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Studying the Effect of Ambient Temperature on Wastewater Degradation in Simulated Self-Purification Aerated Sewer System

Abstract- Designing and operating a simulated gravity sewer system had been accomplished in the current research. The design had been provided with aeration system in order to deliver oxygen to microorganisms presented in sewage water. The system had been used in three different seasons in order to investigate the ambient temperature effect on treating wastewater. The results revealed that ambient temperature had a significant role in organic waste degradation powered by the presence of air into sewage pipes and level tanks. Maximum degradation measured in terms of chemical oxygen demand removal (RCOD) was recorded to be 14.28 under 30 °C ambient temperature and 8 hr of treating time. The results recorded from the current system seemed to be promising in terms of self-purification ability of the transporting sewer system.

Keywords: Simulated sewer system, Self-purification, Organic biodegradation.

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1. Introduction

Sewers have considerable potential for the removal of organic material and nutrients through the physical, chemical and biological processes that take place naturally within a sewer system. The impact of these processes on the chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrogen and phosphorus content of the wastewater can be significant [1]. Microbial processes in wastewater of sewer systems proceed during transportation; these processes take place in the water phase, in the biofilms and in temporarily settled sewer sediments. Soluble as well as particulate wastewater compounds undergo transformation processes [2].

Several investigations were conducted in few past decades on self-purification sewer system in terms of quality and quantity. In terms of quality, it was reported by Huisman et al. [3] that not less than 30% of COD value can be oxidized in full-scale gravity sewer system. In the other hand, experimental results of Raunkjaer et al. [4] presented the change in the dissolved COD/particulate COD ratio and other components such as volatile fatty acids, carbohydrates, lipids, and proteins. These results revealed that self-purification systems might strongly affect the design and operation of wastewater treatment plant (WWTP), which are

presented in the ends of sewer system. Oxidation of organic matter deserves careful attention as it has the potential to reduce the loading of organic matter to WWTP [5].

A comprehensive understanding of a sewer system as being a reactor for microbial processes is therefore needed for sewer design and operation taking into account functioning of the sewer, wastewater treatment and combined sewer overflow effects. The current research investigated the effect of aeration process in simulated sewer system in different ambient temperature.

2. Materials and Methods

I. Wastewater samples

In order to ensure that the tested sewage water samples BOD, COD, SS and VSS levels are within the range of values for the levels of the real sewage water of the main treatment plant of Al-Rustamiyah, the real data were collected for different seasons i.e. winter, spring and summer (between January and June). This variation in the treatment seasons was necessary to assure the difference in weather temperatures (within the range of 10±0.3 to 30±0.5 °C).

II. Pipes System Design

The actual sewer system that connects Adhamiya district and Al-Wazireya neighborhood was experimentally simulated in the current design. PVC pipes of outer diameter of 75.2 mm (3 inches) were used. The pipe system was designed as a square shape with four equal sides. The side length was designed as 4 m and a settling tank was fitted at each corner of the square design to simulate manholes in the real sewer system. The tank have a cylindrical shape with a total volume of 250 L supplied with transparent level measuring pipe and fitted to the system via quarter gate valve. 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. More specifications about the pipes used in the system can be seen in Table 1.

connected with 180° bend pipe. Therefore, the distance of the pipes inside each side was set to be 12 m. Each pipe branch was fitted with a slop of 0.0023 in/in in order to simulate the inclination in real sewer system that assures 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. A pump was used to raise the sewage water above the head back to the entrance tank. Beside the pipes, 90° elbow curved pipes and 180° bend pipes were used to join the pipes and construct the square shape system. A schematic diagram for the system can be seen in Figure 1.

Table 1: Specification of pipes system

Outer diameter (mm)	75.2
Inner diameter (mm)	68
Length (m)	54
Wetted area (mm ²)	3631.68
Roughness Coefficient	0.01
Number of bends	21

The sides of the square shape were designed to include three pipe branches with length of 4 m

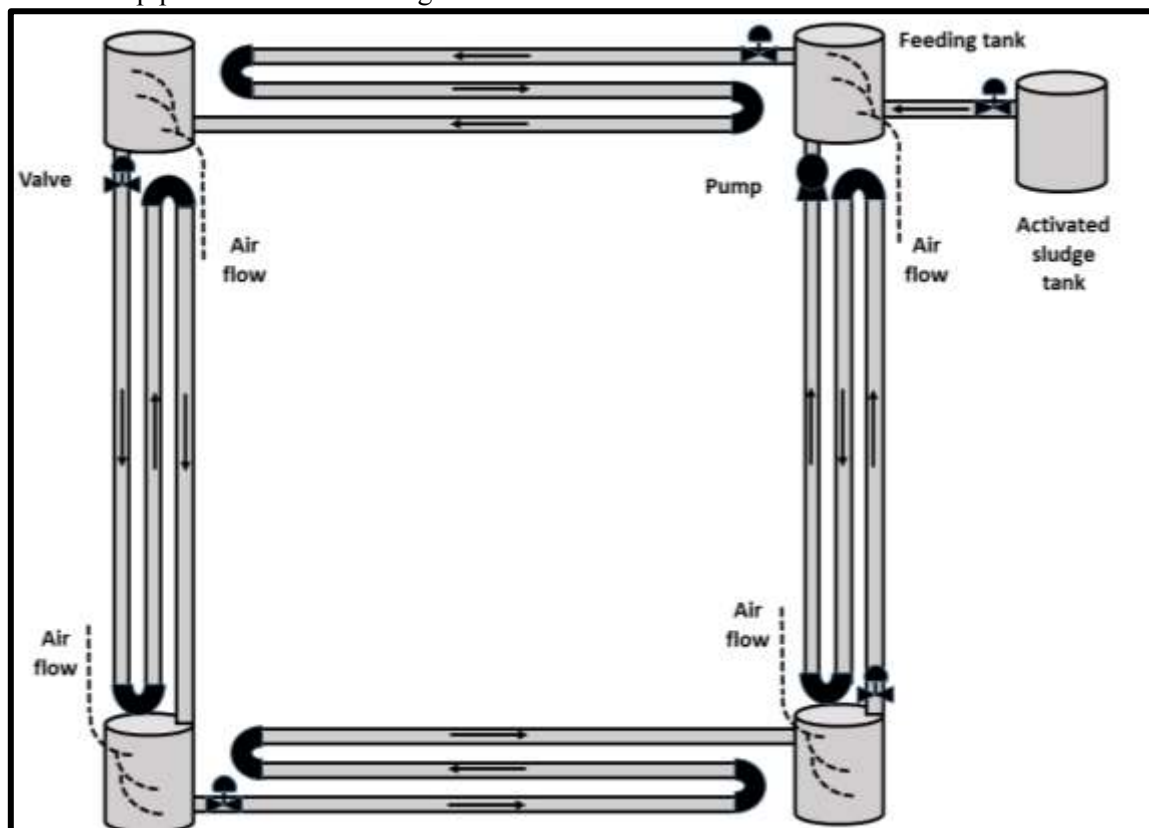


Figure 1: Schematic diagram for the designed system

III. Aeration design

In order to supply air to the system, air was pumped via air compressor. Air was fed into the system in two ways; thin plastic pipes were used to deliver air-to-air nozzles distributed in terms of three nozzles attached to the outlet pipe from each tank. Due to the fact of narrow cross section area of the pipe expressed by the wetted area, 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.

V. Experimental Procedure

The process of aeration experimentation was conducted as the feeding tank filled with sewage water delivered from real sewage system. The water was first examined in terms of BOD₅, COD, SCOD, SS and VSS values [6-8]. Quarter gate valve was opened and the sewage water let to flow due to gravity reaching to the following tank and accumulated. When the water level reach to an appropriate value, the gate valve was set to be opened and sewage water flowed to the next tank. This process continued until 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 tank with the range of partially filled. At the point pump was started to raise water again to feeding tank, all valves were opened, and circulation of water in the system started.

With the circulation process starting, air compressor switched on and air had been delivered to both pipes and tanks. The process continued for eight 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

I. Samples of Wastewater

In order to accomplish a comparison between real and tested water samples, statistical investigation is required. The mean, range, standard deviation and variance values of real data and water samples were tabulated in Table 2.

The results of statistical comparison between the real and tested water sample under temperature of 20 °C can be seen in Table 3.

The statistical values of mean, minimum, maximum, range and standard deviation for the real and tested water samples can be seen in Table 4 under temperature of 30 °C.

Table 2: Statistical parameters of the real and tested water samples at 10±0.3 °C

	Real			Tested		
	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)
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

Table 3: Statistical parameters of the real and tested water samples at 20 °C

	Real			Tested		
	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)
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

Table 4: Statistical parameters of the real and tested water samples at 30±0.5 °C

	Real			Tested		
	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)	BOD ₅ (mg/L)	COD (mg/L)	SS (mg/L)
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 Table 2, 3, and 4, that the mean values of real and tested water samples were relatively close with some differences attributed to the extreme values of the vast real water data. The same reason can explain the differences between standard deviation values. As it can be noticed in the maintained tables, the standard deviation values of the real water were higher than those of the tested samples due to those extreme values. In the other hand, the tested samples can represent the real data in good approach as indicated by the minimum and maximum values. All minimum values of the three temperatures 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 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 sewage water presented in Al-Rustamiyah treatment plant.

II. Experiments of aerobic treatment

Aerobic condition was adopted in treating samples of sewage water under different weather conditions in order to investigate the ability of the existing microorganisms presented in sewage water samples in degrading the organic matters.

III. Aerobic treatment at temperature of 10 °C

For investigating the performance of the system under aerobic conditions at temperature of 10 °C, six sewage water samples were tested. The characteristics of the studied samples and the overall COD removal for holding time of 8 hr were presented in Table 5. As it can be concluded from Table 5, the RCOD values calculated for the six tested samples were relatively low even under treatment time of 8 hr. Maximum removal of 3.85 was achieved for the sample with COD⁰ and SS⁰ of 390 mg/L and 610 mg/L, respectively. This can be attributed to high organic content in the sample comparing with others providing sufficient nutrients for the living microorganisms presented in sewage water. In the other hand, low performance of the system in terms of COD removal for all tested samples could be ascribed to low operation temperature.

In aquatic systems, significant role played by temperature on biomass growth and microorganism settlement is as described by Rao [9]. Microorganism's growth and activity are dependent on the nutrient availability, water flow

rate and ambient temperature. They reported that in warmer regions, biofilm formation takes place at all times of the year, whereas in the moderate waters, biofouling is more pronounced only during the warm months.

The measured COD values were measured at different time intervals to show COD profile during the process and presented in Figure 2.

As it can be seen in the Figure, slight reduction in COD levels had been noticed for almost the tested samples. For the sample with COD⁰ level of 195 and SSO of 150, there was no significant change in COD levels with the duration. This can be ascribed to low organic content if the sample leading to insufficient feed for microorganisms causing in large lack in degradation process .

IV. Aerobic treatment at temperature of 20 CO

Under temperature of 20 OC, seven water samples were tested for operation time of 8 hr. The initial COD levels with initial SS concentrations and the overall COD removal were presented in Table 6.

Table 5: Initial COD levels and over all removal under temperature of 10 °C

COD ⁰ (mg/L)	SS ⁰ (mg/L)	RCOD %
370	610	2
300	600	2
190	150	0.51
390	610	3.85
330	270	1.71
180	420	2.22

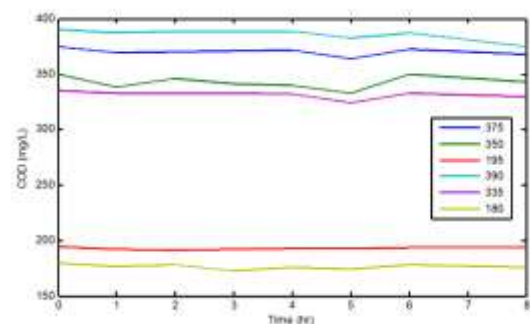


Figure 2: COD profiles under aerobic conditions at temperature of 10 C°

Table 6: Initial COD levels and over all removal under temperature of 20 °C

COD ⁰ (mg/L)	SS ⁰ (mg/L)	RCOD %
200	270	8.80
320	410	12.19
310	400	11.71
290	340	8.47
310	420	11.43
300	330	7.28
300	300	7.33

As it can be concluded in the table, RCOD values were higher comparing with values under operation temperature of 10 °C. this can be resulted as a positive effect of higher ambient temperature that motivate the metabolism of the microorganisms presented in water samples. It had been reported by Villanueva et al. [10] that the growth rate of bacterial biofilm can be increased by the flow and temperature, yet the efficiency of bacterial growth may be declined. Temperature usually increases the metabolic yields and promotes 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 COD values measured at different operation times can be seen in Figure 4 for the seven tested water samples.

As it can be noticed in the Figure that for all COD concentrations, degradation profiles were noticeable for all tested water samples. Combining the results extracted from the Figure with RCOD values tabulated in Table 6, the better COD removal, the highest SSO content in the sample due to sufficient amount of organic waste provided to microorganisms. Highest RCOD of 12.19 was recorded for the sample with COD₀ of 320 mg/L and SSO of 410 mg/L.

V. Aerobic treatment at temperature of 30 OC

With the increase of ambient temperature to 30 OC, eight sewage water samples were tested. The values of COD₀, SSO, and RCOD for 8 hr duration of treatment were presented in Table 7.

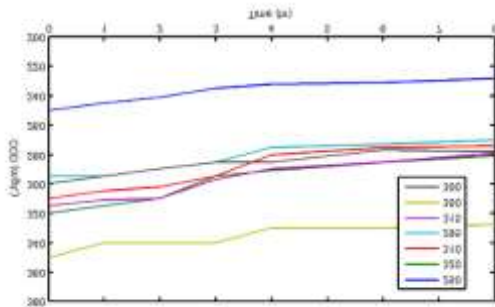


Figure 4: COD profiles under aerobic conditions at temperature of 20 °C.

Table 7: Initial COD levels and over all removal under temperature of 20 OC.

COD ⁰ (mg/L)	SSO ⁰ (mg/L)	RCOD %
280	440	14.28
310	320	9.02
340	300	8.82
360	280	8.62
490	470	13.13
380	240	7.89
400	160	7.22
270	400	13.40

In the other hand, the COD profiles for the treatment under ambient temperature of 30 °C can be seen in Figure 4 for the eight tested samples.

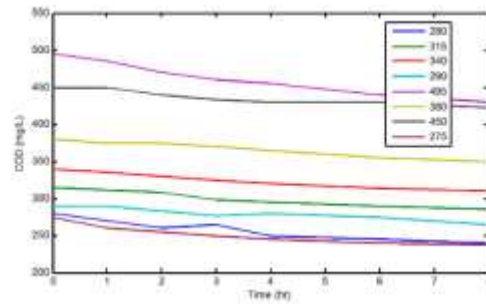


Figure 4: COD profiles under aerobic conditions at temperature of 30 °C.

As it can be concluded from Table 7 that maximum RCOD values of 14.28 and 13.40 were recorded for samples with COD₀ values of 280 and 270 mg/L with SSO values of 440 and 400 mg/L. COD patterns showed significant reduction for all tested samples under ambient temperature of 30 OC. comparing RCOD values of Table 7 and 6 for the treatment under temperature of 20 OC showed the positive effect of temperature increment of 10 OC leading to higher RCOD measurements. Biofilm growth that lead to bio fouling in synthetic treated sewage stream can be accelerated as temperature raised from 30 to 35 OC, but decreased at higher temperatures as reported by Yanga et al. [11]. They reported that an optimal temperature range usually around 35 OC for the growth of microorganisms can be identified. The temperatures of treated sewage generally range from 10 to 35 OC, so faster rates of microorganism's growth are expected at higher temperatures.

A conceptual model for wastewater quality changes during transport in sewers was investigated by Vollertsen et al. [2]. The model concept includes reaeration and main aerobic and anaerobic microbial processes in water phase and sewer biofilm. They reported that aerobic conditions in relatively long intercepting gravity sewers might cause considerable reduction of biodegradable organic COD fractions whereas anaerobic conditions only result in minor changes.

Many reports revealed that using pure oxygen instead of air in self-purification sewer system is more beneficial and more considerable in full-scale systems to prevent septicity [12]. In spite of the fact of higher transfer rate of oxygen over air in water due to the presence of nitrogen that interrupt dissolution of oxygen and cause gas

locking problem, there serious technical drawbacks.

Using oxygen compared with air systems include the need for sophisticated equipment for oxygen generation and the delivery of liquid oxygen, the extra cost of oxygen production, corrosion, careful supervision and fire hazard. A major disadvantage of pure oxygen activated sludge process is the decrease in pH of the mixed liquor due to an accumulation of carbon dioxide in the wastewater, which in turn may cause inhibition of the nitrification process [13].

4. Conclusions

Operating the simulated design of sewer system showed significant results in terms of biodegradation of organic wastes presented in local sewage water. Testing the design in different seasons for investigating the effect of treatment ambient temperature revealed the crucial role of temperature in activating the metabolism of presented microorganisms as noticeable decreasing on COD values was recorded for operating the system in 20 and 30 OC. the role of temperature was coupled with the positive effect of pumping air to the pipes and level tanks to provide oxygen to suspended biomass and maintain aerobic conditions for the process. Noticeable and promising reductions in terms of COD values were corded for operating the system for 8 successive working hours contributing the knowledge to the field of sewage water treatment.

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