

Study on Kinetics of Pollutants Removal in Guheshwori Wastewater Treatment Plant, Kathmandu

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Abstract

Settlement in Kathmandu started from riverbanks. With the increase in population, industrialization and various other economic activities, the wastewater generation has increased significantly. The objective of this study is to assess the performance and determine the kinetics of the only functional centralized municipal Wastewater Treatment Plant (WWTP) based on Oxidation Ditch in the capital Kathmandu of Nepal. The removal efficiencies of the Guheshwori WWTP (GWWTP) for Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) were found to be 76.12% and 78.51% and 76.13% and 76.18% during pre-monsoon and monsoon period, respectively. The nutrient removal efficiencies considering the phosphate was found to be 47.61% and 55.60% and ammonia-nitrogen was 12.67% and 29.11% during the pre-monsoon and monsoon period, respectively. The current removal efficiencies do not meet the final effluent discharge standards set by the Government of Nepal. The analysis of kinetic values of pollutant removal showed that the yield coefficient (Y), decay coefficient (kd), maximum specific growth rate and saturation constant (Ks) for GWWTP were found to be 0.18 (kg VSS /kg COD) and 0.05 (d⁻¹) 5.26 and 27.26 (mg/l), respectively. These values can be beneficial in upgrading or improving the performance of the plant.

Keywords: Oxidation ditch; Activated sludge process; Wastewater treatment plant; Kinetic coefficient; Municipal wastewater

Abbreviations: a: Recycle Ratio; BOD: Biochemical Oxygen Demand; COD: Chemical Oxygen Demand; DO: Dissolved Oxygen; HRT (Θ): Hydraulic Retention Time; k: Maximum Specific Substrate Utilization Rate (d⁻¹); K_d: Cell Death Coefficient; K_s: Half Velocity Constant (g/l); KUKL/PID: Kathmandu Upathyeka Khanepani Limited (Kathmandu Valley Water Supply Limited)/Project Implementation Directorate; MLD: Million Liters Per Day; MLSS: Mixed Liquor Suspended Solid; MLVSS (X): Mixed Liquor Volatile Suspended Solid; Q: Influent Wastewater Quantity; Q_w: Waste Activated Sludge Volume; Q_e: Effluent Wastewater Quantity; R_{su}: Rate of Substrate Utilization; S_e: Effluent COD

Concentration; S_i: Influent Concentration to Reactor After Dilution With Recycle Flow; S_o: Influent COD Concentration; SRT (Θ_c): Solid Retention Time, Mean Cell Residence Time; WWTP: Wastewater Treatment Plant; X: Average MLVSS Along the Oxidation Ditch; X_e: Concentration of MLVSS at Effluent; X_w: Concentration of MLVSS in Activated Sludge; Y: Yield; μ: Specific Growth Rate; μ_{max}: Maximum Specific Growth Rate (d⁻¹).

Introduction

Rivers of Kathmandu valley are related to the culture and civilization of people. That is one of the reasons for the settlement along the riverbanks. These are also related to the religious and cultural activities of people living in the Kathmandu valley. With the rapid increase in population with a growth rate greater than 4%, industrial production and various other economic activities, the volume of wastewater generated has increased. In most urban areas in developing nations, wastewater is disposed of directly, or without effective treatment, into surface water bodies, resulting in their severe degradation; despite the adoption of countermeasures [2,3].

The Constitution of Nepal has provisioned rights for citizens to live in a clean environment (Article 31) and access to clean drinking water and sanitation (Article 35). Local Government Operation Act, 2017 empowers local government to perform formulation of policy, plan, program on secure settlement development and their implementation, monitoring, regulation and evaluation (Section 11.2.g.9), Primary health and sanitation, and nutrition-related policy, law, standard, plan formulation, implementation, and regulation (Section 11.2.i.1). Fixing quality standard on clean drinking water and food, and air and noise pollution control and regulation (Section 11.2.i.5) and Coordination, cooperation and collaboration with private and non-government sectors in the management of solid waste generated from sanitation and health sector (Section 11.2.i.10) and environment protection and biodiversity-related policy, law, standard and plan formulation and their implementation, monitoring and regulation (Section 11.2.j.12). Environment

Protection Rules (EPR), 1997 explicitly prohibited discharge of waste in contravention of the prescribed standards. Therefore, no one is allowed to discharge/emit or cause to discharge/emit the noise, heat, and waste from any mechanical means, industrial establishment or any other place in contravention of the standards prescribed (Ministry of Environment) by notification published in Nepal Gazette (Rule 15). Under the same regulatory provision (Rule 15), Generic/Directive Standards for Industrial Effluents to be discharged to surface water, 2058 B.S, Standards for Tanneries, 1997, Dying Industries, 1997, Fermentation Industries, 1997, Vegetable Ghee and Oils, 1997, Paper and Pulp Industries, 1997, Industries of Sugar, Milk, Cotton Cloths, Soap, 1999 and Generic Standards for Industrial effluents to be discharged in Public Drainage System, 1999 and Standards for the Joint Water Treatment Plants of Industrial Effluents to be discharged to surface water, 1999 were prepared but no standard for domestic wastewater treatment effluent has been prepared. Drinking Water Management Board Act, 2006 has stressed the participation of local bodies and organizations involved in drinking water, sanitation and cleaning in the drinking water and sanitation services. Urban Drinking Water and Sanitation Policy, 2009 has envisioned to adopt environment protection measures and to bring balance with other uses of water resources adopting used water discharge measures.

With the aim of improving the river water quality of Bagmati, 5 treatment plants were constructed in Kathmandu Valley. These were oxidation ditch at Guheshwori, aerated lagoons at Sallaghari and Hanumanghat and non-aerated lagoons at Kodku and Dhobighat [4,5]. Among the 5 treatment plants, only Guheshwori WWTP is functional at the moment [6-9]. The Guheshwori treatment plant was designed in 1996 to serve a population of 58,000 (projected 198,000 in 2021) and has a treatment capacity of 0.19 m³/s. The major components of the treatment plant include barrack, grit chamber, oxidation ditch, clarifiers, and sludge drying beds. The treatment is basically biological. With the majority of oxidation ditches not requiring primary settling [10,11], it was not considered in Guheshwori WWTP. There are two carrousel type oxidation ditches, each with three aerators of size 80 × 20 sqm. The wastewater then flows into two secondary clarifiers for the settling of biomass. Some portion of the sludge is recycled whereas the remaining sludge is sent to sludge drying bed for drying [7]. Guheshwori WWTP was developed under the Bagmati Improvement Project and HPCIDBC is the implementing agency for the operation of the wastewater treatment plant. Under Drinking water management board act, Kathmandu Valley Water supply board has been formed for supplying drinking water in Kathmandu Valley. They have leased KUKL to implement water and sanitation activities of Kathmandu Valley. The Kathmandu Valley Wastewater Management Project implemented by KUKL/PID with the support from ADB has set a target to treat 90.5 MLD and 382.1 MLD of wastewater by 2020 and 2030 respectively in Kathmandu valley. For this, all the treatment plants will be Activated Sludge Process [4]. The redesigning and reconstruction of these treatment plants are at peak at the moment with the High Powered Committee for Integrated Development of Bagmati Civilization and Project Implementation Directorate (PID) of KUKL being the major stakeholders.

Most of the designs of biological treatment systems are designed based on hydraulic considerations. However, due to variation in quality of wastewater and nature of the biochemical processes and reactions occurring in the treatment plants, the kinetic parameter is a very essential parameter for effluent quality and operation [12]. Kinetics study in biological treatment helps us to understand the degradation rate of a particular pollutant by microorganisms which can help us in sizing the plant and to improve the performance [13]. Hence, a study on performance and pollutant removal kinetics in GWWTP was performed.

Materials and Methods

Data collection

Primary data collection through sampling: Grab sampling at GWWTP from 29th April 2018 to 12th August 2018. The sampling was done weekly. The sampling points are given in the following drawing.

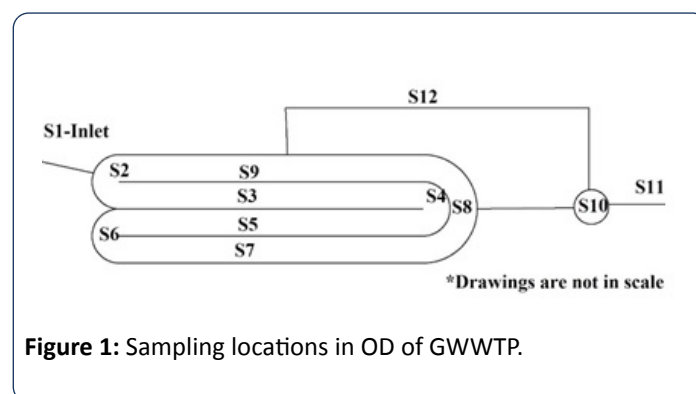


Figure 1: Sampling locations in OD of GWWTP.

Analytical methods: Samples from the influent wastewater, reactor and effluent were analyzed for various physical and chemical parameters in accordance with the Standard Methods (APHA, 2005). Analysis was done for pH, Dissolved Oxygen (DO), Oxidation-Reduction Potential (ORP), Mixed Liquor Suspended Solids (MLSS), Mixed Liquor Volatile Suspended Solids (MLVSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonia nitrogen (NH₄N), Nitrate (NO₃⁻) and phosphate PO₄³⁻. The analytical methodology adopted for the analysis of parameters are presented in **Table 1**.

Table 1: Analytical methods adopted.

S. N	Parameter	Method adopted
1	pH	pH meter
2	DO	4500-0 B. Iodometric method, APHA 21 st edition
3	MLSS	2540 D. APHA 21 st edition
4	MLVSS	2540 E. APHA 21 st edition
5	BOD	5210 B. 5-Day BOD Test, APHA 21 st edition
6	COD	5220 B. Open reflux method, APHA 21 st edition

7	Ammonia	4500 NH ₃ F. Phenate Method, APHA 21 st edition
8	Nitrate	4500 NO ⁻³ B. UV Spectrophotometric method, APHA 21 st edition
9	Phosphate	4500-P E. Ascorbic Acid Method, APHA 21 st edition

pH plays an important role in microbiology and chemistry of wastewater. It affects mostly for the existence of most biological life in the wastewater and its range is very narrow (6-9) [14]. Similarly, DO concentration is another essential parameter that has a significant role in aquatic life including microorganisms. It is the relative measure of oxygen that is available in wastewater. Nitrogen and Phosphorus are essential for the growth of biological organism as these are one of the constituents of the cell. Nitrogen is an essential building block for the synthesis of the protein itself. Also, it is one of the major reasons for eutrophication as the presence of phosphorus enhances algal growth. Organic compounds are one of the parameters used to determine the pollution level of wastewater. This in presence of oxygen is decomposed by a microorganism and is converted to cells and other bi-products as expressed in equation 1. These compounds deplete the DO level of the wastewater thus hampering the aquatic life of the effluent stream. SS is the parameters used as available microorganisms in the reactor that will decompose the substrate in wastewater. This includes all the particles that cannot be filtered and will decant if left without turbulence. VSS is the quantity of volatile portion of suspended solids. Since SS includes inorganic particles too, VSS is the number of organic particles. Hence, this is an even more representative parameter to estimate the concentration of microorganisms [14-16].

Study of Kinetics: The volume, flow and Hydraulic Retention Time (HRT) of each oxidation ditch of Guheshwori WWTP is 10400 cum, 0.095 m³/s, and 15.2 hrs.

Carbonaceous pollutants: During biological wastewater treatment, organic matter is used up producing new biomass, carbon dioxide, and water. However simultaneously, endogenous respiration takes place with new cells begin to consume their own cell tissue to obtain energy for their cells maintenance and simultaneously, release carbon dioxide, water, and ammonia.

The general equation is given in equation 1 and its breakdown is given in equation 2, 3 and 4 respectively.

Organic matter+Oxygen+nutrients+bacteria → CO₂+H₂O+NH₃+New Biomass+other end products1

Oxidation:

CHON or CHONS+O₂+bacteria → CO₂+H₂O+NH₃+waste products+Energy2

Synthesis:

(CHONS)+O₂+Energy → C₅H₇NO₂ (New cell tissue)+H₂O3

Endogenous respiration (Endogenous metabolism):

C₅H₇NO₂ (New cell tissue)+5O₂ → 5CO₂+2H₂O+NH₃.....4

Kinetic parameters determination: To determine the kinetic parameters of the wastewater, we have 2 equations for determining the rate of substrate utilization.

$$R_{su} = \frac{kS_e\bar{X}}{K_s + S_e}$$

Where,

R_{su}=Rate of substrate utilization rate (mg/L.d)

K=maximum specific substrate utilization rate (1/d)

S_eis the concentration of substrate at effluent (mg/l)

K_s=Half velocity constant (substrate concentration when the growth rate is half of the maximum growth rate) (mg/L)

$$R_{su} = \frac{-(S_o - S_e)}{\theta}$$

Where,

S=substrate concentration at influent (mg/L)

=Hydraulic Retention Time (d)

Combining equations 1 and 2, we get

$$\frac{kS_e\bar{X}}{K_s + S_e} = \frac{-(S_o - S_e)}{\theta}$$

Multiplying equation 3 by and inverting we get

$$\frac{\bar{X} \cdot \theta}{S_o - S_e} = \frac{K_s}{k} \cdot \frac{1}{S_e} + \frac{1}{k}$$

Now plotting $\frac{\bar{X} \cdot \theta}{S_o - S_e}$ and $\frac{1}{S_e}$, we get the value of $\frac{K_s}{k}$ and $\frac{1}{k}$, from which the value of K_s and k can be determined.

$$SRT (\theta_c) = \frac{V \cdot \bar{X}}{Q_w X_w + (Q - Q_w) X_e}$$

From [14], we have the equation for plug flow reactor relating SRT, which is given as

$$\frac{1}{\theta_c} = \frac{k(S_o - S_e)}{(S_o - S_e) + (1 + a)K_s \ln\left(\frac{S_i}{S_e}\right)} \cdot Y - k_d$$

Where,

S_i is the influent concentration to the reactor after dilution with recycle flow and a is the recycle ratio

$$S_i = \frac{S_o + aS_e}{1 + a}$$

Putting the values of k, K_s from the graph of $\frac{\bar{X} \cdot \theta}{S_o - S_e}$ and $\frac{1}{S_e}$ a from Guheshwori WWTP, we get the value of

$\frac{k(S_o - S_e)}{(S_o - S_e) + (1 + a)K_s \ln\left(\frac{S_i}{S_e}\right)}$. Plotting $\frac{k(S_o - S_e)}{(S_o - S_e) + (1 + a)K_s \ln\left(\frac{S_i}{S_e}\right)}$ and $\frac{1}{\theta_c}$, we get the value of Y and kd.

Fixed maximum specific growth μ_{max} can be calculated by the following equation.

$$\mu_{max} = K \cdot Y$$

Results

Characteristics of influent wastewater at GWWTP

The characteristics of influent wastewater to oxidation ditch during the pre-monsoon period of the year 2018 is presented in Table 2.

Table 2: Characteristics of incoming wastewater during the pre-monsoon period of the year 2018.

Parameters	Units	29 April	06 May	20 May	27 May	03 June	Average
pH		7.3	7.5	7.7	7.5	7.6	7.52
Conductivity	$\mu\text{S/cm}$	1029	1057	1054	993	1041	1034.8
Temperature	$^{\circ}\text{C}$	25.4	26.1	25.8	24.9	25.1	25.46
SS	mg/L	403.7	408.2	359.3	351.8	334	371.48
VSS	mg/L	173.6	126.6	176.1	175.9	104	151.18
DO	mg/L	0	0	0	0	0	0
COD	mg/L	1286.2	1256.3	1349	1306.3	1287	1296.98
BOD	mg/L	428.7	415.7	418.8	439.8	449.1	430.42
Phosphate	mg/L	20.3	21.2	19.7	19.6	19	19.96
Ammonia	mg/L	77	80.6	74.7	80.1	79.6	78.4
Nitrate	mg/L	20.7	18.9	18.7	18.9	18.6	19.16

Similarly, the characteristics of influent wastewater to oxidation ditch during the monsoon of the year 2018 is presented in Table 3.

Table 3: Characteristics of incoming wastewater during the monsoon period of the year 2018.

Parameters	Units	18-Jun	25-Jun	2-Jul	9-Jul	15-Jul	22-Jul	29-Jul	5-Aug	12-Aug	Average
pH		7.4	7.5	7.3	7.1	7.2	7.3	7.2	7.4	7.5	7.32
Conductivity	$\mu\text{S/cm}$	1020	979	991	993	997	1012	1018	1030	1052	1010.22
Temperature	$^{\circ}\text{C}$	24.7	26.8	25.5	24.9	24.7	26.1	25.2	24.9	25.2	25.33
SS	mg/L	276	241.7	253	289	252.4	280	250.8	292.3	283.6	268.73
VSS	mg/L	138	116.1	104	142	121.2	92.4	120.4	117	88	115.39
DO	mg/L	0	0	0	0	0	0	0	0	0	0.00
COD	mg/L	1032.4	1076	993.2	901.3	950	941.4	923.9	1050	1099.5	996.37
BOD	mg/L	341.2	327.1	272.8	267.9	271.2	241.1	239.7	256	315	281.33
Phosphate	mg/L	16.4	17.4	15.9	19.5	16.3	18.4	17.7	19.8	20.9	18.03
Ammonia	mg/L	76.7	73.8	71.8	68.8	72	79	82	75	81	75.57
Nitrate	mg/L	18.2	17.4	19	18.4	19.2	18.4	20.3	19.7	21.2	19.09

Treatment performance of GWWTP

Carousel type oxidation ditch (extended aeration) has the advantage of treatment reliability; better performance, easy and

low-cost operation and maintenance and ability to absorb shock loads. They have aerobic and anoxic zones for effective nutrient removal [17,18] however the oxygen requirement is high and sludge formation is low [19,20]. The Mixed Liquor Suspended

Solids (MLSS) value is very high in the range of 3000-4000 mg/l and low Food to Microorganism (F/M) ratio in the range of 0.1 to 0.18 [19-21]. The characteristics of the wastewater collected from the sampling points (**Figure 1**) analyzed during the pre-monsoon and monsoon period is shown in **Tables 4 and 5**.

Table 4: Wastewater characteristics during the pre-monsoon period of the year 2018 at various sampling points.

Parameters	Units	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
pH		7.52	7.28	6.88	7.32	6.78	7.34	7.48	7.78	7.84	7.74
Cond	μS/cm	855.40	845.00	844.00	841.00	841.20	842.80	844.40	843.40	830.60	823.20
Temp	mg/L	24.92	24.74	24.32	24.36	24.92	24.66	24.56	24.66	24.62	24.50
SS	mg/L	829.94	831.12	805.70	831.44	848.74	857.20	856.16	862.64	109.96	102.66
VSS	mg/L	338.90	357.52	322.88	336.62	332.04	308.26	300.98	335.44	46.46	40.98
DO	mg/L	1.32	0.72	1.32	0.42	1.18	0.46	0.00	0.00	0.00	0.00
COD	mg/L	555.08	517.44	418.28	397.56	303.90	291.72	299.52	304.92	304.28	309.66
BOD	mg/L	262.36	204.08	166.12	159.36	127.14	119.38	117.44	96.30	109.98	102.72
Phosphate	mg/L	13.70	13.38	13.58	13.50	13.46	13.90	13.74	13.54	10.64	10.44
Ammonia	mg/L	74.10	72.64	71.38	70.38	69.16	69.00	68.78	68.80	68.40	68.40
Nitrate	mg/L	19.26	19.16	20.10	19.70	22.10	20.70	19.42	18.90	18.70	18.50

Table 5: Wastewater characteristics during the monsoon period of the year 2018 at various points.

Parameters	Units	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
pH		7.32	7.58	7.56	7.42	7.60	7.64	7.52	7.57	7.57	7.58
Cond	μS/cm	1010.22	840.67	844.89	842.22	842.78	839.78	846.11	844.11	860.67	854.89
Temp	mg/L	25.33	26.46	25.83	26.67	26.60	26.48	26.61	26.67	26.49	25.72
SS	mg/L	268.73	622.07	628.24	617.44	607.59	598.98	607.02	607.91	616.02	109.49
VSS	mg/L	115.39	267.61	274.21	268.18	267.69	252.36	252.33	255.98	276.73	47.10
DO	mg/L	0.00	1.38	0.47	1.46	0.58	1.47	0.50	0.00	0.00	0.00
COD	mg/L	1003.18	352.38	332.70	279.80	270.81	216.53	204.10	211.23	221.22	217.29
BOD	mg/L	281.33	141.39	132.76	105.30	97.54	80.91	76.84	75.02	54.18	69.99
Phosphate	mg/L	18.03	12.92	10.47	10.18	8.92	9.03	8.58	8.01	7.96	8.79
Ammonia	mg/L	75.57	63.09	71.17	71.06	66.80	65.26	64.44	60.01	59.78	60.19
Nitrate	mg/L	19.09	26.66	21.06	20.24	18.50	19.56	17.56	17.14	19.51	15.57

The removal efficiencies (in percentage) during the monsoon and pre-monsoon period are presented in **Tables 6 and 7**.

Table 6: Percentage removal efficiency of WWTP during the pre-monsoon period of the year 2018.

Parameters	29-Apr	6-May	20-May	27-May	3-Jun	Average
COD	74.57	74.42	75.45	76.94	79.22	76.12
BOD	72.80	77.84	77.41	72.92	79.69	76.13
Phosphate	49.75	51.42	43.65	48.47	44.74	47.61
Ammonia	7.66	14.76	9.91	18.48	12.56	12.67

Table 7: Percentage removal efficiency of WWTP during the monsoon period of the year 2018.

Parameters	18-Jun	25-Jun	2-Jul	9-Jul	15-Jul	22-Jul	29-Jul	5-Aug	12-Aug	Average
COD	78.86	77.86	80.94	80.79	78.81	80.47	77.42	76.50	74.89	78.51
BOD	82.30	84.50	77.38	78.98	75.52	74.53	63.66	74.02	74.76	76.18
Phosphate	49.39	53.45	52.83	60.51	46.63	59.24	56.50	61.11	60.77	55.60
Ammonia	28.68	29.67	21.31	21.66	23.06	36.58	33.41	29.87	37.78	29.11

Kinetic study

The kinetics parameters obtained from the GWWTP is presented in **Table 8** and **Figure 2(a) and (b)**.

Table 8: Values obtained from tests to determine the kinetic coefficients.

Date	SRT	1/Se	XwVSS	XeVSS	X	1/SRT	So-S/ HRT.X	$k(S_o-S_e)/(S_o-S_e)+(1+a)K_s \ln(S_o/S_e)$
29-Apr	1.27	0.00306	5920.1	42.1	343.4	0.786	4.409	5.065
6-May	1.32	0.00311	5613.4	37.2	332.7	0.757	4.436	5.061
20-May	1.24	0.00302	5711.9	43.2	327.3	0.808	4.909	5.072
27-May	1.18	0.00332	5821.3	41.7	312.9	0.850	5.070	5.061
3-Jun	1.19	0.00374	6025.0	44.4	329.1	0.842	4.891	5.050
18-Jun	1.16	0.00458	5789.1	38.5	301.9	0.861	4.257	5.002
25-Jun	1.17	0.00420	5102.4	37.6	274.1	0.856	4.823	5.016
2-Jul	1.10	0.00528	4521.3	43.3	245.1	0.911	5.177	4.982
9-Jul	1.09	0.00578	5126.4	35.5	253.3	0.917	4.538	4.956
15-Jul	1.35	0.00497	4780.1	26.6	279.5	0.739	4.228	4.981
22-Jul	1.43	0.00544	4191.1	29.5	273.1	0.698	4.378	4.970
29-Jul	1.43	0.00479	3738.3	33.6	259.5	0.698	4.351	4.980
5-Aug	1.17	0.00405	4712.5	34.6	253.8	0.853	4.996	5.016
12-Aug	0.96	0.00362	5981.6	32.6	247.3	1.041	5.256	5.032

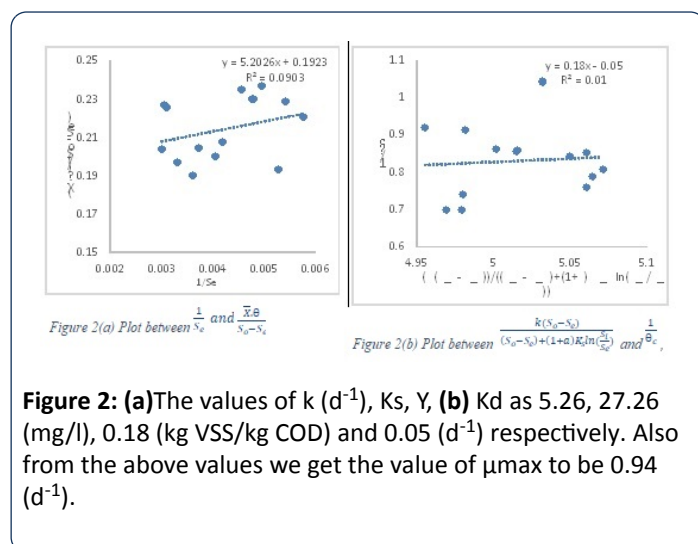


Figure 2: (a) The values of k (d^{-1}), K_s , Y , (b) K_d as 5.26, 27.26 (mg/l), 0.18 (kg VSS/kg COD) and 0.05 (d^{-1}) respectively. Also from the above values we get the value of μ_{max} to be 0.94 (d^{-1}).

Discussion

The removal of COD and BOD was found to be 72.28% and 81.51% respectively. However, the removal of nutrient is very low and fails to meet the discharge standard set by the Ministry of Forest and Environment. The treatment plant is not functioning properly mainly because

- SRT is less than 2. With the less SRT value, performance is poor and nutrient removal is possible only if the SRT is greater. The typical SRT value for oxidation ditch is 15-30 days [14,22,23]
- MLVSS of oxidation ditch of Guheshwori WWTP is very less compared to typical MLVSS value required for this type of WWTP. The average value at the plant is 288 ± 20.43 mg/l at a 95% confidence interval. The typical MSLL value of oxidation ditch is 3000-5000 mg/l [14,22,24,25]
- The typical recycling of Activated Sludge should be in the range of 75% to 150% of the influent but the recycling ratio is

very less with only 180 cum of RAS is recycled [14,22,24,25]. This is one of the reason for less MLVSS value at the plant

The kinetic values k (d^{-1}), K_s , Y and K_d were found to be 5.26, 27.26 (mg/l), 0.18 (kg VSS /kg COD) and 0.05 (d^{-1}). Maximum substrate utilization rate (k) and half velocity constant are in the range of 2-10 d^{-1} to 10-60 mg/l [14,22]. The yield was very low. The low DO level and possible of settling of MLVSS might have lead to the low value of yield. The K_d value is slightly less than the typical value of 0.06-0.15. Less K_d value indicates larger sludge volumes from biological treatment [12,14].

Conclusion

Wastewater treatment plants in Nepal has been designed based on experiences and kinetic values obtained from other countries. Similar studies can be carried out so as to improve the performance of the plants. HPCIDBC has been recording the daily data of influent and effluent of the wastewater but this data has not been effectively used to analyze or identify the problem. Based on the study, the yield is very low, which suggests the biological process is not effectively helping the WWTP to remove the pollutant. There is no effluent standard for municipal wastewater treatment plants and this is one of the reasons that no proper attention is paid for effluent quality. There should be a provision of penalty for discharging wastewater beyond the standard.

No attention has been paid for the removal of nutrients. As the effluent is discharged to Bagmati River, which is one of the holy rivers of Nepal, nutrient removal should also be considered and retrofitting an anaerobic tank before the oxidation ditch can help in removal of phosphorus [14,26].

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