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Inhibitors of Aerobic Treatment System and its Control Measures

[1]Prof. Neena Sunny, Anjali Roy[2], Anju Pavithran[2], Maria Johnson[2], Shafana P H[2]

[1]Professor, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India
[2]Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India

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Abstract -*Population growth and industrialization have led to hike in wastewater generation which can in fact cause unfavorable ecological conditions. Therefore, it becomes necessary to have efficient wastewater treatment system. Aerobic treatment systems are notable for producing well stabilized sludge and requiring lesser amount of time. Despite the advantages, these treatment processes are sensitive to various inhibitors. The present study deals with the important inhibitors such as pH, temperature, OLR and DO. The control measures adopted for maintaining these inhibitors at optimum levels are also studied.*

Key Words: **pH, temperature, OLR, DO, optimum levels, control measures**

1.INTRODUCTION

Aerobic wastewater treatment systems optimize the microbial degradation process to break down pollutants in wastewater to produce well-stabilized sludge. For these systems it is essential to monitor various inhibitors such as pH, temperature, dissolved oxygen, nitrogen and phosphorus to maintain optimal biomass growth rates for the microbial populations. There are several parameters that inhibit the proper functioning of an aerobic treatment system. The main inhibitors studied include pH, temperature, dissolved oxygen and organic loading rate (OLR). Control measures are taken to keep these inhibitors at optimal levels to improve system efficiency. Optimal level of dissolved oxygen must be maintained so that aerobic organisms can break down organic matter into smaller molecules. In addition, these systems must be balanced in terms of pH and temperature and they have to be maintained at levels which is not harmful to microbes. Higher OLR values can destabilize the reactor and thus impair the performance of the reactor. This study also deals with different control procedures that are used to keep these inhibitors at optimal levels in order to improve the system efficiency.

2. INHIBITORS OF AEROBIC TREATMENT SYSTEM

2.1 pH

The pH has a great influence on the growth rate of microorganisms. pH affects the function of metabolic enzymes. Acidic conditions (low pH) or alkaline conditions (high pH) will change the structure of the enzyme and stop its growth.

The observations and tests on wastewater show that pH must be maintained in a range favorable for biological activity in wastewater treatment. Experimental studies have shown that the pH value ranges from 6.5 to 8.0, with the optimal activity is 6.7 to 7.3. Within this range, the pH value changes to 0.3 pH units can cause a change in alkalinity of 200 ppm or more. Since the change in alkalinity is larger and its linearity compared to pH, the tracking of alkalinity is more reliable than pH and makes it easier to detect changes, allowing operators to react more quickly to enable biological processes to normal levels. In aerobic wastewater treatment, in which oxygen is added to microorganisms and feed, the present invention includes a method of maintaining alkalinity within a predetermined range to maintain the pH of wastewater between about 6.5 to 8.0 (preferably 6.7 to 7.3) during the treatment. The method steps include: (a) determining the alkalinity of the wastewater at multiple points in aerobic wastewater treatment; (b) adjusting the alkalinity near these points to a desired level by changing the rate of oxygen supply and/or the concentration of microorganisms and feed. About 100 mg $CaCO_3$ /L is needed, to control the alkalinity to keep the pH within the desired range without the addition of chemicals or additives (H Forbes Davis and James P Harshman, 1990).

The experimental studies conducted on Palm Oil Mill Effluent (POME) shows that aerobic granules can settle considerably well in pH 9 compared to the other pH (pH 7and 5) medium and pH 9 has highest COD removal percentage on first few days. However, pH 9 had the least effect on the reduction of aerobic granule concentration.. Comparing with other pH values, the concentration of aerobic granules at pH 5 drops the most at the same time. The pH of POME affects the performance of aerobic granules. The POME with pH 9 had the highest COD removal rate on 3rd day (93%), and pH 7 had the lowest COD removal rate (77%). However, at all pH values, the COD removal percentage was stable and reached a similar value on the 21st day. The maximum COD removal rate recorded is approximately 95% at pH 7 on the 15th day. The SVI value (Sludge Volume Index) at pH 9 showed a lower value than the pH 7 on the 21st day. A lower SVI indicates that aerobic granules can settle better. Compared with pH 5 and 7, pH 9 has a more compact and round structure of aerobic granules (K Gopi, et al 2014)

The bacteria and other biological entities that play an important role in wastewater treatment, and exert most effective in the pH value ranging from neutral to slightly alkaline from pH 7 to 8 in municipal and industrial wastewater. In order to maintain the optimal pH conditions for these biological activities, the wastewater must have sufficient alkalinity to neutralize the acid produced by the active biomass during the wastewater treatment process. Alkalinity is so important to the wastewater industry because of its ability to maintain the proper pH in the wastewater as it undergoes treatment. The amount of alkali added depends on the amount of impurities in the incoming waste, the type of treatment used in the treatment plant, the amount of natural alkalinity of the incoming wastewater, the allowable pH value of the effluent wastewater, the amount of waste used by the plant, the number of gallons of waste processed by the plant and whether the plant is denitrifies the wastewater before final treatment and discharge (Martin Marietta Magnesia Specialties, 2015).

2.2 Temperature

The high-strength organic waste water analysis showed that the BOD removal rate in the bioreactor increased with a temperature increase from 20°C to 30°C, 40°C and 50°C, but reduced with a temperature increase from 50°C to 60°C. Experimental results show that the structure of the microbial community in bioreactor is significantly dependent on temperature. Endogenous respiration rate coefficient of microorganisms in aerobic solid phase bioreactor increased with increasing temperature. Sludge production in the bioreactor is reduced at high temperature. (BR Lim, et al. 2001)

The test for aerobic biological treatment of pharmaceutical wastewater showed that the removal efficiency of soluble COD decreased with increasing temperature from 30°C to 60°C. The decrease was from 62% to 38%. The biological treatment of this wastewater could not be carried out at temperatures above 60°C. The influence of temperature was also compared to a two-stage biological treatment process. More soluble COD removal was attained when both the reactors were operated at 30°C compared to a system in which the two stages were operated in sequence at 55°C and 30°C. It indicates that higher temperatures may have a negative impact on process performance (Timothy M La Para, et al. 2001).

The effects of temperature on the removal of organic carbon and nitrogen in an activated sludge process were evaluated. A steady state simulation was carried out to analyze wastewater effluent concentrations with variable kinetic parameters obtained from different temperature coefficients in a wide temperature range from 15°C to 35°C. The temperature range between25-30°C was highlighted as it is often the most frequently operated temperature range in sewage treatment plants in India. It has also been observed that at temperatures less than 20° C and above 30°C, discharge limits were violated from the guideline values (E Tejaswini, etal, 2019).

The analysis of the influence of temperature in wastewater treatment shows that the operating pattern of aerobic biological treatment is in the mesophilic range which is around 30°C. It is stated that the acceptance temperature for the operation of the activated sludge process is around 37.5°C and it is considered to be the highest temperature for the growth of mesophilic microorganisms. The digestion and nitrification process becomes inactive when the temperature exceeds 50°C and on the other hand methane production stops when the temperature is below 15°C (Hussein Abed Obaid Alisawi, 2020).

2.3 Organic loading rate (OLR)

The use of soluble and particulate organic substances is referred to as the Organic Loading Rate (OLR). The study shows that the decrease in OLR improves the formation and stability of aerobic granular sludge (AGS). Aerobic granular sludge (AGS) is a new type of microbial community that can simultaneously remove carbon, nitrogen, phosphorus and other contaminants in a single sludge system. The results confirmed that the activated sludge that had grown under an influential OLR gradient that decreased from 5.5 to 3.5 kg COD m^{-3} d^{-1} had complete granulation with an average size of 438 μm and an exopolysaccharide (PS) -Protein ratio (PN) of more than 2.Decreased OLR regulation is suitable for specific growth characteristics of microbes (Zhiming Zhang, *etal*. 2018).

In wastewater treatment, aerobic granular sludge (AGS) technology is comparatively a new alternative to the activated sludge process. Biomass bio granulation occurs when adequate ambient conditions are ensured in a reactor and one of the determining factors is the organic loading rate (OLR). Organic loading rates within the range of 2.5–15.0 g COD/(dm^3 ·d) have been used to treated medium or high-strength wastewater in most AGS processes. Previous studies have shown what values for OLR that facilitate the granule formation in AGS technology should be of between 2.50 and 7.50 g COD/(dm3 ·d). Whenever the OLR is low, the granules become difficult to cultivate (Joanna Czarnota, Adam Masłoń, 2019).

An OLR of 0.4±0.2 g COD/(dm^3 ·d) gave the appearance of granules after 3 months. They were small, accounting for 30% fraction of the flocs present in the sludge. In turn, Zhang et al. (2011) reported that with an OLR equal to 0.58 g COD/(dm^3 ·d), the resulting granules have a loose, porous and hollow structure. In addition, the granules became unstable when their diameter exceeded 1 mm. (Derlon et al. 2016).

2.4 Dissolved Oxygen

Dissolved Oxygen (DO) is added to Aeration Basin to improve the oxidation process by adding oxygen to aerobic microorganisms so they can convert organic waste to inorganic by-products.

Experimental studies were conducted on dairy wastewater to determine the treatability of dairy wastewater by SBR and to evaluate the effect of oxygen and MLSS concentrations on COD removal efficiency COD removal efficiency was achieved in excess of 90% while the COD concentration ranged from 400 to 2500 mg / L. The dissolved oxygen in reactor was 2 to 3 mg / L and the MLVSS was around 3000 mg / L The best saturation sludge was obtained at 3 mg / L dissolved oxygen Conditions No accumulation of sludge was observed below dissolved oxygen concentration between 2 and 3 kept mg / L Increased dissolved oxygen in the reactor can remove bio flakes and cause sedimentation of disturbances sludge in the sedimentation phase and high turbidity in the wastewater (Mohseni Bandpey A, Bazari H, 2004)

Studies show that the dissolved oxygen level of 2 mg / L is a good target in biological treatment, the lower the dissolved oxygen, the more efficient the oxygen transfer. Aerobic organisms that remove more organic matter are really effective as long as oxygen is present but there is a risk of "dead zones" in the lower levels. If the DO is 5 or more, it is advisable that the dead zones be minimal as normal currents will flow and the mixture will carry the oxygenated mixed fluid through all equipment When the DO is high or low, sedimentation problem can occur due to flocculation and resuspension of inert materials processes; with a DO content of 10 to 12 mg / L The first indicator of low DO conditions is the growth of filamentous microorganisms Proper monitoring of the ventilation system allows us to avoid low DO (Theobald, 2013)

3. CONTROL MEASURES FOR THE INHIBITORS

3.1 pH

According to studies done on municipal wastewater, a sequencing batch reactor (SBR) with an operational control based on-line measurement of pH value is well suited for pH control. The pH control has two set point switched programmed to control the aerator. During aeration phase, reject-water is pumped at fixed flow rate from storage tank into aerated reactor. Due to nitrification, pH value decreases despite the alkalinity input of reject-water until lower set point (pH=7.2) is reached. Then the aeration is switched off. Under anoxic conditions, denitrification process starts. Denitrification and continues reject-water flow recovers alkalinity. When the next set point (pH = 7.6) is reached, aeration starts again. This control mechanism continues until the end of the aeration phase. The pH value is kept within the specified range, no additional lye or acid dosage is required, but only controlled aeration. The reactor is shifted from oxidation to reduction depending on the current pH value in order to balance alkalinity and to reduce CO_2 stripping. The reject-water flow transport 15% of total plants nitrogen load to SBR. The characteristic pH value of reject-water is 11.9 to 12.8. (B Wett, R Rostek, W Rauch and K Ingele, 1998).

The optimal pH value for aerobic process is about neutral pH, i.e 7-7.8, in pulp and paper wastewater treatment process. In order to control the pH value, an automatic dosing system is installed in the system, and strong acid (HCl) and strong alkali (NaOH) are added to the system as a neutralizing solution. They conducted studies on simulation of pH cascade control system based on PID, shows that it can contribute to excellent control effect. It has strong capacity adaptive to the change of controlled parameters and also good control effect is achieved when structure of the objective model is intensively disturbed. The cascade control system based on PID has the advantages of fast raising, short response time, high adjusting accuracy, good steady-state performance and small overshoot, and can competently fulfill the automatic control of pH. (Jiayu Kang, Mengxia Wang and Zhongjun Xia, 2009).

According to the studies conducted on municipal and industrial waste, bacteria and other entities are most effective at pH 7 to 8. In order to maintain these optimal pH conditions, the most effective bases are magnesium hydroxide and sodium hydroxide, which can neutralize the acid formed. Magnesium hydroxide can able to supply more alkalinity than caustic soda. The amount of alkali is determined by amount of pollutants in incoming waste, the type of treatment that is used in plant, amount of natural alkalinity in influent water, pH of influent water, permitted pH of effluent discharged from plant, the number of gallons of waste processed by plant and whether the plant denitrifies the effluent prior to final treatment and discharge. Studies have shown that caustic soda is one of the most common alkalis used in wastewater treatment to provide alkalinity, but the properties of magnesium hydroxide make it an extremely superior alkaline product in the treatment system. The benefits of magnesium hydroxide include: Provides higher alkalinity per gallon, safer to use, does not cause scaling problems, non-toxic, environmentally friendly, buffers to a moderately alkaline pH of 9.0, uses the same pump as caustic soda, and provides long-term alkalinity (Martin Marietta Magnesia Specialties, LLC, 2015).

Studies were conducted on pH neutralization process in industrial wastewater. The pH measurement is the measurement of dissociation of acid or alkali molecules into ions. The PID technique is used as pH control systems in industrial wastewater treatment. PID controller gives the difference between the set points and process variable by yielding response with desired value. The PID (Proportional-Integral-Derivative) controller has three parameters, where Proportional gives change in input directly proportional to control error. The Integral gives change in input proportional to integral error and to eliminate offset. The Derivative is prediction of future rate of change. Combined Fuzzy Logic based PID control provide an optimally performing intelligent system. Based on the type of treatment system, the desirable pH value is entered manually. When pH value is less than desired value, Fuzzy logic controller and PID controller maintains the corresponding pH value while manipulating the process control variable. Strong base (NaOH) and strong acid (HCl) is used to maintain the pH range in the treatment system. The combination control mechanism (PID and fuzzy logic controller) used to control the pH neutralization system covers the existing operating range of all pH values. Compared with the normal fuzzy logic controllers, the combination controller is very stable. This design method is applicable to any pH neutralization process plant with mechanical flow meters. The reliability of the combination controller is depends on the flow control valve, pH meter, because these devices can be changed during real time controller design and implementation. (Sakthi Sridevi P, Prema ,2017).

3.2Temperature

Studies were carried out in various industrial pulp and paper effluents. They focused on minimizing the production of sludge so that most of the bacterial biomass produced is consumed by protozoa and metazoa predators. Through the circulation of temperature-controlled water, the ambient temperature was maintained in the treatment process(N Lee and T. Wetlander,1996).

Experiments with wastewater from pulp and paper mills showed the effect of temperature fluctuations on treatment efficiency and solids discharges. The effect of controlled temperature shifts (35°C to 45°C; 45°C to 35°C) and periodic temperature oscillations (31.5°C to 40°C, period of 6 days, over 30 days) were evaluated. The temperature shifts caused values of higher effluent suspended solids (ESS) (25-100 mg/L) and a decrease in the removal efficiency of soluble COD (up to 20%). Higher ESS levels were observed by a slow (2°C/day) versus faster (10°C/12h) shift. The soluble COD removal efficiency decreased in both cases similarly. The temperature oscillations also caused higher values of ESS and lower removal efficiency of sCOD(5% decrease). (Fernando Morgan Sagartume, et.al, 2003).

The experimental studies done on wastewater from the swine industry which is a very high strength wastewater suitable for a self-heating aerobic thermophilic treatment shows that temperature up to 75°C were reached without external heating by using venturi-type aerators but these conditions were detrimental for the microflora. Better COD removal efficiency was achieved at a temperature of 50°C. A coil was placed in the tanks to allow cooling, which was recorded and controlled by a computer. (PiesseJuteau, et.al, 2003).

Experiments on the Autothermal thermophilic aerobic digestion (ATAD) which is an exothermic process where sludge is subjected to temperatures greater than 55°C for at least 4 hours, over 6-10 days shows that organic solids are degraded and the heat produced during the microbial degradation is used to achieve the thermophilic range. In addition to adequate reactor insulation, efficient aeration and mixing are required to maintain the thermophilic range. It produces biologically stable product achieving a reduction in biomass while using smaller digesters, when comparing mesophilic aerobic to anaerobic digestion. The investigations were done on municipal wastewaters. (Noreem M Layden, et.al, 2007).

3.3 Organic loading rate (OLR)

The organic load can be controlled by pretreatment to reduce BOD and TSS concentration or by increasing the infiltration area to reduce mass loading per unit area. A direct correlation was found between organic loading rate (kg solids/ m^2 d) and the solids accumulation rate was found in the four-fold range of the assessed organic load rate. As the effective size of the media increased, the solid accumulation rate decreased significantly. However, not one of the loading conditions evaluated resulted in a solids equilibrium, that could allow unlimited operation of a filter without ponding. Control of organic loading rates of municipal waste may be carried out by decreasing BOD or by increasing the area of infiltration to reduce the mass loading per unit area. (Washington state department of health, 2002).

The hydraulic retention time (HRT) of municipal wastewater is 70 to 15 minutes, and the efficiency of removing organic compounds from wastewater has changed from 85.2% in reactor I to 93.8%, and in reactor II from 62.9% to 87.1%.The contribution of oxidation, biomass synthesis, denitrification and intracellular storage to the elimination of organic compounds depends on the type of carrier and the hydraulic retention time (HRT). More than 20% of the organic load fed into reactors I and

II was used for cell oxidation. 6.1 to 14.5% of the incoming load was removed as a result of sludge yield.(M Zielinska and I Wojnowska-Baryla,2004).

The use of microbial fuel cells (MFCs) was studied to reduce the chemical oxygen demand (COD) of wastewater from paper mills while generating electricity in a continuous flow system. With a hydraulic retention time (HRT) of six hours, the COD removal with unaltered wastewater (506 mg/L COD) (organic loading rate, OLR = 2.0 kg COD/(m^3 d)) was 26±2%, with a power density of 5.9±0.2 W/m^3 (210±7 mW/m^2). This power is similar to the maximum power density (5.2±0.4 W/m^3) obtained in conventional tests, using slightly lower strength wastewater (405 mg/L COD) in the same equipment. Increasing the HRT to 25 hours (OLR = 0.5 kg COD/(m^3 d)) increases the COD removal rate (41±2%) but significantly reduces the power (2.8±0.3 W/m^3). Although the strength of the sewage affected the removal rates, the conductivity of the solution (0.8 mS/cm) was mainly a factor in low power production. These results indicate that MFC can be used to reduce organic loads in wastewater at relatively short HRT while also generating energy. (Liping Huanga, Shaoau Chengb, Farzaneh Rezaeic and Bruce E Logaub, 2019).

3.4 Dissolved oxygen (DO)

The blowers are the first stage in a diffuse air system. Proper design of the blower system is required for efficient control of dissolved oxygen concentration. During the design process, it is important to consider that the airflow demand will vary during the day, week and the year since as well as in the entire aeration tank . The flexibility of a blower system is decisive for the performance of the aeration system, since systems have to cope with large load fluctuations. Blowers are the largest single user of treatment plants. Today motivates adequate ventilation control. The control of ventilation systems becomes even more important when sewage treatment plants are subject to stricter limits and when energy efficiency is a top priority. The dissolved oxygen concentration could not be viewed on its own without taking into account the temperature and the aerobic SRT. At a lower SRT and a lower temperature, the higher concentrations of DO are required to compensate for a loss in the nitrification rate. In processes with denitrification, increased DO values can impair the denitrification performance if rich water is returned to anoxic zones (L Amand, et al. 2013).

It is believed that microbubble aeration is highly efficient for oxygen supply in aerobic wastewater treatment. The formation of biofilms on the carriers was increased by microbubble aeration due to the strong adhesion of the microbubbles to the solid surface in a study in synthetic municipal sewage. The efficiency of microbubble aeration was apparently higher than that of traditional bubble aeration (lei zhang, et al., 2016).

The experiments were carried out in models of solid surface jet aerators with openings of circular, elliptical, rectangular, square and rectangular shape with rounded edges for a range of discharges and opening areas, the ventilation parameters of each model being measured for numerous discharges and penetrations. Depth, oxygen transfer factor and oxygenation efficiency were calculated. It was found that the aerators with square openings had the lowest value for oxygen transfer factor and efficiency, while the aerators with rectangular openings with rounded edges had the highest value for these parameters under similar conditions. Conditions of discharge (Bishnu Kant Shukla, et al., 2019).

4. CONCLUSIONS

The major inhibitors like temperature, dissolved oxygen (DO), pH and organic loading rate (OLR) that inhibit the proper functioning of aerobic treatment system and the various control measures adopted to maintain these inhibitors at optimum level to improve the efficiency of system were studied.

For pH, optimal range for effective biological activity is 6.5 to 8.0 and is maintained by neutralizing the wastewater with strong acid and string base. For proper working of an aerobic treatment system a temperature between 25-30 °C is desirable. The required temperature may be achieved through the exothermal microbial degradation. In the case of OLR 2.5 to 7.5 g COD/dm^3.day is effective and can be controlled by using MFCs, changing HRT or controlling the BOD. The typical range of DO for the proper functioning of aerobic treatment unit is 2 to 3 mg/L and to control them microbubble aerators and blower systems can be used.

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