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Characterization of Sludge and Design of Activated Sludge Process for Sewage Treatment

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Abstract: *Activated sludge process is most common biological treatment. High efficiency and easy operation are advantages of the process. Characterization of the sewage is important aspect of the treatment methodology. The chemical and biological oxygen demand and their relative values help in deciding the treatment methodology. In the current work, the analysis of the sludge is carried out. Also the various important parameters like ultimate biological oxygen demand, rate constant and effect of temperature on the rate constant are studied. The activated sludge tank is designed and parameters such as hydraulic retention time, air requirement are estimated.*

Keywords - Sludge, cell mass, retention time, oxygen demand, organic matter, rate constant.

I. INTRODUCTION

Biological wastewater treatment methods include attached and suspended growth processes. In attached growth methods, trickling filters are commonly used for wastewater treatment. Activated sludge process is used in most of the sewage treatment plant. The characterization of activated sludge and effluent is important aspect of facility design. The amount of oxygen required for chemical oxygen demand (COD) fulfillment is most important parameter along with biological oxygen demand (BOD). Their ratio plays key role in estimation of biodegradability of the effluent. The characterization of the sewage includes physical, chemical and biological characterization. The studies on activated sludge characterization and treatment have been carried out by various investigators [1-3]. Also various aspects of biological treatments have been investigated [4-6]. Biological treatment methods find application in removal of pollutants like phenol, heavy metals and many specific pollutants [7-11]. The studies on various aspects of activated sludge processes have been reported by various investigators. In the present work characterization of sewage and design of activated sludge process is carried out by using conventional methods and calculations.

II. LITERATURE REVIEW

Chen et.al carried out an investigation on modeling the dissolved oxygen distribution [12].They measured sediment oxygen demand in the laboratory using undisturbed sediment core samples. They developed the three-dimensional water quality model. They conducted model sensitivity analysis. Talib and Amat investigated artificial neural network for COD prediction[13].They studied the parameters like dissolve oxygen (DO), biological oxygen demand (BOD),suspended solid (SS), pH, ammonia (NH_3), temperature, nitrate (NO_3), total solid (TS) and phosphate (PO_4). Azeez carried out an investigation on effect of temperature on the treatment of industrial wastewater using chlorella vulgaris alga[14].He performed laboratory experiments for nutrient uptake study by the unicellular green microalgae (Chlorella vulgaris) grown in batch system. He obtained COD, BOD, nitrogen and phosphorus removal close to 90 percent. He observed that growth rate constant was affected by temperature. It was the most important physical factor influencing the efficiency of nutrient Removal. An investigation was carried out by Sharma and Gupta to study oxygen (BOD, OD, COD) in water and their effect on fishes [15]. They investigated the effect of pollution on water and fish diversity of river Ganga .They emphasized that reduction in dissolved oxygen concentration is one of the most important factor. Saidi et.al. carried out investigation on effect of presence of heavy metals on biological treatment [16]. According to him, the number, weight and activity of microorganisms can be good indicators of wastewater contamination with heavy metals. Biological wastewater treatment processes have negative effect of the heavy metal presence. Zaidi and Pal investigated influence of temperature on physico-chemical properties of ecosystem [17]. They studied effect of temperature on parameters like pH, alkalinity, nitrate, turbidity, total solid, total dissolved solid, total suspended solid, total hardness, biochemical oxygen demand and chemical oxygen demand. They found that fluctuating climatic conditions affect the water quality to a great extent. Ghodale and Kankal carried out an investigation on the effect of activated carbon (AC) on adsorption of biochemical oxygen demand [18]. They studied effect of various parameters like adsorbent dose, pH, treatment time and agitation speed on the organic matter removal. They also explained adsorption isotherms and applied

them to the experimental data. According to an investigation carried out by Wirnkor et.al. activated carbon from Fluted Pumpkin is very good adsorbent for treatment of wastewater [19]. They treated vegetable oil industry using this adsorbent. Their studies indicated that the adsorbent prepared at lower temperature had poorer adsorbent properties. Ngang and Agbazue carried out an investigation on groundwater pollution due to biochemical oxygen demand, chemical oxygen demand and elevated temperatures [20].They studied borehole water quality. They found that many boreholes were highly polluted. The temperature variations in the boreholes, according to them can be attributed to the factors like differences in borehole depths, topography or nearness of boreholes to the thermal injection source such as power plants. Seng et.al. carried out investigation on effect of EM Ball on DO, BOD and COD of wastewater treatment plant [21]. They carried out collection of wastewater by composite sampling method. Effective microorganisms (EM) are capable of effectively destroying the organic matter. The DO increase of 15-17 percent was observed by them in the investigation. The EM balls prepared by them in the laboratory were more effective than commercial EM balls. Ukpaka investigated the effect of chemical and biochemical oxygen demand (COD) and BOD) on crude oil degradation [22]. He developed model for effect of COD and BOD on crude oil degradation in water. An investigation was carried out by Ghani and Idris, to produce biogas from leachate[23]. They performed three sets of experiments. They evaluated the performance by using pollutant removal efficiency and biogas production. They observed that the volatile suspended solids (VSS) content of the feed affects the biogas production rates. In the current research paper characterization of sludge is carried out. The sludge is used for the treatment of waste water for reducing chemical and biological oxygen demand. The effect of temperature on the activated sludge is also studied.

III. CHARACTERIZATION

3.1 Physical Characterization

The domestic sludge normally has same density as that of water. The colour of the domestic wastewater is normally earthy brown. It smells musty. It is postulated that with increase in temperature up to 60^oC, the activity decreases. The dissolved oxygen content and viscosity also decreases with temperature [24]. The total solid content of the sewage is divided into three groups' namely suspended solids, colloidal solids and dissolved solids. Suspended solids are further divided as settleable and nonsettleable. Colloidal solids are very finely divided solids which cannot be settled out or filtered. Dissolved solids remain in sewage just like salts. The solid content can be also classified as organic and inorganic or volatile and non-volatile. Generally proportion of these solids(volatile and nonvolatile) is 45:55 in sewage[24].

3.2 Chemical Characterization[24]

Important characteristics of sewage are pH, nitrogen, chloride, phosphorus, fats, oil and grease, sulphates, sulphides, phenols, surfactants, pesticides, dissolved oxygen and gases like hydrogen sulphide and methane. Human and waste discharges have considerable chlorides. There is no effect of biological actions on chlorides. It is postulated that the pH value of 7-7.5 is good for bacterial action. Phosphorus is essential for biological activities. Fats and oils can clog filters. Also they affect the ecology of the ponds or reservoirs if disposed. The dissolved oxygen content is important measure of organic matter. The aquatic animals need dissolved oxygen content more than 5 mg/l. The desirable dissolved oxygen content is 10 mg/l. Chemical and biological oxygen demands(COD and BOD) are important measures of chemically and biologically degradable organic matter. Biological organisms such as protista organisms like bacteria, algae and protozoa. Pathogenic bacteria are also discharged from infected human bodies[24].

3.3 Analysis Methods

In the present investigation COD and BOD of the sewage was determined by using standard methods. The chemical oxygen demand (COD) is determined by using COD digestion apparatus. The BOD was determined by using dilution method. In the present investigation the biological oxygen demand is estimated at various time and compared with the theoretical values estimated from the kinetic equation.

IV. CALCULAIONS

4.1 Expression for BOD

The BOD exerted at any time t is given by

$$BOD_t = BOD_u(1- e^{-kt}) \quad (1)$$

BOD_u is the ultimate first stage BOD.First stage BOD is indicator of oxygen consumed by organic matter. The value of K is determined by using Thomas method.

According to this method,

$$\left(\frac{t}{BOD_t}\right)^{1/3} = (K\,BOD_u)^{-1/3} + \frac{K^{2/3}}{6\,BODu^{1/3}}\,t \qquad (2)$$

BOD_t is the BOD at any time t.
When the LHS of the equation is plotted against t , K and BOD_u are determined from slope and intercept.
The value of K at given temperature(T) can be determined by using following equation

$$K_t = K_{20}\,\theta^{(T-20)} \qquad (3)$$

V. DETERMINATIN OF ULTIMATE BOD AND RATE CONSTANT

The sewage sample was collected and analyzed after 2,4,6, 8, 10 and 12 days(Table1, Fig.1). The data was used for estimation of ultimate BOD and rate constant K(Table2,Fig.2).Then the BOD at any time t was determined by using the rate equation. Equation 2 is used with following interpretations.
K = 6b/a where a is intercept and b is slope
From fig.2, b=0.008 and a=0.437
The value of K is estimated to be 0.1098 day^{-1}.
BOD_u was calculated and was found to be 109.13 mg/l

Table 1:Time –BOD_t data

Time t, days	2	4	6	8	10	12
BOD	20	38	52	65.1	70	72

Table 2: Data for Thomas Method

Time t, days	2	4	6	8	10	12
$\left(\frac{t}{BOD_t}\right)^{1/3}$	0.46	0.47	0.49	0.50	0.52	0.55

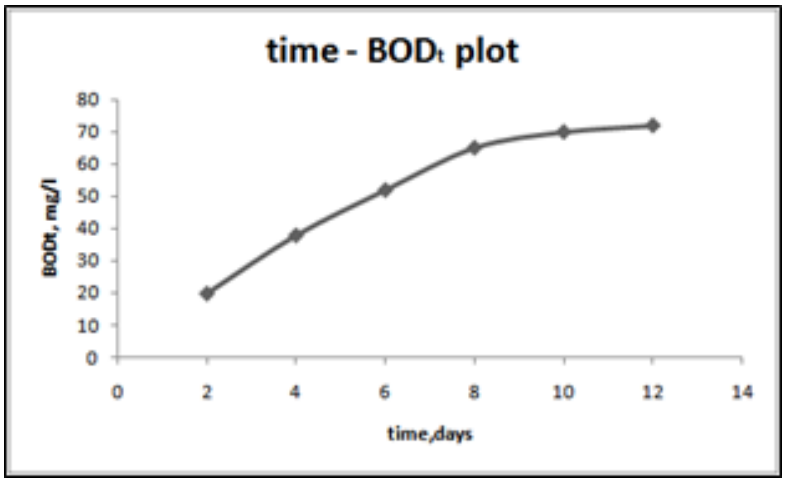

Figure 1: BOD at various time t

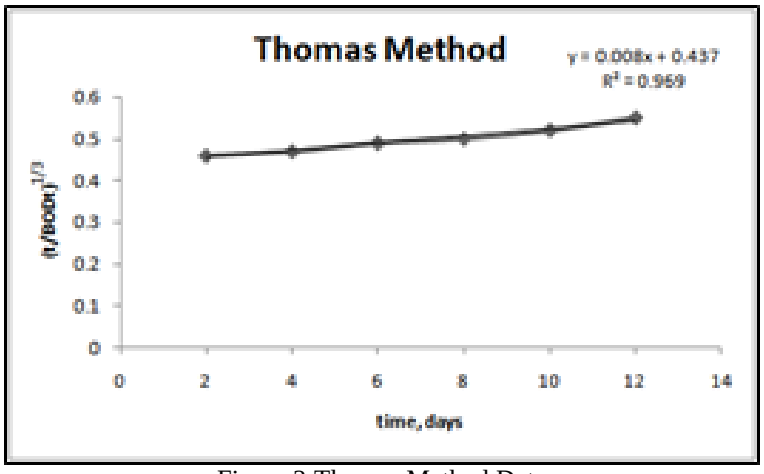

Figure 2:Thomas Method Data

VI. EFFECT OF TEMPERATURE ON THE RATE CONSTANT

For studying effect of temperature on the rate constant, 5 day was determined at 20 ^{0}C. The rate constant k_{20}= 0.1098 day^{-1} as determined earlier(Tablr3, Fig.3). The value of θ is taken 1.047 from literature.5 day BOD at 20 ^{o}C was observed to be 45 mg/l . Equation 3 is used for determination of the value of K at various temperatures

From equation (1), $BODt = BOD_u(1- e^{-kt})$

Table3:Effect of temperature on rate constant

T^{o}K	20	25	30	35	40
$K= K_{20}\ \theta^{(T-20)}$	0.1098	0.138	0.174	0.2186	0.27
BOD_5 mg/l	45	54.39	63.4	72.54	80.84

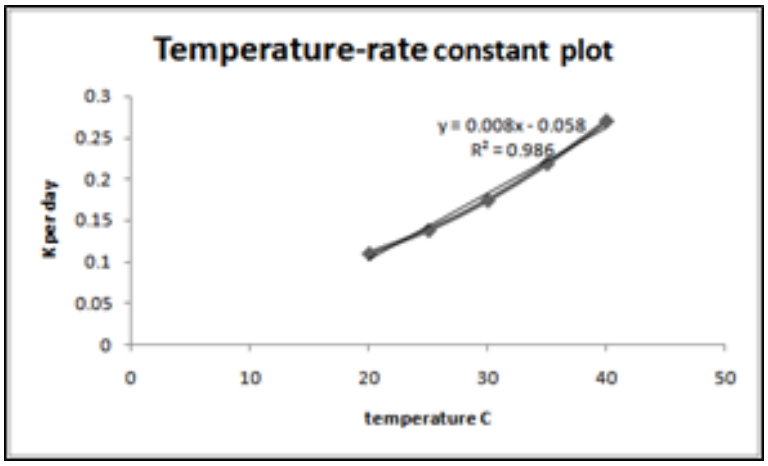

Figure 3: Temperature –rate constant plot

VII. DISCUSSION

The typical value of K for domestic sewage is reported to be 0.1 per day(24). The obtained value is 0.1098 per day, which is in agreement with the reported data. The values of BOD and K varied linearly with temperature in the temperature range of 20 to 40 ^{o}C.

VIII. ACTIVATED SLUDGE TREATMENT

The main objective of biological treatment is to coagulate and remove colloidal solids and also to remove non settleable colloidal solids. Also it is envisaged to stabilize the organic matter with the help of microorganisms. These treatment systems are classified as suspended growth and attach growth. Also aerobic and anaerobic treatments are another classification.

8.1 Design of facility

Sewage flow= 10000 m^3/d
Influent BOD_5=45 mg/l
Effluent BOD=5 mg/l
Effluent suspended solids=6 mg/l
Mixed liquor volatile suspended solids(MLVSS)= 1000 mg/l
Return sludge concentration=4000 mg/l
Y=0.6, K_d= 0.06 day^{-1}, θ_c= 10 days
MLSS/MLVSS=0.8

a. Determination of concentration of substrate or soluble BOD5 in effluent
   BOD5 of effluent = 0.63SS= 0.63X6= 3.78 mg/l
   Effluent soluble BOD S = Effluent BOD5 – 0.63 SS=5-3.78=1.22 mg/l
   Influent soluble BOD So = Influent BOD5= 45 mg/l
   Influent
b. Determination of process efficiency E

E= $(S_0-S)/S_o$ X 100= (45-1.22)/45 = 97.28 %
Overall efficiency =(45-5)/45 = 88.88 percent

c. Reactor volume

$$xV = \frac{YQ(S_0 - S)\theta_c}{1 + \theta_c k_d}$$

Where x= MLVSS, Q= sewage flow rate, S_0 = Influent soluble BOD, S= Effluent soluble BOD, θ_c= cell residence time, k_d= rate constant

$1000\ V = \frac{0.6\ X1000\ 0\ (45-1.22)10}{1+10X0.06}$, V= 1641.75 m^3

d. Sludge to be wasted
The quantity of the sludge produced per day is given by
$Q_w = (Vx)/(\theta_c\ X_r)$ = (1641.75 x 1000)/(10x 4000x0.8)= 51.3 m^3/day

e. Determination of recirculation flow
$Q_rX_r = (Q+Q_r)\ X$
$3200\ Q_r = (10000+Q_r)\ 1000$
Q_r= 4545.45 m^3/day
$r = Q_r/Q$ = 0.4545

d. Hydraulic Retention time = θ = V/Q= 1641.75/10000= 0.1641 days=3.94 hours

e. Kg O_2 /day = 1.47 $Q(S_0 - S)$ – 1.42((V. x)/(θ_c) = 410 kg/day
Oxygen required per kg of BOD removed = 410/(43.78/10^6 x10 x 10^6)= 0.936 .It is between 0.1 and 1, hence acceptable.

f. Volume of air at STP = oxygen demand/(oxygen transfer efficiency X 0.2784)=18408.7 m^3 per day , Design air requirement= 2X18408.7=36817.5 m^3 per day.

g. Check F/M ratio
F/M= S_0/(θ.X) = 0.274 which is between 0.2 and 0.4 for completely mix process and hence acceptable.

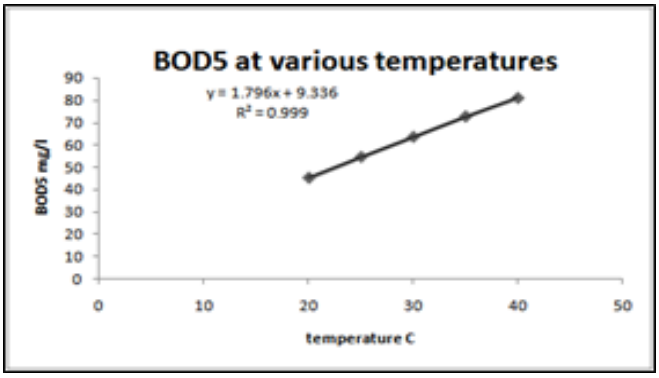

Figure 4: BOD_5 at various temperatures

IX. CONCLUSION

In the current investigation, the values of rate constant k and ultimate BOD were estimated by using Thomas method. The value of K is estimated to be 0.1098 day^{-1}, which in agreement with typical values of K for sewage wastewater. The effect of temperature was also studied. The process efficiency was 97.28 percent and overall efficiency was 88.88. percent.F/M ratio for the designed facility was satisfactory.Hydralic retention time was 3.94 hours. It can be concluded that the designed activated sludge process is satisfactory can it can be scaled up to pilot plant or larger facility.

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