically located at Navi Mumbai.

The water left after the production of several products is termed as dairy waste water. The effluent from milk processing unit contains soluble organics, suspended solids, trace organics which releases gases, causes taste and odor, imparts colour and turbidity, and promote eutrophication which affects and disturb the environment. [8] Hence proper treatment is must before disposal however instead of disposing this dairy waste water it is recycled after proper treatment and used for washing and gardening purpose.

3.1 Design details

- Mahanand industry utilizes about 5000 m^3/day of fresh water.
- The treated and untreated effluent discharge amount was 2750 m^3/day i.e. 55% of the total water used.
- Waste water quality was determined by estimating physical, chemical, and biological characteristics of waste water.
- Waste water sample was collected by fabricated water sample of its capacity and transported to lab, where analysis was done for a period of 2 days.
- The sample collected were analyzed for temperature, pH, BOD and COD.
- Temperature of waste water ranged from 26.2 ^oC to 35.40^oC
- The colour of dairy waste water was white.
- pH was found as 9.68
- BOD value was around 250 mg/l
- COD value was 781.57 mg/l

4. METHODOLOGY

4.1 Screening

Screening is the very first operation carried out at a sewage treatment plant. It removes the floating materials. The screens are kept inclined at about 30 to 60^0 to the direction of flow. The velocity through the screens should not more than 0.8 to 1 m/s. We have provided steel bars in the screen, having width of 1 cm and paced at 5 cm clear spacing.

4.2 Design of Grit Chamber

A rectangular grit chamber is designed to remove particles with diameter of 0.2 mm with specific gravity of 2.65.Taking settling velocity of particles ain the range of 0.016 to 0.022. Horizontal velocity of flow is taken as 0.3 m/s.

$$V_s = \frac{(G-1)\times \gamma_w \times d^2}{18\mu} = \frac{(2.65-1)\times 9810\times 0.0002^2}{18\times(8.90\times10^{-4})}$$

$$=0.04 \text{ m/s}$$

This is the settling velocity of 0.2 mm sized organic particles in water. As waste water viscosity will be more than water which will affect the settling velocity .Hence taking 50% settling velocity as compared to settling velocity of particles in water.

$Q = 2750\ m^3/d = 31.83\ l/s = 0.03183 \cong 0.032\ m^3/s$

$Q = A \times V$

$0.032 = A \times 0.3$

$A = 0.12\ m^2$

Providing a depth of 1.2 m, free board of 0.3 m and 0.3 m space for accumulation of grits and width of grit chamber as 1m.

Length of channel:-

Horizontal velocity $\propto$ detention period. It means that more the detention period, more horizontal distance could be travelled. Settling velocity is taken as 0.02 m/s

$$\text{Detention Period} = \frac{\text{Water Depth}}{\text{Settling Velocity}} = \frac{0.6}{0.02} = 30 \text{ seconds.}$$

$L = 0.3 \times 30 = 9m$

Increasing by (10 to 50%) taking it as 30%

$= \frac{9}{0.70} = 12.85 \cong 15$ m.

Provide a grit chamber of size as 15×1×1.2 m having a flow velocity of 0.3 m/s

4.3 Design of Primary Sedimentation Tank

$Q = 2.75$ MLD, $S_{S0}=450$ mg/l
Preferring plain sedimentation.
Assuming overflow rate of 18 m^3/m^2/day

1. Plan area of tank = $\frac{Q_D}{\text{Over flow rate}}$

$= \frac{2750}{18}$

$= 152.77 \approx 160m^2$

Provide tank of 200m^2
LxB =200m^2
L= 20m
B= 10m

2. Assuming detention period of 4 hr

Volume of tank = $Q_D \times t_D = \frac{2750}{24} \times 4 = 600\ m^3$

Height of tank =600/200 = 3m

Design a rectangular continuous tank of size as 20×10×3 m.

Setting velocity of concerned particles is called as surface overflow rate which decides efficiency of tank

V_s=18m/day =0.208 mm/s

The flow velocity of tank V_f

$$V_f = \frac{L\times V_s}{H} = \frac{20\times1000\times0.208}{3\times1000} = 1.39 \text{ mm/s}$$

Design of RBC module to treat 2750 m³/day ≈ 3000 m³/day

Assumptions: - Hydraulic loading rate =110 l/m²/day, Diameter of disc = 3m, c/c spacing between disc=20mm.

$Q = 3000\ m^3/day = 0.035\ m^3/sec.$

Area of disc = $\frac{\pi}{4} \times 3^2 = 7.068\ m^2$

Total surface area of 1 disc = $(2\times 7.068) + (\pi D\times0.1)$
$=14.14\ m^2$

Total surface area required $= \frac{3000\times1000}{110} = 27272.73\ m^2$

No. of discs $= \frac{27272.73}{14.14} = 1928.7 \approx 1930$

Total length of shaft required = $1930\times\frac{2}{100} = 38.6$m.

Assumption

Let length of each shaft be 10m

Therefore total number of Rotating Biological contactor required = $\frac{38.6}{10} = 3.86 \approx 4$

Therefore provide 4 - RBC in series with 50% submergence in water with clear spacing of 10 cm rotating at 6 rpm

Volume of tank = $\frac{\pi}{4}\times (3+0.1)^2 \times0.5\times4\times10 = 150\ m^3$

Hydraulic Retention Time = $\frac{Volume}{Q} = \frac{150}{125} = 1.2$ hr.

Check should be between 1-1.5 hrs ∴ OK

Raw BOD_5 = 250 mg/l

Influent BOD = 0.7 ×250 =175 mg/l.

Organic loading = $\frac{\frac{175\times10^{-6}}{10^{-3}}\times3000}{27272.7}$ = 0.019 $\frac{kg}{\frac{m^2}{day}}$ (upto 0.022 $\frac{kg}{\frac{m^2}{day}}$)

∴ OK

a. Secondary Sedimentation Tank

Surface loading rate mostly preferred for secondary sedimentation tank is 15 to 30 $m^3/m^2/day$. Adopting a surface loading rate of 20 $m^3/day/m^2$

Q = 2750 m^3/day

1. Surface area required = $\frac{2750}{20}$ = 137.5 m^2.

Adopting solids loading of 125 $kg/day/m^2$ for MLSS of 2000 mg/l

2. Surface area required = $\frac{2750\times2000}{1000}\times\frac{1}{125}$ = 44 m^2.

Preferring maximum surface area of 137.5 m^2

∴ Surface Area = 137.5 $m^2 \cong$ 140 m^2

Adopting a circular tank, Area = $\frac{\Pi}{4}\times D^2$

$$140 = \frac{\Pi}{4}\times D^2$$

D = 13.35 m ≅ 15 m.

Weir loading for circular weir placed along periphery of tank having length equal to πD

= $\frac{2750}{15}$ = 58.35 $m^3/day/m$ **< 150** ∴ **OK**

Hence, provide settling tank of 15 m diameter.

b. Design of Sludge Digestion Tank

Assumptions: - 2.75 MLD treatment plant,

60 % suspended solid removal in PST. Moisture content of sludge is 96 %; digested sludge solid content is 8%

Specific gravity of raw and digested sludge is 1. 1.03 and 1.04 respectively

Mean cell residence time is 15 days and efficiency, η = 60 %

Weight of solids in raw sludge w = $Q_o\times SS_o\times\eta$

$$= 2.75\times10^6\times450\times10^{-6}\times0.6$$

= 742.5 kg/day ≅ 750 kg/day.

Weight of volatile solids = 0.7 × 750 = 525 kg/day. Weight of non volatile solids = 0.3 × 750 = 225 kg/day.

Volume of raw sludge, $V_1 = \frac{100\times750}{(100-96)}\times\frac{1}{1.03\times1000}$

= 18.20 m^3/day.

Weight of non volatile solid in digested sludge

= 0.35 × 52

= 183.75 kg/day.

Volume of raw sludge, $V_1 = \frac{100\times750}{(100-96)}\times\frac{1}{1.03\times1000}$

= 18.20 m^3/day.

Weight of non volatile solid in digested sludge = 0.35 × 525

= 183.75 kg/day.

Total weight of digested sludge = 183.75 + 225

=408.75 kg/day.

Volume of digested sludge, $V_2 = \frac{100\times408.75}{8}\times\frac{1}{1.04\times1000}$

= 4.91 m^3/day.

∴ Volume (V) = $\left(V_1-\frac{2}{3}(V_1-V_2)\right)\times t_D$

$$= \left(18.20-\frac{2}{3}(18.20-4.91)\right)\times15$$

= 140.1 m^3

Volume of gas = 0.6 ×525 = 315 m^3 OR

Volume of gas = 0.9×0.65×525 = 307.12 m^3

Selecting maximum of the two values.

∴ Volume of CH_4 = 0.65 × 315 = 204.75 m^3.

Calorific value = 8600×204.75 = 1.76 ×10^6 kcal.

Preferring High Rate Sludge Digester.

5.0 RESULTS AND DISCUSSION

- Provide a Grit Chamber of size as 15m ×1m ×1.2m.
- Design a rectangular Sedimentation Tank of size as 20 m × 10 m × 3 m.
- Providing 4 - RBC in series with 50% submergence in water with clear spacing of 10 cm at 6 rpm.
- Provide Secondary Sedimentation Tank of 15 m diameter.
- Preferring High Rate Sludge Digester with volume of Sludge Digester as 140 m^3.

6.0 CONCLUSION

Mahanand Dairy plant currently uses Activated Sludge Process in which the sludge is to be recirculated and proper F/M ratio is to be maintained, thus proving to be hectic and costly. In this paper we have successfully designed various unit of treatment plant using Rotating Biological Contactor as a biological method to decompose the organic matter by bringing it in sufficient contact of air as RBC is an effective method of treating wastewater and offers an alternative technology to conventional activated sludge process because of its ease to maintain and operate, having high process stability with less space requirement. RBC system proves to be economical as tertiary removal is not required.

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