***Chapter Four***

***Results and Discussion***

**4.1 Introduction**

In this chapter, the results of all experiments conducted in the current research were tabulated and discussed. The results of operating the system under aerobic conditions for different ambient temperatures were compared and discussed. Results of seeded experimentation with activated sludge combined with aeration had been collected and discussed. The chapter included the estimation of reaction kinetics and the calculations used and results collected for mass transfer coefficient as well.

**4.2 Real Wastewater Measurements**

In order to ensure that the tested sewage water samples BOD5, COD, SS and VSS concentration are within the range of real sewage water concentration of the main treatment plant of Al-Rustamiyah, comparison had been accomplished. The real data were collected for different seasons i.e. winter and spring (between January and May, 2015). This variation in the periods was necessary to assure the difference in weather temperatures (within the average range of ±10 to ±30 OC). The real data of the collected real wastewater can be seen in Appendix C.

On the other hand, the values of the tested water samples in terms of BOD5, COD SS SCOD and VSS were records in Table 4.1 for operation temperature of ±10 OC.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.1** Characteristics of tested wastewater samples in the pilot system at 10 OC | | | | |
| **BOD5**  **(mg/l)** | **COD**  **(mg/l)** | **SS**  **(mg/l)** | **VSS**  **(mg/l)** | **SCOD**  **(mg/l)** |
| 310 | 410 | 280 | 205 | 190 |
| 545 | 650 | 395 | 295 | 265 |
| 455 | 570 | 405 | 280 | 260 |
| 290 | 355 | 235 | 170 | 145 |
| 260 | 340 | 230 | 155 | 120 |
| 465 | 560 | 385 | 275 | 235 |
| 500 | 600 | 405 | 290 | 250 |
| 355 | 455 | 250 | 180 | 175 |
| 310 | 390 | 220 | 145 | 155 |
| 250 | 365 | 255 | 195 | 135 |

As it can be seen in Appendix C that the data of the treatment plant sewage water are quit large and cannot be handled in its current form. In order to simplify it to be ready to accomplish a comparison between water samples properties used in the current study, statistical investigation was required. The mean, range, standard deviation and variance values of real sewage data and tested wastewater samples were tabulated in Table 4.2.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.2** Statistical parameters of the real and tested wastewater samples at 10 OC | | | | | | |
|  | **Real\* (mg/l)** | | | **Tested\*\* (mg/l)** | | |
| **BOD5** | **COD** | **SS** | **BOD5** | **COD** | **SS** |
| **Mean** | 359.71 | 456.39 | 290.45 | 374 | 469.50 | 306 |
| **Minimum** | 180 | 250 | 153 | 250 | 340 | 220 |
| **Maximum** | 650 | 780 | 520 | 545 | 650 | 405 |
| **Range** | 470 | 530 | 367 | 295 | 310 | 185 |
| **Standard deviation** | 114.80 | 126.18 | 99.53 | 107.46 | 114.88 | 80.55 |

\* Wastewater from Al-Rustamyih WWTP.

\*\* Wastewater from pumping station.

On the other hand, the values of BOD, COD, SS, VSS and SCOD for the tested sewage water samples under temperature of ±20 OC were tabulated in Table 4.3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.3** Characteristics of tested wastewater samples at 20 OC | | | | |
| **BOD5**  **(mg/l)** | **COD**  **(mg/l)** | **SS**  **(mg/l)** | **VSS**  **(mg/l)** | **SCOD**  **(mg/l)** |
| 290 | 350 | 240 | 180 | 140 |
| 370 | 440 | 330 | 265 | 180 |
| 335 | 410 | 340 | 250 | 165 |
| 305 | 375 | 295 | 235 | 150 |
| 310 | 385 | 255 | 200 | 160 |
| 440 | 530 | 255 | 190 | 210 |
| 500 | 585 | 315 | 235 | 230 |
| 545 | 650 | 405 | 315 | 260 |
| 375 | 460 | 300 | 230 | 185 |
| 315 | 420 | 350 | 275 | 170 |

The results of statistical comparisons between the real sewage and tested wastewater samples under temperature of 20 OC can be seen in Table 4.4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.4** Statistical parameters of the real and tested wastewater samples at 20 OC | | | | | | |
|  | **Real (mg/l)** | | | **Tested (mg/l)** | | |
| **BOD5** | **COD** | **SS** | **BOD5** | **COD** | **SS** |
| **Mean** | 350.08 | 433.72 | 314.16 | 378.50 | 460.50 | 308.50 |
| **Minimum** | 180 | 280 | 156 | 290 | 350 | 240 |
| **Maximum** | 680 | 762 | 530 | 545 | 650 | 405 |
| **Range** | 500 | 482 | 374 | 255 | 300 | 165 |
| **Standard deviation** | 120.39 | 121.27 | 77.69 | 88.32 | 97.79 | 50.77 |

The results of measuring BOD5, COD, SS, VSS, and SCOD for the tested wastewater samples under temperature of 30 OC were summarized and listed in Table 4.5.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.5** Characteristics of tested wastewater samples at 30 OC | | | | |
| **BOD5**  **(mg/l)** | **COD**  **(mg/l)** | **SS**  **(mg/l)** | **VSS**  **(mg/l)** | **SCOD**  **(mg/l)** |
| 315 | 400 | 290 | 215 | 165 |
| 390 | 475 | 230 | 170 | 180 |
| 405 | 480 | 360 | 260 | 200 |
| 370 | 440 | 265 | 200 | 175 |
| 325 | 415 | 305 | 230 | 170 |
| 255 | 345 | 195 | 150 | 140 |
| 255 | 350 | 195 | 140 | 145 |
| 340 | 435 | 285 | 210 | 175 |
| 275 | 375 | 255 | 185 | 155 |
| 235 | 340 | 220 | 165 | 140 |

The statistical values of mean, minimum, maximum, range and standard deviation for the real sewage and tested wastewater samples can be seen in Table 4.6 under temperature of 30 OC.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.6** Statistical parameters of the real and tested wastewater samples at 30 OC | | | | | | |
|  | **Real (mg/l)** | | | **Tested (mg/l)** | | |
| **BOD5** | **COD** | **SS** | **BOD5** | **COD** | **SS** |
| **Mean** | 324.43 | 416.37 | 265.16 | 316.50 | 405.50 | 260 |
| **Minimum** | 180 | 280 | 120 | 235 | 340 | 195 |
| **Maximum** | 450 | 520 | 480 | 405 | 480 | 360 |
| **Range** | 270 | 240 | 360 | 170 | 140 | 165 |
| **Standard deviation** | 71.39 | 67.50 | 72.01 | 60.23 | 52.20 | 52.23 |

It can be concluded from comparing the statistical parameters presented in Tables 4.2, 4.4, and 4,6, that the mean values of real sewage and treated wastewater samples were relatively close with some differences attributed to the extreme values of the vast real sewage water data. The same reason can explain the differences between standard deviation values. As it can be noticed in the maintained tables that the standard deviation values of the real sewage water were higher than those of the tested samples due to those extreme values. In the other hand, the treated wastewater samples can be considered as a good representative to the real sewage data with good approach as indicated by the minimum and maximum values. All minimum values of the three temperatures water samples were higher than the corresponding of the real measurements while the maximum values behaves in contract manner. It can be examined from the tables that all the maximum values of the tested wastewater samples were lower in values than that of the real ones. This gave a significant indication that the chosen water

samples lied in the range of the real water measurement and capable to simulate the real wastewater presented in Al-Rustamiyah treatment plant.

**4.3 Experiments of Aerobic Treatment**

As discussed in section 3.3, aerobic condition was adopted in treating samples of wastewater under different weather temperatures in order to investigate the ability of the existing microorganisms presented in sewage water samples in degrading the organic matters.

**4.3.1 Adjusting the Aeration Process**

In order to investigate the role of aerobic condition in the partial treatment of sewage water, aeriation process had been adjusted firstly. This had been investigated as conducting experimentation under the three ambient temperature in three stages. The first three experiments were conducted with no air pumping to show the possibility of the presented microorganisms alone in degrading the presented organic matters. While three other experiments were conducted under partially aerobic conditions i.e. aeriation was operated in discrete mode. Air was supplied for the first operating hour then its cut off for the second hour and so on. The third stage was implemented via conducted three experiments with fully aeriation time but with delivering air to two tanks only. Feeding and the diagonal (the opposite in diagonal side) were let to be aeriated with its connecting pipes while others were dropped out with no air. The results were presented in Table 4.7 for the three ambient temperature for the three tested stages.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 4.7** Averaged COD removal under no air, discrete aeriation time and two points aeriation modes | | | | | | | | |
| No Air | | | Discrete aeration time | | | Two points aeriation | | |
| **RCOD %** | | | **RCOD %** | | | **RCOD %** | | |
| **10 OC** | **20 OC** | **30 OC** | **10 OC** | **20 OC** | **30 OC** | **10 OC** | **20 OC** | **30 OC** |
| 0.27 | 2.6 | 3.1 | 0.31 | 3.2 | 3.6 | 0.35 | 3.9 | 4.3 |

The results presented in the Table 4.7, revealed that for the three ambient temperatures, no significant degradation levels had been recorded in terms of COD removal when no air was supplied to the system. This can be ascribed to the inability of the living microorganisms in degrading the organic contaminates without the required oxygen needed for aerobic metabolism.

On the other hand, conducting the experiments with discrete time intervals as well as with partial aeriation for two tanks only showed better performance comparing with no air mode. Yet RCOD levels were relatively low but the results of two tanks aeration showed better records. Discrete aeriation can deliver continues aeration to microorganisms for half of the duration time giving the living biomass a discrete ability in conducting significant degradation with lag periods.

Furthermore, delivering continuous aeriation for the system for the whole duration in specific points seemed to be more efficient in terms of degradation. In spite of air was delivered to the system partially, but the living microorganisms can conduct significant degradation in large space of the system. This can be attributed to air transfer within the system due to current as wastewater flow in the system. Form the findings of the current part of experiments, it's clear that adopting aeration in all tanks

for the whole treatment duration is the best choice as the three operating mode have no promising results.

**4.3.2 Aerobic Treatment at Temperature of 10 OC**

For investigating the performance of the system under aerobic conditions at ambient temperature of 10 OC, six wastewater samples were treated. The characteristics of the studied samples and the overall SCOD removal for holding time of 8 hr were presented in Table 4.8.

|  |  |  |
| --- | --- | --- |
| **Table 4.8** Initial SCOD and SS levels and overall removal under temperature of 10 OC. | | |
| **SCODO**  **(mg/l)** | **SSO**  **(mg/l)** | **RSCOD**  **%** |
| 375 | 510 | 2 |
| 350 | 600 | 2 |
| 195 | 150 | 0.51 |
| 390 | 610 | 3.85 |
| 335 | 270 | 1.61 |
| 180 | 420 | 2.22 |

As it can be concluded from Table 4.8 that the calculated RSCOD values for the six treated wastewater samples were relatively low even under treatment time of 8 hr. Maximum removal of 3.85 was achieved for the sample with SCODO and SSO of 390 and 610, respectively. This can be attributed to high organic content in the sample comparing with others providing sufficient nutrients for the living microorganisms presented in wastewater. On the other hand, low performance of the

system in terms of SCOD removal for all tested samples because of low operational temperature.

In aquatic systems, significant role was played by temperature affecting biomass growth and microorganisms settlements as described by Rao (2010). Microorganism's growth and activity are dependent on the nutrient availability, water flow rate and ambient temperature. He reported that in warmer regions, biofilm formation takes place at all times of the year, whereas in the moderate waters, bio filming process is more noticeable only during the warm months.

The SCOD values measured at different time intervals were plotted vs time to show SCOD profile during the process as presented in Figure 4.1

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SCOD (mg/l)

**Figure 4.1.** SCOD profiles under aerobic conditions at temperature of 10 OC.

As it can be seen in the Figure, slight reduction in SCOD levels can be noticed for almost the treated water samples. For the sample with SCODO level of 195 and SSO of 150, there was no significant change in SCOD levels with the duration. This can be ascribed to low organic content in the sample leading to insufficient feed for microorganisms causing in large lack in degradation process.

**4.3.3 Aerobic Treatment at Temperature of 20 OC**

Under temperature of 20 OC, seven wastewater samples were treated for operation time of 8 hr. The initial SCOD levels with initial SS

concentrations and the overall SCOD removal were presented in Table 4.9.

|  |  |  |
| --- | --- | --- |
| **Table 4.9** Initial SCOD and SS levels and overall removal under temperature of 20 OC. | | |
| **SCODO**  **(mg/l)** | **SSO**  **(mg/l)** | **RSCOD**  **%** |
| 250 | 270 | 8.80 |
| 320 | 410 | 12.19 |
| 310 | 400 | 11.61 |
| 295 | 340 | 8.47 |
| 315 | 420 | 11.43 |
| 350 | 330 | 6.28 |
| 300 | 300 | 7.33 |

As it can be concluded from the table, RSCOD values were higher comparing with values under operation temperature of 10 OC. This can

be resulted by the positive effect of higher ambient temperature that motivated the metabolism of the microorganisms presented in the water samples. It had been reported by Villanueva *et al.* (2011) that the growth rate of bacterial biofilm can be increased by increasing flow and temperature, yet the efficiency of bacterial growth may be declined. Temperature usually increases the metabolic yields and promote enzymatic activities of degradation of presented organic substances. The effect of temperature can further extended to alter the compositions of bacterial species. The profiles of SCOD values measured at different operation times can be seen in Figure 4.2 for the seven treated water samples.

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SCOD (mg/l)

**Figure 4.2** SCOD profiles under aerobic conditions at temperature of

20 OC.

As it can be seen in the Figure 4.2, that for all SCOD concentrations, degradation profiles were noticeable for all treated

wastewater samples. Combining the results extracted from the Figure with RSCOD values tabulated in Table 4.8, the better SCOD removal, the highest SSO content in the sample due to sufficient amount of organic waste provided to microorganisms. Highest RSCOD of 12.19 was recorded for the sample with SCODO of 320 mg/L and SSO of 410 mg/L.

**4.3.4 Aerobic Treatment at Temperature of 30 OC**

With the increase of ambient temperature to 30 OC, eight wastewater samples were tested. The values of SCOD O, SSO, and RSCOD for 8 hr duration of treatment were presented in Table 4.10.

|  |  |  |
| --- | --- | --- |
| **Table 4.10** Initial SCOD and SSO levels and overall removal under temperature of 30 OC. | | |
| **SCODO**  **(mg/l)** | **SSO**  **(mg/l)** | **RSCOD**  **%** |
| 280 | 440 | 14.28 |
| 315 | 320 | 9.52 |
| 340 | 300 | 8.82 |
| 290 | 280 | 8.62 |
| 495 | 470 | 13.13 |
| 380 | 245 | 7.89 |
| 450 | 165 | 6.22 |
| 275 | 400 | 13.45 |

The SCOD profiles for the treatment under ambient temperature of 30 OC shown in Figure 4.3 for the eight treated samples.

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SCOD (mg/l)

**Figure 4.** **3.** SCOD profiles under aerobic conditions at temperature of

30 OC.

As it can be concluded from Table 4.10 that maximum RSCOD values of 14.28 and 13.45 were recorded for samples with SCODO values of 280 and 275 mg/L with SSO values of 440 and 400 mg/L, respectively. SCOD patterns showed significant reduction for all treated sewage samples under ambient temperature of 30 OC. Comparing RSCOD values of Table 4.10 and 4.9 for the treatment under temperature of 20 OC showed the positive effect of temperature increment of 10 OC leading to higher RSCOD measurements.

**4.4 Results of Seeded Experimentation**

In the previous section, experimentations of aerobic treatment had been conducted and discussed. The effect of suppling air to the system had a significant impact in motivating microorganism's metabolism combining with the positive effect of increasing ambient temperature. Although RSCOD values for treated sewage water in the current system for 8 hr of treatment time were noticeable and significant in term of removing SCOD. SCOD can be treated in relatively short operation time measured in hours not in days as it required for removing particulate slowly biodegradable SCOD. Yet an enhancement can be delivered to the system by supporting the treatment process by seeding with activated sludge as discussed in section 3.3. The results of seeded experimentation were presented in the coming sections.

**4.4.1 Seeded treatment with different feeding ratios**

Firstly, attempts were conducting to investigate the amount of activated sludge needed to be added to the system. Four experiments were conducted in ambient temperature of 10 OC with different activated sludge mixing ratios. Volumetric ratios of 30, 40, 50, and 60 v/v activated sludge to waste water were examined for 8 hr of operation time. The results were presented in Table 4.11.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.11** RSCOD levels for different activated sludge ratios under 10 OC | | | | |
| v/v | 30/70 | 40/60 | 50/50 | 60/40 |
| RSCOD % | 8.12 | 9.08 | 11.54 | 10.62 |

The results presented in the Table 4.11 showed an increasing pattern in terms of RSCOD from 30 to 50 v/v ratios. This can be attributed to the increase in amount of the living microorganisms presented in the system to conduct significant degradation. On the other hand, a decrease in the level of removal had been noticed combining

with increasing the ratio beyond 50 v/v. It seemed that increasing the amount of biomass above this threshold had a negative impact on the microorganisms' activity due to the severe increase in number that led to unbalance between it and the presented organic matter. Increasing the number of microorganisms above that balance can cause a starvation issue as the new generated living cells combined with the already existed cells competing the limited feeding sources.

From another prospective, loading the system with high amount of activated sludge that have higher density than wastewater can cause flow problems. Partial clogs and obstructions can be occurred in the pipes, bends and elbows. The restriction in the flow can lead to partial accumulation of the organic materials in some points in the system and reduction in the flow velocity leading to a decrease in the overall SCOD removal. Based on the current observations, the seeded treatment experimentations will be conducted with 50 v/v activated sludge to wastewater ratio which was the optimum ratio for the current system.

**4.4.2 Seeded Treatment at 10 OC**

For investigating the system performance seeded with activated sludge under ambient temperature of 10 OC, the samples presented in Table 4.11 were treated for 8 hr of operation time. Ten sewage water samples were treated and the measurement of CODO, SCODO, SSO, VSSO, SCODF and RSCOD values were presented in Table 4.12.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4.12** Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD removal under temperature of 10 OC. | | | | | |
| **CODO**  **(mg/l)** | **SCODO**  **(mg/l)** | **SCODF**  **(mg/l)** | **SSO**  **(mg/l)** | **VSSO**  **(mg/l)** | **RSCOD**  **%** |
| 410 | 300 | 262 | 280 | 205 | 12.67 |
| 650 | 525 | 453 | 395 | 295 | 13.71 |
| 570 | 430 | 373 | 405 | 280 | 13.26 |
| 355 | 265 | 235 | 235 | 170 | 11.32 |
| 340 | 260 | 230 | 230 | 155 | 11.54 |
| 560 | 410 | 355 | 385 | 275 | 13.41 |
| 600 | 450 | 390 | 405 | 290 | 13.33 |
| 455 | 330 | 290 | 250 | 180 | 12.12 |
| 390 | 295 | 260 | 220 | 145 | 11.86 |
| 365 | 240 | 210 | 255 | 195 | 12.50 |

It can be seen in the Table 4.12 that for all treated sewage samples, RSCOD values calculated in terms of SCOD were higher than that measured at same ambient temperature without seeding process. This can be attributed to the addition of activated sludge powered by aeriation that led to severe degradation of organic matters. As reported by Descoins *et al.* (2012), aerobic biological treatment consists of supplying oxygen to activated sludge presented in sewage water in order to maintain and grow microorganisms. Both the carbon-based pollutants and the nitrogen based pollutants are then degraded inside the reactors by the combined biological activities of heterotrophic and autotrophic bacteria.

As it can be noticed in Table 4.12 that RSCOD values were close for all treated sewage samples and ranging between 11 to 13. Yet the profiles of SCOD and RSCOD regarding treatment time can be seen in Figures 4.4 and 4.5, respectively.

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**Figure 4.4.** SCOD profiles under aerobic conditions with seeding at temperature of 10 OC.

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**Figure 4.5.** RSCOD profiles under aerobic conditions with seeding at temperature of 10 OC.

It can be obtained from above Figure 4.5 that profiles of degradation were clear to notice and SCOD levels were decreased as time increased for all tested samples. Yet, for treating sewage samples under same temperature with aeriation only showed no significant degradation in terms of COD degradation. The results obtained from seeded experimentations coupled with aeriation showed promising aspects although with low ambient temperature. This can be shown in the presence of more active microorganisms delivered to the system via activated sludge seeding. Investigating the system performance under higher operation temperature will highlight the role of seeding process coupled with relatively high ambient temperate as presented in the succeeding sections.

**4.4.3 Seeded Treatment at 20 OC**

Ten sewage water samples were treated under aeriation conditions and seeding process for the ambient temperature of 20 OC to show the validity of the treatment under this temperature. The water samples with characteristics presented in Table 4.3 were treated. Values of CODO, SCODO, SSO, VSSO, and RSCOD were tabulated in Table 4.13 and RSCOD values were calculated at the end of 8 hr of treatment time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4.13** Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD removal under temperature of 20 CO | | | | | |
| **CODO**  **(mg/l)** | **SCODO**  **(mg/l)** | **SCODF**  **(mg/l)** | **SSO**  **(mg/l)** | **VSSO**  **(mg/l)** | **RSCOD**  **%** |
| 350 | 280 | 228 | 240 | 180 | 18.57 |
| 440 | 355 | 270 | 330 | 265 | 23.94 |
| 410 | 330 | 254 | 340 | 250 | 23.03 |
| 375 | 285 | 224 | 295 | 235 | 21.40 |
| 385 | 290 | 233 | 255 | 200 | 19.66 |
| 530 | 405 | 327 | 255 | 190 | 19.26 |
| 585 | 480 | 369 | 315 | 235 | 23.13 |
| 650 | 520 | 376 | 405 | 315 | 27.69 |
| 460 | 335 | 265 | 300 | 230 | 20.90 |
| 420 | 295 | 215 | 350 | 275 | 27.12 |

Comparing the calculated RSCOD values presented in the Table 4.13 with that calculated for treatment at ambient temperature of 10 OC presented in Table 4.12, it's obvious that degradation in terms of SCOD removal is higher. The highest RCOD levels of 27.69 and 27.12 were recorded for the samples of CODO of 650 and 420, respectively. This can be attributed to higher operation temperature that motivated the microorganism's metabolisms. In the other hand, the recorded RSCOD values calculated for the seeded treatment can be further compared with results presented in Table 4.8 for aeriation only (yet RCOD values were calculated based on influent COD not SCOD). Seeded experimentation showed more significant COD removal and seemed to be more active in treating organic substances presented in sewage water samples. This can

be ascribed to the presence of sufficient microorganisms due to the increase in bacterial cultures originally presented in sewage water as a results of activated sludge addition.

In Figure 4.6, SCOD degradation profiles for all treated sewage water samples were plotted against 8 hr of treatment time while calculated RSCOD profiles were presented in Figure 4.7 for the treated water samples at ambient temperature of 20 OC.

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**Figure 4.6.** SCOD profiles under aerobic conditions with seeding at temperature of 20 OC.

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**Figure 4.7.** RSCOD profiles under aerobic conditions with seeding at temperature of 20 OC.

Examining SCOD profiles for all treated sewage water samples retained that significant degradation was achieved. Yet RSCOD profiles showed that the removal increased with time increasing until reaching its maximum values for all treated samples. Further investigations on the system behavior will be conducted for higher ambient temperature to show that effect on temperature increment coupling with the addition of activated sludge.

**4.4.4 Seeded Treatment at 30 OC**

Operating the system under 30 OC for ten sewage water samples was conducted with seeding with activated sludge. The treatment time was 8 hr and water samples were withdrawn in different time intervals. Table 4.14 presentsCODO, SCODO, SSO, VSSO, and RSCOD values for the tested samples.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4.14** Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD removal under temperature of 30 CO | | | | | |
| **CODO**  **(mg/l)** | **SCODO**  **(mg/l)** | **SCODF**  **(mg/l)** | **SSO**  **(mg/l)** | **VSSO**  **(mg/l)** | **RSCOD**  **%** |
| 400 | 280 | 205 | 290 | 215 | 26.78 |
| 475 | 355 | 270 | 230 | 170 | 23.94 |
| 480 | 395 | 278 | 360 | 260 | 29.62 |
| 440 | 345 | 255 | 265 | 200 | 26.09 |
| 415 | 305 | 216 | 305 | 230 | 29.18 |
| 345 | 240 | 190 | 195 | 150 | 20.83 |
| 350 | 230 | 183 | 195 | 140 | 20.43 |
| 435 | 315 | 233 | 285 | 210 | 26.03 |
| 375 | 250 | 188 | 255 | 185 | 24.80 |
| 340 | 210 | 165 | 220 | 165 | 21.43 |

High values of RSCOD were calculated for treating sewage water under ambient temperature of 30 OC with activated sludge seeding. Comparing the calculated RSCOD values with those calculated under ambient temperature of 20 OC presented in Table 4.13 revealed better organic reduction. The presence of extra microorganisms had a dominant influence yet maximum RSCOD was achieved as 29.62 % and 29.18 % for samples with CODO of 480 and 415 mg/L while the maximum RCOD value of 14.28 was recorded for treatment without seeding under the same ambient temperature.

It can be concluded from Tables 4.12 to 4.14 that maximum RSCOD values were recorded for higher VSSO values in treated wastewater samples for all operational temperature. This harmony raised

from the needs of the presented microorganisms in the original waste water and that delivered by activated sludge that required extra organic substrates for feeding and growing up. It's clear that a significant balance was achieved between the increased amounts of microorganism's colonies with the delivered organic nutrients so the living organisms had no negative issues deals with starvation due to high organism's content and lack of food. Volatile solids normally represents the amount of organic solids in water. The greater the concentration of organic or volatile solids, the stronger the wastewater as the amount of volatile solids in wastewater is frequently used to describe the strength of the waste. If the solids in wastewater are mostly organic, its impact on a biological treatment plant is greater than if the solids are mostly inorganic. In Figure 4.8, degradation profiles of SCOD for the treatment under ambient temperature of 30 OC, while Figure 4.9 represents the RSCOD profiles increasing vs treatment time for all treated sewage samples under the same ambient temperature.

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**Figure 4.8.** SCOD profiles under aerobic conditions with seeding at temperature of 30 OC.

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**Figure 4.9.** RSCOD profiles under aerobic conditions with seeding at temperature of 30 OC.

As it can be seen in Figure 4.8, that all treated sewer samples showed degradation profiles in terms of SCOD while the higher RSCOD profiles was conducted for samples with SCOD of 395 and 305 as showed in Figure 4.9. This can be ascribed to the higher organic suspended solids content expressed by the higher VSSO values.

To this point, the results obtained in section 4.4 for the seeded treatment with activated sludge coupled with aeration showed a promising degradation levels expressed by the reduction in SCOD values in relatively short retention time of 8 hr for all treated sewer water samples that have different characteristics.

**4.5 Kinetics of Degradation Process**

The proposed kinetics for the degradation of organic matters presented in sewage water had been explained and first order model was used to fit the experimental data with the aid of nonlinear least square error method as discussed in section 3.6.

As it recorded the highest removal values, seeded experimentations were chosen to fit the data and degradation rate constants for all treated sewage water for three ambient temperature had been calculated. Equation 3.4 was used as a model equation and minimized via equation 3.5 in order to find the constant value of k. The calculated k values were implemented back in equation 3.4 to calculate predicted SCOD values used for R2 calculations. The results of calculated k and the corresponding R2 values for degradation under 10 OC ambient temperature were tabulated in Table 4.15. The convergence between the measured SCOD values and the predicted ones can be further presented via plots. Figure 4.10 presented the real vs predicted SCOD values for ambient temperature of 10 OC.

|  |  |  |
| --- | --- | --- |
| **Table 4.15.** Initial SCOD, rate constant k and R2 values for 10 OC | | |
| SCODO (mg/L) | k (hr-1) | R2 |
| 300 | 0.0205 | 0.8957 |
| 525 | 0.0200 | 0.9717 |
| 430 | 0.0211 | 0.8843 |
| 265 | 0.0176 | 0.9276 |
| 260 | 0.0172 | 0.9069 |
| 410 | 0.0195 | 0.9601 |
| 450 | 0.0203 | 0.9324 |
| 330 | 0.0193 | 0.8681 |
| 295 | 0.0178 | 0.9263 |
| 240 | 0.0191 | 0.9306 |

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| **Figure 4.10.** The real vs predicted SCOD values for treatment under temperature of 10 OC. | |

Table 4.16 presented the values of calculated rate constants and R2 for degradation process under 20 OC for seeded experimentation. The predicted SCOD values for ambient temperature vs real SCOD values were plotted and presented in Figure 4.11 for seeking the convergence.

|  |  |  |
| --- | --- | --- |
| **Table 4.16.** Initial SCOD, rate constant k and R2 values for 20 OC | | |
| SCODO (mg/L) | k (hr-1) | R2 |
| 280 | 0.0342 | 0.7518 |
| 355 | 0.0420 | 0.8683 |
| 330 | 0.0374 | 0.8895 |
| 285 | 0.0349 | 0.8979 |
| 290 | 0.0335 | 0.8781 |
| 405 | 0.0291 | 0.9314 |
| 480 | 0.0386 | 0.9202 |
| 520 | 0.0482 | 0.9188 |
| 335 | 0.0367 | 0.8284 |
| 295 | 0.0428 | 0.9723 |

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| **Figure 4.11.** The real vs predicted SCOD values for treatment under temperature of 20 OC. | |

The values of calculated k and R2 for the degradation under ambient temperature of 30 OC were tabulated in Table 4.17 while the convergence between the predicted and real SCOD values can be examined in Figure 4.12 for the treated sewage waters.

|  |  |  |
| --- | --- | --- |
| **Table 4.17.** Initial SCOD, rate constant k and R2 values for 30 OC | | |
| SCODO (mg/L) | k (hr-1) | R2 |
| 280 | 0.0470 | 0.7518 |
| 355 | 0.0383 | 0.8683 |
| 395 | 0.0556 | 0.8895 |
| 345 | 0.0455 | 0.8979 |
| 305 | 0.0539 | 0.8781 |
| 240 | 0.0331 | 0.9314 |
| 230 | 0.0349 | 0.9202 |
| 315 | 0.0413 | 0.9188 |
| 250 | 0.0454 | 0.8284 |
| 210 | 0.0371 | 0.9723 |

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| **Figure 4.12.** The real vs predicted SCOD values for treatment under temperature of 30 OC. | |

Investigating the results presented in Table 4.15 for ambient temperature of 10 OC, the calculated k values did not follow a specific pattern in terms of SCODO values and SSO values. This can be attributed to low and close values of degradation constant k due to low ambient temperature. Low temperature had a negative impact on living biomass activity as presented in Langenhoff & Stuckey (2000), so limited SCOD degradation expressed by low RSCOD values presented in Table 4.12 were due to low reaction rate. In another hand, increasing temperature led to faster reaction rates as higher k values were calculated for ambient temperature of 20 OC tabulated in Table 4.16. The fastest reaction rates were recorded for the highest treatment temperature of 30 OC expressed by the highest k values of 0.0556 hr-1 for sample with SCODO of 395 listed in Table 4.17.

Exploring the data in Tables 4.16 and 4.17 revealed that higher k values were obtained for sewage water with higher VSSO as noticed in Tables 4.13 and 4.14. These findings led to an estimation that VSSO presence in the sample provided a significant motivation for microorganisms in degrading organic matter vigorously leading to fast action rate. Rate constant values of 0.0482 and 0.0428 hr-1 were recorded for samples with VSSO values of 315 and 275 mg/L, respectively, for ambient temperature of 20 OC. while for degradation at 30 OC, values of rate constant of 0.0556 and 0.0539 hr-1 were calculated for VSSO values of 260 and 230 mg/L. These findings related reaction rate with VSSO values regardless SCODO and SSO measurements or the fraction of VSS presented in total SS (VSSO/SSO) percentages. So removal of SCOD kinetics can be attributed to the high strength of the wastewater, these results demonstrate that the strength of the wastewater would be a major parameter affecting in sewer treatment.

**4.6 Dissolved Oxygen Mass Transfer Coefficient Estimation**

As discussed in the current research, all experiments were conducted under aerobic conditions, estimation of how much oxygen had been dissolved in the water is a crucial mater. Estimation of amount of oxygen can be approached via estimation of overall mass transfer coefficient KLa of oxygen that already transferred to sewage water.

The values of DO and the corresponding pH measurements for three water samples under continuous aeriation for 30 min were tabulated in Table 4.18.The samples were chosen at ambient temperature of 10, 20, and 30 OC.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.18.** DO and pH values for aerated waste water under different ambient temperature | | | | | | |
| **Time (min)** | **Temperature** | | | | | |
| **10 OC** | | **20 OC** | | **30 OC** | |
| **DO (mg/L)** | **pH** | **DO (mg/L)** | **pH** | **DO (mg/L)** | **pH** |
| 0 | 2 | 7.52 | 2.14 | 7.73 | 1.7 | 7.82 |
| 1 | 2.16 | 7.6 | 2.53 | 7.66 | 3.98 | 7.87 |
| 2 | 2.77 | 7.65 | 3.92 | 7.69 | 5.05 | 7.9 |
| 3 | 3.52 | 7.73 | 4.93 | 7.74 | 6.13 | 7.95 |
| 4 | 4.35 | 7.78 | 5.71 | 7.77 | 6.91 | 798 |
| 5 | 5.19 | 7.86 | 6.32 | 7.79 | 7.49 | 8.04 |
| 6 | 5.97 | 7.91 | 6.83 | 7.82 | 7.85 | 8.09 |
| 7 | 6.63 | 7.97 | 7.22 | 8.87 | 8.16 | 8.12 |
| 8 | 7.17 | 8.02 | 7.51 | 7.9 | 8.37 | 8.17 |
| 9 | 7.58 | 8.05 | 7.75 | 7.93 | 8.52 | 8.2 |
| 10 | 7.89 | 8.11 | 7.94 | 7.95 | 8.6 | 8.22 |
| 11 | 8.1 | 8.13 | 8.1 | 7.98 | 8.68 | 8.25 |
| 12 | 8.25 | 8.16 | 8.19 | 8.01 | 8.73 | 8.28 |
| 13 | 8.36 | 8.21 | 8.3 | 8.04 | 8.75 | 8.3 |
| 14 | 8.43 | 8.24 | 8.36 | 8.06 | 8.77 | 8.33 |
| 15 | 8.47 | 8.27 | 8.42 | 8.09 | 8.77 | 8.36 |
| 16 | 8.51 | 8.27 | 8.47 | 8.12 | 8.8 | 8.38 |
| 17 | 8.53 | 8.3 | 8.5 | 8.14 | 8.81 | 8.38 |
| 18 | 8.55 | 8.33 | 8.52 | 8.14 | 8.79 | 8.41 |
| 19 | 8.56 | 8.36 | 8.54 | 8.17 | 8.79 | 8.44 |
| 20 | 8.57 | 8.38 | 8.57 | 8.2 | 8.79 | 8.44 |
| 21 | 8.57 | 8.38 | 8.58 | 8.22 | 8.8 | 8.46 |
| 22 | 8.57 | 8.41 | 8.58 | 8.22 | 8.79 | 8.46 |
| 23 | 8.58 | 8.41 | 8.58 | 8.25 | 8.78 | 8.49 |
| 24 | 8.58 | 8.44 | 8.59 | 8.25 | 8.78 | 8.49 |
| 25 | 8.58 | 8.46 | 8.59 | 8.28 | 8.77 | 8.49 |
| 26 | 8.58 | 8.46 | 8.6 | 8.3 | 8.77 | 8.46 |
| 27 | 8.58 | 8.46 | 8.61 | 8.3 | 8.78 | 8.49 |
| 28 | 8.58 | 8.49 | 8.61 | 8.33 | 8.77 | 8.47 |
| 29 | 8.58 | 8.49 | 8.6 | 8.33 | 8.77 | 8.47 |
| 30 | 8.58 | 8.52 | 8.61 | 8.33 | 8.77 | 8.45 |

The tabulated data were used to estimate KLa value by minimizing equation 3.13 presented in section 3.7.2 while equation 3.12 was used as model equation in order to fit the experimental data to the proposed model. Values of KLa for different ambient temperature were presented in Table 4.19.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 4.19.** KLa values for different ambient temperature | | | |
| T(OC) | 10 | 20 | 30 |
| KLa (min-1) | 0.1692 | 0.2074 | 0.3419 |

The results tabulated in Table 4.19 demonstrated that as temperature increased, estimated KLa values proportionally increased. As temperature increased, the viscosity and surface tension of water decreased. Liquids with low viscosity have low resistance which increase mass transfer from gas to liquid phase. When the liquid viscosity is high, the formation of larger bubbles is more preferable, which decreases the overall gas hold up, thus the overall mass transfer coefficient decreased (Singh & Majumder, 2010).

The mass transfer coefficient is inversely proportional to the surface tension. Mass transfer of gases to liquids with high surface tension is low as higher surface tension in liquids leads to the formation of bigger bubbles and lower the overall volumetric mass transfer coefficient. Besides that, low surface tension provides low stretching resistance. A reverse relationship between temperature and solubility has been explained due to the change in water crystallinity. At higher temperatures, the crystalline structure of water molecules trapping the gas is broken and water capability of capturing the gas molecules

decrease, thus the solubility of oxygen is reduced at high temperatures (Kazim, 2012).

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**Figure 4.13.** Real and predicted DO values under ambient temperature of 10 OC.

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**Figure 4.14.** Real and predicted DO values under ambient temperature of 20 OC.

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**Figure 4.15.** Real and predicted DO values under ambient temperature of 30 OC.

It can be seen in Figures 4.13 to 4.15 that a significant approach between real and predicted values of DO had been achieved. The calculated values of R2 were high has the maximum value for ambient temperature of 30 OC as presented in Figure 4.15 were the two patterns were almost identical. This gave a significant indication that the proposed model and the adopted mathematical approach were successful in predicting KLa values in very high accuracy.