Biodegradation of organic content via activated sludge seeding coupled with aeration in simulated self-purification sewer system

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Abstract

Partial degradation of organic materials presented in sewage water had been conducted in the current research in a simulated sewer system. The process had been improved by aeration and seeding with activated sludge to reveal the effect of increasing the amount of biomass in the system. Three ambient temperatures were conducted as 10, 20, and 30 ^{O}C to display the influence of temperature on the degradation process. The results revealed that adding activated sludge to the system in a ratio of 50/50 (v/v) had a significant influence on the degradation as more microorganisms required more organic nutrients. In the other hand, increasing the operating temperature indicated positive influence in terms of soluble chemical oxygen demand (SCOD) removal as temperature motivated the living biomass towards severe degradation.

Keywords: simulated sewer system, activated sludge, partial degradation.

التحلل البايولوجي للملوثات العضوية بواسطة الاطيان المنشطة المعززة بالتهوية في منظومة محاكاة للمجاري ذاتية التنقية

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الخلاصة

تم في هذا البحث دراسة التحلل الجزئي للمواد العضوية الموجودة في مياه المجاري بواسطة منظومة محاكاة لنظام التصريف. تم تعزيز النظام بالتهوية المستمرة والاطيان المنشطة لمعرفة تأثير زيادة كمية الاحياء المجهرية الموجودة في النظام. تم اختبار النظام تحت ثلاثة درجات حرارة محيطية ١٠، ٢٠، و ٣٠ درجة مئوية لمعرفة تأثير درجات الحرارة على عملية التحلل. اظهرت النتائج ان اضافة الاطيان المنشطة بنسبة ٥٠ /٥٠ (حجم / حجم) ادت الى تأثير ايجابي على التحلل حيث ان ازدياد كمية الاحياء المجهرية تتطلب ازدياد في المواد العضوية المتحللة. من جانب اخر، ادت زيادة درجة الحرارة المحيطية الى ازدياد ايجابي في ازالة الاوكسجين المتطلب كيمياويا حيث تؤدي زيادة درجة الحرارة الى زيادة نشاط الاحياء المجهرية مؤدية الى زيادة في تحلل المواد العضوية.

1- Introduction

Rapid population growth and urbanization are causing rapid changes in civilizations demands and issues of living. One of the most important issue and requirement is the significant increase in fresh water consumption. Humanity is facing a crucial problem in suppling water for the growing societies with the fact of water resources limitation and water environmental pollution. With these criteria's, appropriate solutions such as wastewater recycling and reuse had been raised and polarized global interests.

Biological waste water treatment occur entirely by biological mechanisms. These biological processes reproduce, in a certain way, the natural processes that take place in water body after a waste water discharge. In a water body, organic matter is converted into inert products by purely natural mechanisms, characterizing the self-purification phenomenon. In a waste water treatment plant, the

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same basic phenomena occur, but the difference is that there is an introduction of technology. This technology has the objective of making the purification process develop under controlled conditions (Sperling, 2007). A sewer system can serve not only as transportation network for sewage water but also as a transformation reactor for municipal waste water as it contains significant amount of biomass in form of suspended bacteria or sewer wall biofilm (Shoji et al., 2015).

Biodegradation is the decay of substances via living biomass as Bactria, fungi, algae of other biological means. It is frequently used in relation to biomedicine, waste management, ecology, and the natural environment bioremediation. It is now commonly associated with environmentally-friendly products, capable of decomposing back into natural elements.

Organic material presented in sewer system can undergo significant degradation in the presence of microorganism in both aerobic and anaerobic conditions. Aerobic biological treatment consists of supplying oxygen to the biomass presented already in sewage water or to the activated sludge in bioreactors in order to maintain and grow microorganisms. Both the carbon-based pollutants and the nitrogen based pollutants are then degraded by the combined biological activities of heterotrophic and autotrophic bacteria (Henze et al., 2000).

In another hand, anaerobic digestion is a biological phenomenon that appears when oxygen and nitrate concentrations are very low in the system. Under specific temperature and for sufficient residence times, specialized micro-organisms become active. The organic nutrients present in the sewage are then used by these microorganisms which partially convert it into a mix of methane and carbon dioxide (Descoins et al., 2012).

2- Materials and methods

2.1- Waste water samples

For each ambient temperature, ten sewage water samples had been collected and treated. The samples were collected in three different seasons between January and June to assure the temperature differences of 10, 20 and 30 ^{o}C. Sewage water samples were compared with real sewage water data of Al-Rustamiyah main treatment plant The statistical mean, range, maximum and minimum values of real sewage data and treated sewage water samples had been calculated and compared as presented in Table 1.

Table 1. Statistical parameters of the real sewage and treated water samples

	Real (mg/l)						Treated(mg/l)					
	10 ^{o}C		20 ^{o}C		30 ^{o}C		10 ^{o}C		20 ^{o}C		30 ^{o}C	
	COD	SS	COD	SS	COD	SS	COD	SS	COD	SS	COD	SS
Mean	456	290	433	314	416	265	469	306	460	308	405	260
Minimum	250	153	280	156	280	120	340	220	350	240	340	195
Maximum	780	520	762	530	520	480	650	405	650	405	480	360
Range	530	367	482	374	240	360	310	185	300	165	140	165

2.2- Simulated System Design

PVC pipes of outer diameter of 75.2 mm (3 inches) were used in the current design to simulate the actual sewer system that connect Al-Adhamiya district and Al-Wazireya neighborhood. A square shape with four equal sides' with length of 4 m with settling tanks of capacity of 250 L in each corner had been designed and conducted. The settling tanks were used to simulate manholes in the real system and to observe sewage water level during operation. An extra tank was connected to one of the level tanks and rested outside the square system used to deliver the activated sludge to the system throw pipe connection with a valve.

Each pipe branch were fitted with a slop of 0.0023 in/in in order to simulate the inclination in real sewer system that assure the gravitational flow. Due to this inclination the total head between the entrance of water in the feeding tank and the deliverance point was set to be 0.23 ft. at the deliverance point. The sides of the square shape was designed to include three pipe branches with length of 4 m connected with 180O bend pipe. So the distance of the pipes inside each side was set to be 12 m.

The sides of the square shape was designed to include three pipe branches with length of 4 m connected with 180^{O} bend pipe. So the distance of the pipes inside each side was set to be 12 m. Each pipe branch were fitted with a slop of 0.0023 in/in in order to simulate the inclination in real sewer system that assure the gravitational flow. Due to this inclination the total head between the entrance of water in the feeding tank and the deliverance point was set to be 0.23 ft. from the deliverance point. A photographic images for the simulated system can be seen in Figure 1.

Figure 1. Photographic images for the designed system

2.3- Activated sludge and aeration design

Activated sludge is rich with active biomass was delivered to the system in order to increase biodegradation efficiency. As it noted in section 2.2, an extra tank was assigned to activate sludge deliverance. The tank was filled with activated sludge that delivered from Al-Rustamiyah sewage treatment plant with a biomass concentration of 4500 mg/L. The seeded experiments was started with 50/50 (v/v) sewage water with activated sludge mixed in feeding tank.

Air was pumped via air compressor and fed into the system in two ways, thin plastic pipes used to deliver air to air nozzles distributed in terms of three nozzles attached to the effluent pipe from each tank. Due to the fact of narrow cross section area of the pipe, partially flow cannot be guaranteed inside the system so aeration process inside the pipes may not be possible all the treatment duration. So another method of aeration had been adopted expressed in supplying air via nozzles to the tanks itself as tanks were always partially filled with sewage water. These two procedures were adopted together to ensure the deliverance of air to the microorganisms presented in the system.

2.4- Experimental Procedure

Starting, sewage water delivered from real sewage system was fed into feeding tank. The water samples were first examined in terms of COD, SCOD, SS and VSS values. The feed stock was set to be a mixture of activated sludge with the real sewage water with a proportion of 50/50 v/v. Effluent valve beyond the feeding tank was opened and the sewage water let to flow due to gravity reaching to the following tank and accumulated. When the level of water raised in the tank to certain level, sewage water let to flow to the following tank. This process continued until a sewage water reached to the deliverance point with the consideration of adding more sewage water to the feeding tank in necessity to maintain water levels in all tanks with the range of partially filled. A pump was used to rise the sewage water above the head back to the entrance tank. At this point, the pump was started to raise water again to feeding tank and all valves were opened and circulation of water in the system started.

When the circulation process started, air had been delivered to both pipes and tanks via air compressor. The process continued for 8 successive working hours and samples were withdrawn in intervals of 1, 2, 3, 4, 6, and 8 hours measured from the aeration starting and stored in plastic containers in dark place in order to be analyzed.

3- Results and Discussion

3.1- Seeded Treatment at 10 ^{O}C

For investigating the system performance seeded with activated sludge under ambient temperature of 10 ^{O}C, ten sewage water samples were treated and the measurement of CODO, SCODO, SSO, VSSO, SCODF and RSCOD values were presented in Table 2.

Table 2. Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD parameters (mg/L) removal under temperature of 10 OC.

COD^{O}	$SCOD^{O}$	$SCOD^{F}$	SS^{O}	VSS^{O}	RSCOD
410	300	262	280	205	12.67
650	525	453	395	295	13.71
570	430	373	405	280	13.26
355	265	230	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 noticed that for all treated sewage samples, RSCOD values calculated in terms of SCOD were noticeable even though the system was under low ambient temperature. This can be attributed to the addition of activated sludge powered by aeration 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 2 that RSCOD values were close for all treated sewage samples and ranging between11-13. The profiles of SCOD and RSCOD regarding treatment time can be seen in Figures 2 and 3, respectively.

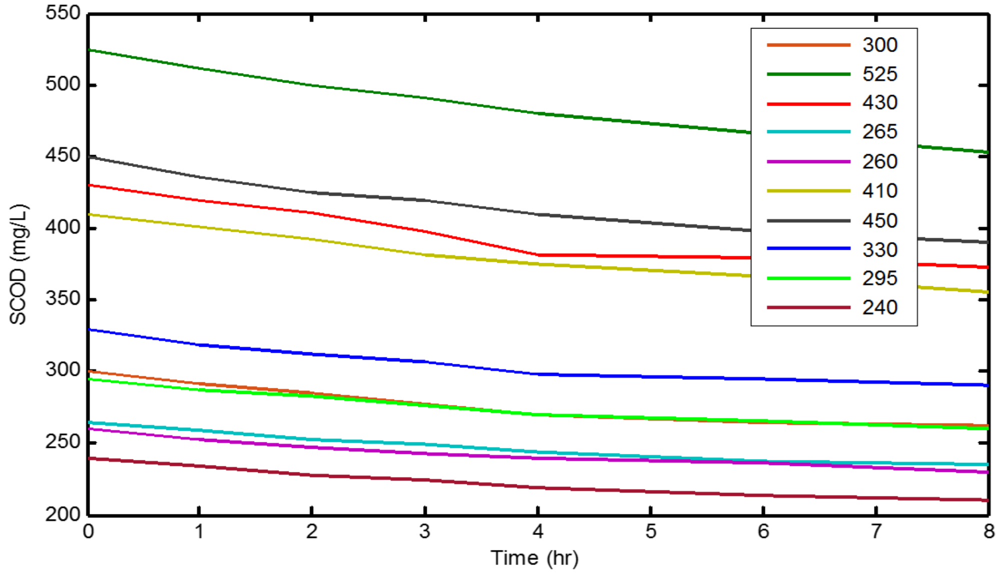

Figure 2. SCOD profiles under aerobic conditions with seeding at temperature of 10 OC.

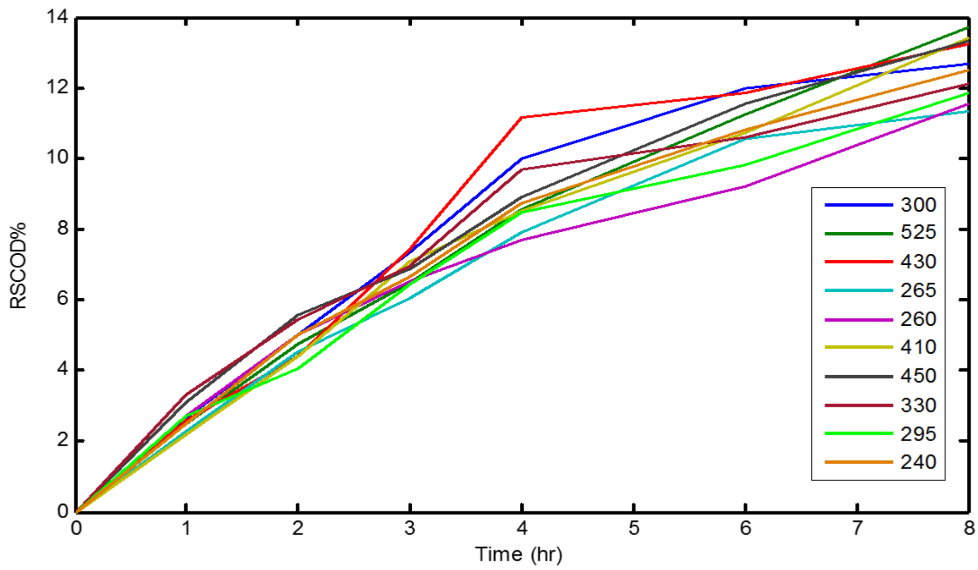

Figure 3. RSCOD profiles under aerobic conditions with seeding at temperature of 10 OC.

It can be obtained from above figures that profiles of degradation were clear to be noticed and SCOD levels were decreased as time increased for all tested samples. The results obtained from seeded experimentations coupled with aeration showed promising aspects although with low ambient temperature. This can be ascribed to the presence of high concentration of 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.

Table 3. Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD removal under temperature of 20 OC.

COD^O	$SCOD^O$	$SCOD^F$	SS^O	VSS^O	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

3.2- Seeded Treatment at 20 ^{O}C

Ten sewage water samples were treated under aeration conditions and seeding process for the ambient temperature of 20 ^{O}C to show the validity of the treatment under this temperature. Values of CODO, SCODO, SSO, VSSO, and RSCOD were tabulated in Table 3 and RSCOD values were calculated at the end of 8 hr of treatment time.

Comparing the calculated RSCOD values presented in the table with that calculated for treatment at ambient temperature of 10 ^{O}C presented in Table 2, 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 natural ecosystems, microorganisms play a dominate role in mineralizing various organic pollutants. The organisms involved in the self-purification processes in a natural water system can be broadly divided into two groups according to their habitat. The surface attached organisms colonize all the surfaces occurring in the water, e.g. stones, water plants, bank reinforcements and weirs. In another hand, the water stream is colonized by suspended microorganisms such as bacterial flocs, plankton and microscopic crustaceans (Gebara, 1999). Artificial biological wastewater treatment systems copied natural systems and provided a favorable artificial environment. The microorganisms retained in such systems may be in suspended growth forms as in the activated sludge process, or in the attached growth form as in the trickling filters or rotating biological contactors.

In Figure 4, 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 5 for the treated water samples at ambient temperature of 20 ^{O}C.

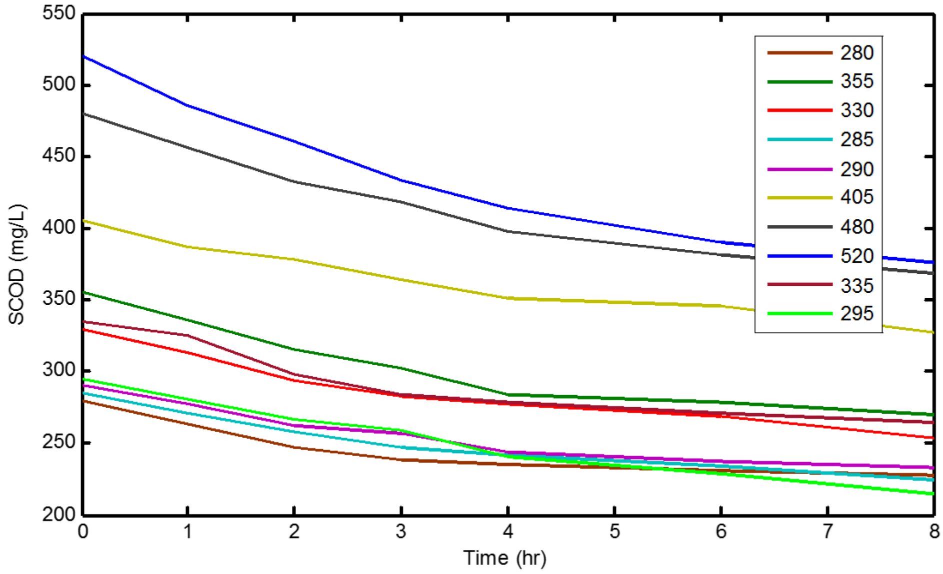

Figure 4. SCOD profiles under aerobic conditions with seeding at temperature of 20 OC.

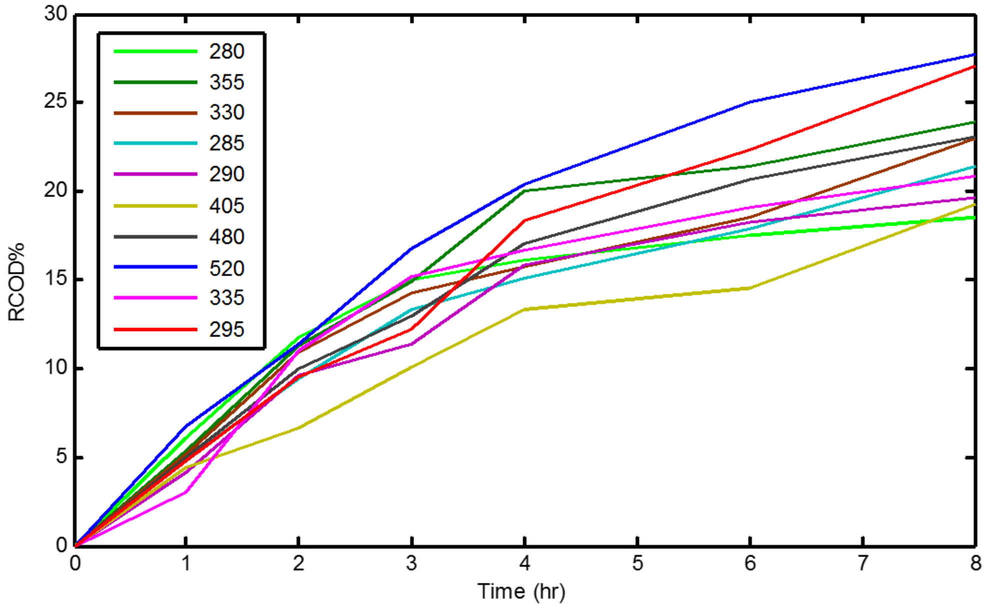

Figure 5. RSCOD profiles under aerobic conditions with seeding at temperature of 20 OC.

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

3.3- Seeded Treatment at 30 ^{O}C

Operating the system under 30 ^{O}C 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 presents CODO, SCODO, SSO, VSSO, and RSCOD values for the tested samples.

Table 4. Initial COD, SCOD, SS, VSS, final SCOD and overall SCOD removal under temperature of 30OC.

COD^O	$SCOD^O$	$SCOD^F$	SS^O	VSS^O	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	26.032
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 ^{O}C with activated sludge seeding. Comparing the calculated RSCOD values with those calculated under ambient temperature of 20 ^{O}C presented in Table 3 revealed better organic reduction. It seemed that rising operation temperature beyond 20 ^{O}C had a significant effect in terms of organic substrate degradation as indicated in the results of the experimentations. 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.

It can be concluded from Tables 2-4 that maximum RSCOD values were recorded for higher VSSO values in treated sewage water samples for all operational temperature. This harmony obtained 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 represent 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 6, degradation profiles of SCOD for the treatment under ambient temperature of 30 ^{O}C, while Figure 7 represents the RSCOD profiles increasing vs treatment time for all treated sewage samples under the same ambient temperature.

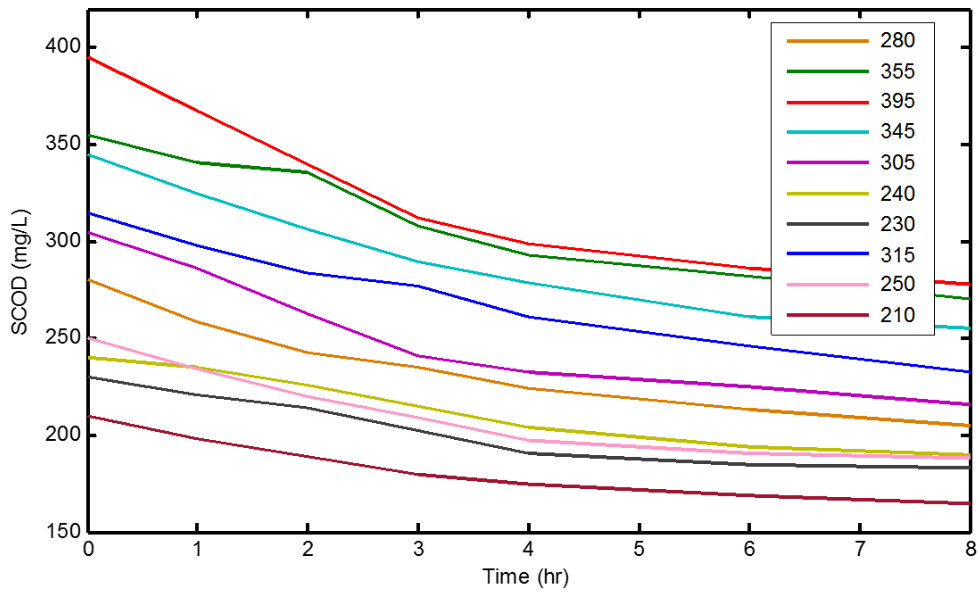

Figure 6. SCOD profiles under aerobic conditions with seeding at temperature of 30 OC.

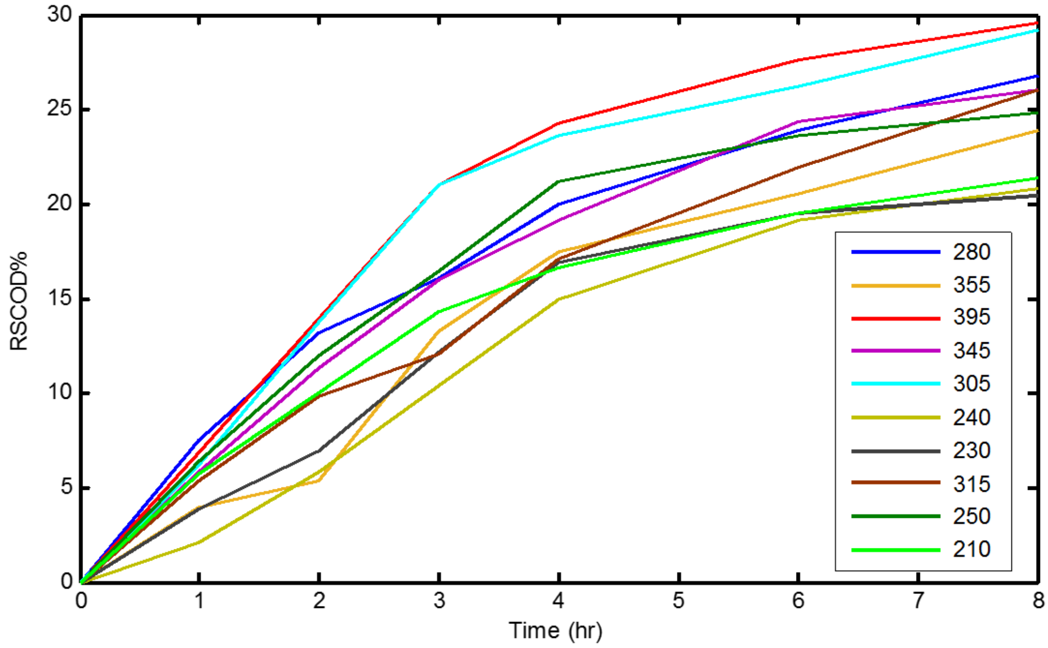

Figure 7. RSCOD profiles under aerobic conditions with seeding at temperature of 30 OC.

As it can be seen in Figure 6, that all treated sewer samples represented degradation profiles in terms of SCOD while the higher RSCOD profiles was conducted for samples with SCOD of 395 and 305 as demonstrated in Figure 7. This can be ascribed to the higher organic suspended solids content expressed by the higher VSS^{O} values.

To this point, the results obtained for the seeded treatment with activated sludge coupled with aeration presented 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. According to Tench (1994) the rate of oxidation of wastewater is proportional to the number of viable micro-organisms in the activated sludge and the concentration of the substance adsorbed on the floc surface. Based on experimental trials with full-scale activated sludge plants, the researcher noted that the active biomass is a decreasing proportion of the sludge as its concentration is increased. He also suggested that there is an optimum sludge concentration for each plant and that the sludge could be varied greatly without significantly affecting the plant treatment efficiency. An increase in mixed liquor suspended solids beyond the optimum concentration caused only a small reduction in effluent quality.

4-Conclusions

Investigating the performance of simulated sewer system with the presence of activated sludge seeding had been conducted. The results revealed that partial degradation of the organic materials presented in the sewage water can be achieved as water travel through sewer system via suppling air and activated sludge to the system. The crucial effect of ambient temperature had been proved as maximum degradation in terms of SCOD removal had been recorded for higher ambient temperature of 30 ^{O}C. the significant influence of temperature in activating the metabolism of living biomass presented in the system seemed to have the dominant role in the degradation process. This influence combined with the increase in the living microorganism's amount had a promising impact in terms of partial *degradation* of organic wastes towered cleaner and safer environment.

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