Evaluation of Anaerobic Treatability of Between Cotton and Polyester Textile Industry Wastewater

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1. Introduction

Recently, the fast increase in the cost of energy and the decrease in the used economic fossil fuel reserves cause an increase in the interest to the energy production from wastes using anaerobic biotechnology (Speece, 1996). The anaerobic treatment is defined as the biological separation of organic wastes in anaerobic conditions and also the production of their last products, such as CH_4, CO_2, NH_3, and H_2S (biogas). The processes, employed by anaerobic bacteria, have been widely used in treatment of municipal wastewaters and varying types of industrial wastewaters for removal of organic material in the wastewaters and also produce biogas as energy from the wastewaters. Treatment capacity of an anaerobic digestion system is primarily determined by the amount of active microorganism population retained within the system dependent on wastewater composition, system configuration and operation of anaerobic reactor (Zainol et al., 2009).

2. Important

Textiles and apparel sector, one of the important industries in the world, is a vital contributor to Turkey's economy, accounting for approximately 10 percent of the country's gross domestic product. It is the largest industry in the country, constituting approximately 15 percent of manufacturing and about one-third of manufactured exports. Nowadays, the country produces the eighth-largest volume of man-made fibers in the world, at 1.2 million tons per year (Pelot, n.d.). Therefore, textile industries are vitally distributed in the country. The variety of raw materials, chemicals, processes and also technological variations applied to the processes cause complex and dynamic structure of environmental impact from the textile industry (Sapci & Ustun, 2003). The textile industries as pretreatment (desizing - scouring - bleaching) and dyeing processes generate large quantity of wastewater containing unreacted dyes, suspended solids, dissolved solids, and biodegradable and non-biodegradable other auxiliary chemicals (Raju et al., 2008, Somasiri et al., 2008, Georgiou et al., 2005, Isik & Sponza 2004). For example, polyester is a material produced on a large scale as a component of textile fiber, which results in a great deal of discharge wastewater with various additives and detergents, including wetting agents, softening agents, antioxidant, surfactant, detergent, antiseptic and dyes (Yang, 2009). Cliona et al. (1999) reported that the dyes can be classified on their chemical structure (azo, anthraquinone, azine, xanthene, nitro, phthalocyanine, etc.) or application methods used in the dyeing process (acid, basic, direct, reactive, etc) (Somasiri et al., 2008). Therefore, these industries have also shown a significant increase in the use of synthetic complex organic dyes as coloring material. The discharge of these textiles is viewed to have negative effect on the environment in this area, also damaging the quality of water sources and may be toxic to treatment processes, to food chain organisms and to aquatic life (Talarposhti et al., 2001). Therefore, it is of paramount importance to know its exact nature, in order to implement an appropriate treatment process (Marmagne & Coste, 1999). For the foregoing reasons, textile industries wastewater was selected for the research.

On the other hand, the country has around 1.9 million employees in the textile and apparel sector (Pelot, n.d.). Therefore, wastewater of these industries has generally been a combination of textile and municipal wastewater. If the municipal wastewater mixes with the other kind of wastewater, it has lost its domestic property, and is considered to be process wastewater. Biological treatment may be a good alternative as the operational costs are relatively low when compared to most of the physical/chemical technologies. Although recent studies of anaerobic treatment of textile wastewater using several high-rate up-flow anaerobic sludge blanket reactors were conducted, however studies about anaerobic treatment of mixture wastewater (both textile and municipal wastewater) are deficient. For the foregoing reasons, between textile industries wastewater and municipal wastewater were applied for the research.

The aim of this work was to study the treatment of textile wastewater using an up-flow anaerobic sludge blanket (UASB). Textile wastewater was selected for the research due to its total volume (53.5% of all types of industry in Turkey). In this study, firstly, treatability of textile polyester wastewater diluted with a municipal one is examined in an UASB system according to organic loading rate (OLR), hydraulic retention time (HRT), as well as important anaerobic operating parameters. Three reactors were operated at mesophilic conditions (37±0.5 °C) in a temperature-controlled water-bath with hydraulic retention times (HRTs) of 5 days, and with organic loading rates (OLR) between 0.314(±0.03) – 0.567(±0.05) kg COD/m^3/day. Three different dilution ratios (45%, 30% and 15%) of municipal with real polyester textile wastewater are employed. Secondly, the effects of glucose and lactose selected as a co-substrate, with constant HRT values of 5 days, on the systems with same dilution ratios for each reactor (30%) were examined. All these results evaluated in the manuscript. Thirdly, to show a difference of anaerobic treatability between polyester wastewater diluted with municipal wastewater and cotton textile wastewater diluted with municipal wastewater, all these results compared with previous study (Zengin & Aydinol, 2007). The previous study about real cotton textile wastewater treatment were run two hydraulic retention times (HRTs) of 4.5 and 9.0 days, and with organic loading rates (OLR) between 0.087(±0.016) – 0.517(±0.090) kg COD/m^3/day. Three different dilution ratios (15%, 30% and 40%) of municipal with textile wastewater were employed at same mesophilic conditions. Fourthly, regarding mixed wastewater, co-substrate effect on anaerobic treatment evaluated according to COD removal efficiency. For this reason, assessment of anaerobic treatment results from previous experiments which were used glucose (as co-substrate) with varied dilution ratios (60%, 40%, 45%, 30%, and 15%) of municipal with cotton textile wastewater experiments and these trials which were used same co-substrate with different dilution ratios (45%, 30% and 15%) of municipal with real polyester textile wastewater were examined.

The results showed that the municipal wastewater rate in both the polyester wastewater and the cotton wastewater did not have a substantial change in COD removal efficiency. Textile polyester wastewater diluted with different ratio of municipal one was not treated in UASB as a satisfied for COD removal efficiency even though values of alkalinity, SS and pH are founded optimum range for successful operation of the digester. In addition, even if when either glucose or lactose as a co-substrate was added mixed wastewater; it was not seen positive effect for anaerobic treatment of polyester wastewater. However, addition of co-substrate (glucose) in cotton wastewaters had a positive effect on the COD removal efficiency. Therefore, COD removal efficiency of textile wastewater on anaerobic digestion change especially depends on textile wastewater types. Before the anaerobic treatment of polyester wastewater, it should be treated via advance technology.

3. Information

3.1 Sampling

In this study, original wastewater samples were obtained from the knit fabric wastewater and polyester process wastewater of two different industries located in Istanbul, Turkey. First industry, knit fabric industry, dyed of fiber, wool yarn and fabric (before knit process) or texture (after the unit). This industry wastewater was used during the start-up period of anaerobic treatment in the study. Second industry uses only polyester fabrics which are dyed using dispersive dyes. Used cotton textile wastewater for comparing of anaerobic treatment results in the study was taken from another industry in Istanbul, which detail information was given previous study (Zengin & Aydinol, 2007). In addition, municipal wastewater used for dilution was supplied from a municipal wastewater plant in Istanbul. All samples were delivered to the laboratory cooled and kept 4 ˚C during the experimental study.

3.2 Experimental set-up

Three reactors, made of serum bottles similar to studies cited in literature (Tang et al., 1999, Sacks & Buckley, 1999, Cordina et al., 1998, Fang & Chan, 1997, Madsen & Rasmussen 1996, Soto et al., 1993, Guiot et al, 1986) were used, each having a volume of 1.2 L and operated for 80 days at mesophilic conditions (37±0.5 °C) in a temperature-controlled water- bath (Ben-Marie device) with two hydraulic retention times (HRTs) of 4.5 and 9.0 days (Fig 1). The upper side of the reactors (14% of reactor volume) had a slope similar to a gas collection funnel. The biogas collected here was measured by the method of volume displacement.

Prior to experiments, 3 UASB reactors were inoculated with granular biomass (25% of the working volume) obtained from Tekel Brewery Inc. (Istanbul, Turkey) and N_2 gas passed through them. The reactors then were filled to their respective volumes with textile wastewater (61% of the total volume). After the start-up period, the real textile wastewater obtained from effluent of textile houses in Istanbul, Turkey fed to the reactors with domestic wastewater. The treatment process was monitored and components of wastewater samples were analyzed in the Environmental Engineering Laboratory at Yildiz Technical University (YTU), Istanbul, Turkey. A detailed schematic diagram of the experimental set-up is shown in Fig. 1.

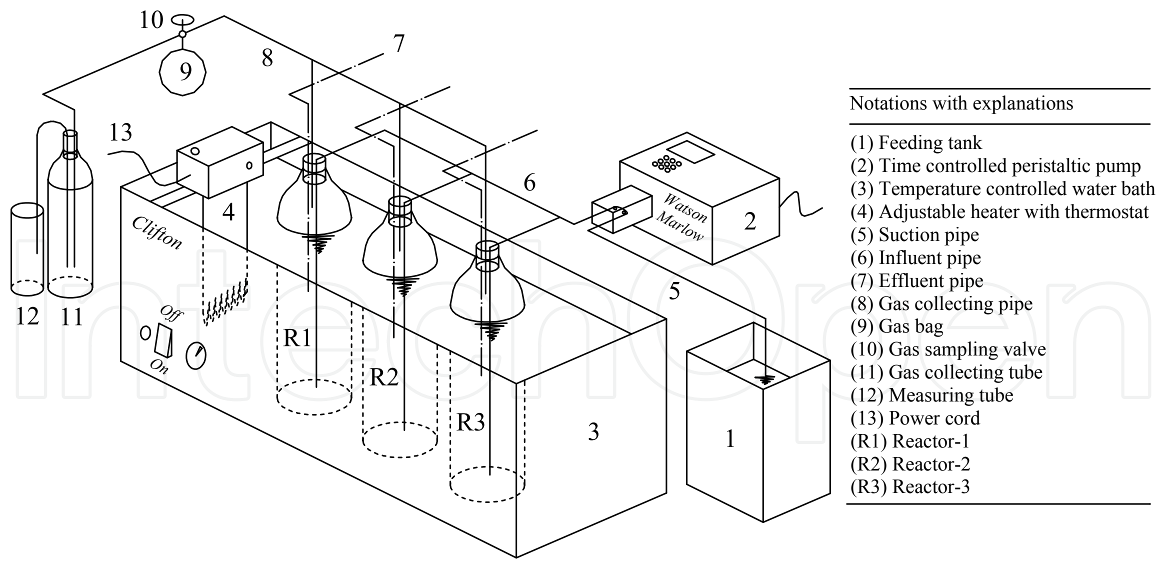

Fig. 1. Detailed schematic of the experimental set-up

3.3 Analytical methods

The temperature, pH, biogas volume (ml) and COD removal efficiency (%) were measured daily. Alkalinity (mg/L as $CaCO_3$), TSS (Total Suspended Solids) (mg/L), and VFA (Volatile Fatty Acids) were measured three times a week according to Standard Methods of APHA-AWWA (1995) (Table 1). During the study, the operational temperatures of the reactors were monitored with a digital thermometer, and pH was measured by a Jenway 3040 Ion Analyzer. The other parameters were determined by the procedures described in Method Numbers 5220-B (Open Reflux Method for COD), 2320-B (Titration Method for Alkalinity), 2540-D (Total Suspended Solids Dried at 103-105 °C) and 5560-C (Distillation Method for VFA) respectively. Concentration of heavy metals (Table 1) were analyzed by the procedure described in Method Number 3111-B (Direct Air Acetylene Flame Method) with an ATI Unicam 929AA-Spectrometer.

Hydraulic retention time (HRT) is a measure of the amount of time the digester liquid remains in the digester. Organic loading rate (OLR) is a measure of the biological conversion capacity of the anaerobic treatment system. COD removal efficiency (COD_{RE}) of UASB reactors being output parameter was considered as a measure of treatment performance. COD_{RE} value is defined as follows:

$$COD_{RE}\,(\%) = (COD_i - COD_e) / COD_i * 100 \quad (1)$$

where COD_i is the influent COD concentration and COD_e is the effluent COD concentration.

Six anaerobic reactors having a total volume of 200 ml were also operated to determine COD fractions of wastewater samples. These reactors were conducted for about 1800 hours at mesophilic conditions (37±0.5 °C), maintained by an adjustable aquarium heater with thermostat (Otto Aquarium Company, Taiwan). Each of them was seeded with 30 mg/L as Mixed Liquor Volatile Suspended Solids (MLVSS) of acclimated granular sludge and homogenized with 100 ml of textile and municipal wastewater. Filtrates of samples obtained from vacuum filtration by means of glass microfibre filters having a pore size of 0.45 µm (Whatman glass microfibre filter) were defined as "soluble fractions". Filter wastewaters and raw wastewaters were fed in the different COD fraction reactors.

4. Results and discussion

4.1 Start-up period

The system was fed by the knit fabric textile wastewater for the adaptation of bacteria. In this study, the start- up period was conducted by the original wastewater (Table 1) which did not have much pollution. Knit fabric is used in textile industry work for all kinds of printing

Characterization of parameters	Knit fabric wastewater	Polyester process wastewater	Cotton process wastewater (Zengin & Aydinol, 2007, Sapci, 2002)
pH	6.4	8.72	9.4
COD (mg/L)	640	3218	1757
TKN (mg/L)	43	204	16
Total P (mg/L)	5	21	34
Alkalinity (mg/L as$CaCO_3$)	1200	230	1750
Sulphate (mg/L)	300	130	760
Detergent (mg/L)	2	2	10
Oil-Grease (mg/L)	-	10	50
Color (Pt-Co)	175	-	520
TSS (mg/L)	47	250	95
Mg(mg/L)	<0.03	3.7	2.2
Fe(mg/L)	0.45	2.1	1.8
Mn(mg/L)	<0.03	0.23	0.3
Zn (mg/L)	1.11	0.8	10
Pb (mg/L)	0.03	<0.03	0.3
Cr (mg/L)	0.68	0.45	3
Ni (mg/L)	<0.01	<0.01	0.4
Co (mg/L)	<0.01	-	<0.03
Cu (mg/L)	0.03	<0.01	0.3

Table 1. Characterization of the studied textile wastewater (cotton process, polyester process and knit fabric)

and sizing. For example, fiber, wool, yarn and cloth print are produced. The sector is an integrated foundation that can produce everything needed with woven workbenches.

In the start-up period, three reactors were fed the same characterized wastewater for HRT for 9 days. Each reactor was fed with 0.071 kg COD/m^3/day of organic loading rate (OLR) without co-substrate. In the next step, glucose used as co-substrate was increased up to 0.245 kg COD/m^3/day of OLR, step by step. Variations of pH and COD parameters observed in the start-up period are given in Fig. 2 (HRT=9 days). During the start-up period, COD efficiency increased step by step, and also the value of pH was determined to be stable (Fig.2). Operating temperature in the systems was carefully maintained between 38±2 °C. During this period, some fluctuations were recorded for the values of biogas (between 25 and 170 mL/day) and SS (between 20 and 55 mg/L). In 2nd reactor and 3rd reactor, fluctuations of them showed a similar behavior.

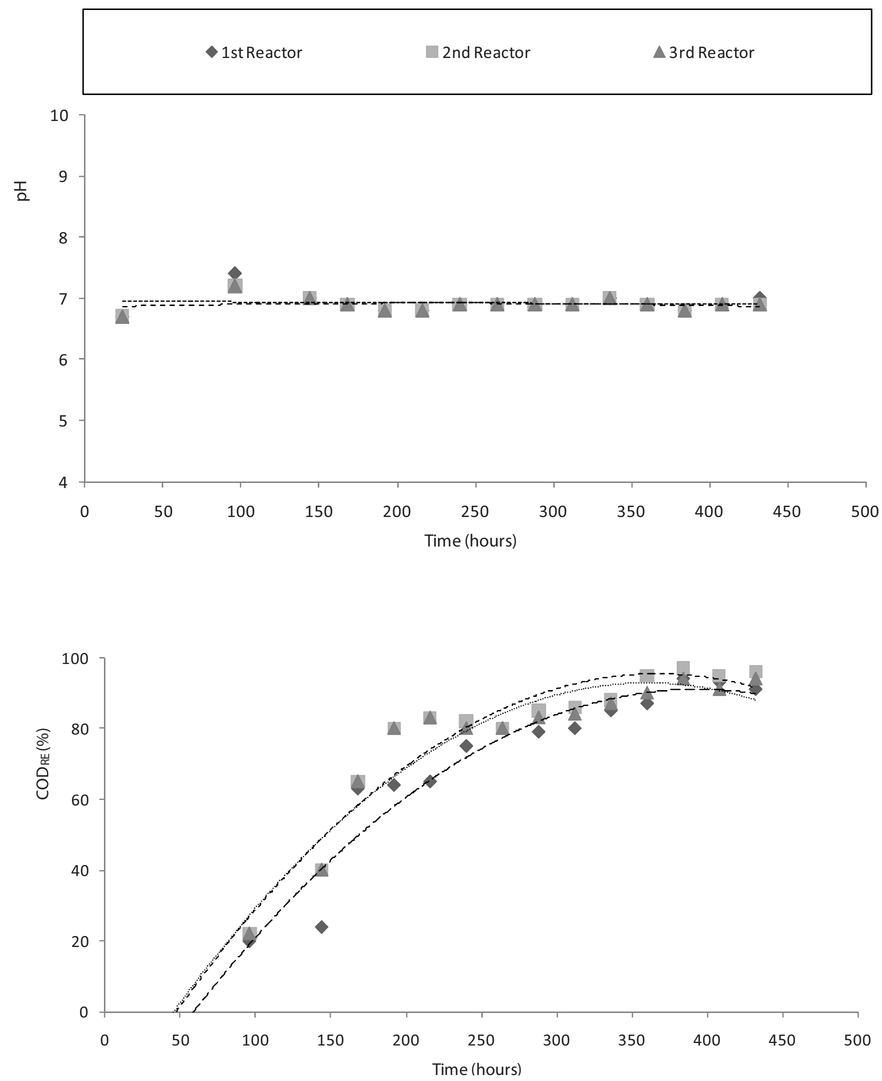

Fig. 2. Variation of pH and COD_{RE} (%) during the start-up period (HRT=9 days).

4.2 Treatment of polyester textile wastewater with municipal wastewater (HRT 5 days) (1st system)

Before, three UASB reactors are fed with diluted polyester textile industry wastewater with municipal wastewater and glucose for helping acclimatization period of bacteria. After the acclimatization period, the process are fed the different ratios mixed wastewaters (without co-substrate), operated for 504 hours, and fed under batch mode for period 24 hours. During the first 145 hours period, COD removal efficiency is drastically decreased from 30 to 5 % for each reactor. Values of alkalinity, SS and pH are founded optimum range of literature required for successful operation of the digester (Metcalf & Eddy, 2003, Kalogo et al., 2001). After the 145 hours, COD removal efficiencies are investigated in the effluent waters of all reactors. No differences have been observed. Hence, graphs of operational parameters changes of a representative anaerobic digestion are not given in the manuscript. Yang (2009) reported that antioxidants used in textile industry to inhibit the oxidation of the fiber could resist the oxidation of contaminations in wastewater treatment and antiseptic take negative effect on growth of bacteria. Therefore, these pollutants discharged from various stages of the polyester manufacturing process are characterized by hard oxidation, toxicity and poor biodegradation. Additionally, the wastewater resources are dying units of polyester products. Some of dyes are toxic and carcinogenic and require separation and advanced treatment of textile effluents before discharge into treatment plant (Georgiou et al., 2005). Hsieh et al. (2007) emphasized that traditional treatment methods were often ineffective in reducing COD of dyes which were highly complex and varied chemical structures

4.3 Treatment of polyester textile wastewater with municipal wastewater and glucose as co-substrate (HRT 5 days) (2nd system)

The effects of glucoses as co-substrate are researched in the reactors. Mixed wastewater charges including 45, 30 and 15% of municipal wastewater with real polyester textile wastewater are studied for the treatability in UASB systems.

Before the trial, the reactors fed with knit wastewater with co-substrate due to adaptation of bacteria. When finding approx. 80% COD removal efficiency, the three reactors are fed the mixed wastewater with an OLR of 0.166(±0.03), 0.178(±0.02), 0.227(±0.04) kg COD/m3/day for HRT of 5 days, respectively. Fig. 3 denotes that COD removal efficiency, pH an alkalinity of all effluent water give parallel behaviour, even though different mixtures used. It indicates that COD removal efficiency of three reactors sluggishly decreased approx. from 75% to 40% (in first 300th hours), even with the feeding of co-substrate, easily decomposable monosaccharides, such as glucose. At the same time, the VFA values from the beginning to the end value of the effluents increase. These differences from beginning to end of the trial are calculated almost 125 mg/L. This sluggish reduction in COD removal efficiency and increasing VFA value result in toxic conditions for methane production bacteria. On the other hand, even though VFA values of effluent in all reactors enhance during the digestion period, the pH values are slowly increased approx from 7 to 7.5. Similarly, the alkalinity also increased approx from 1000 mg/L to 1750 mg/L, expressed as $CaCO_3$. Kalogo et al. (2001) reported that VFA values must be below 100-1500 mg/L, and alkalinity between 1000-4000 mg/L. Therefore, during this period, buffer material is not used because there is neither decrease in alkalinity nor passes limit value of VFA. In the study, this change in the parameters may be caused by instability, even though the values were under the limits for anaerobic systems.

Biogas production has some fluctuations, although it is observed that values of pH, alkalinity and VFA, and COD removal efficiency in the effluents are almost parallel for the whole study period. Kalogo et al. (2001) found that COD removal was not in agreement with biogas production. In the study, biogas fluctuations are caused by gas bubbles which could not overcome partial pressure. Bubbles occur due to result of internal biological activities in anaerobic reactors. The bubble formation process and gas production rate in the bioreactors are greatly influenced hydrodynamic conditions existing in the reactor (Pauss et al., 1990). In the past decade, it has become apparent that many potential applications of dynamic anaerobic models can be cited for gas production under dynamic condition. A description of mass transfer for the major gaseous products carbon dioxide (CO_2) and methane (CH_4) from the liquid into the gas phase under dynamic substrate loading conditions showed that gas solubility as in the case of CO_2 and H_2S more often a liquid phase transport resistance has a flux equation (Merkel & Krauth, 1999). The 3 reactors containing polyester wastewater with 45, 30, and 15% of municipal wastewater and glucose showed similar downward COD removal efficiencies (Fig. 3). Therefore, it can be concluded that municipal mixture ratio and added glucose as a co-substrate in the polyester wastewater does not have a substantial change in COD removal efficiency.

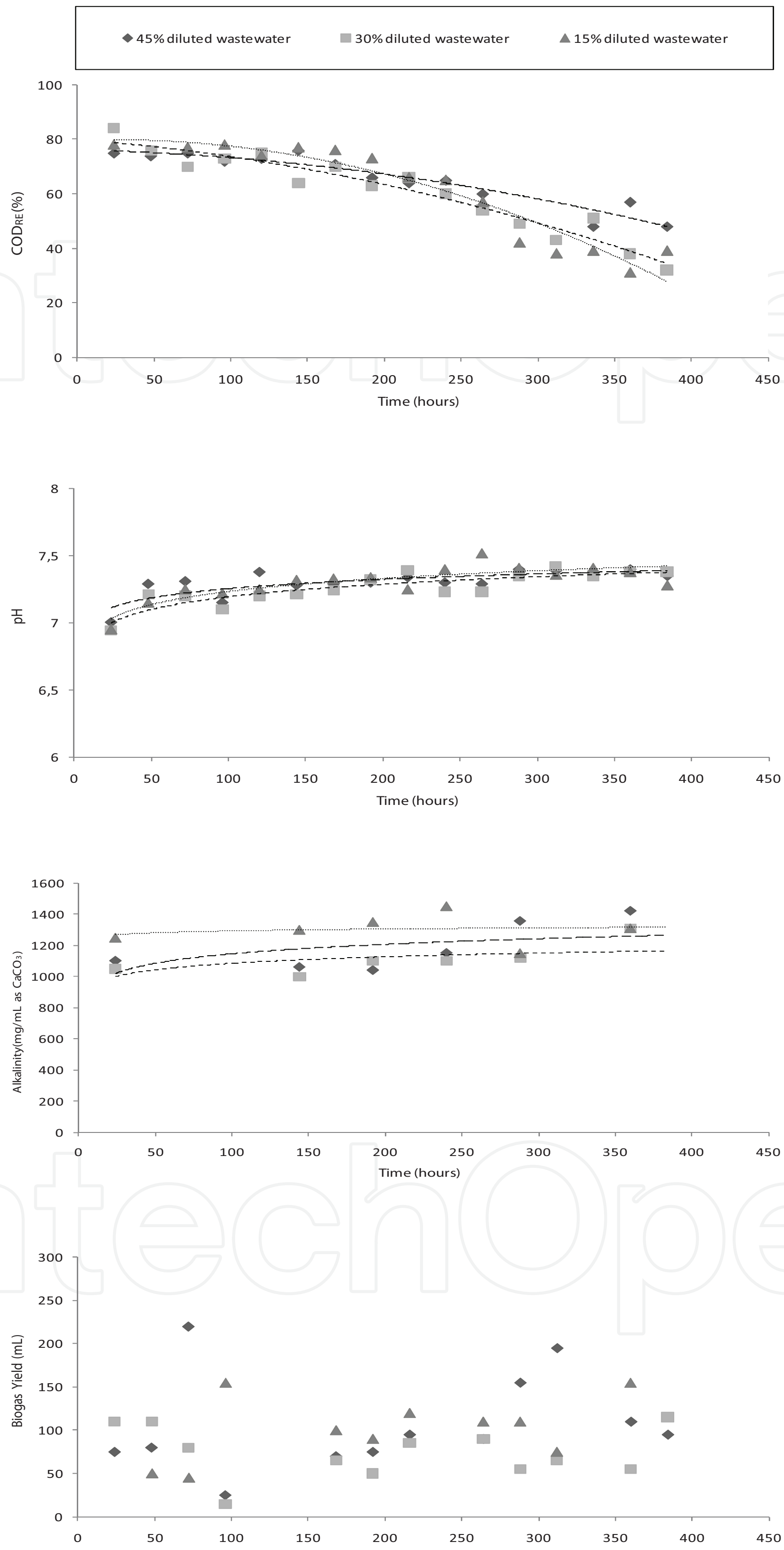

Fig. 3. Mixed wastewater charges including 45, 30 and 15% of municipal wastewater with co- substrate (glucose)

4.4 Treatment of polyester textile wastewater with municipal wastewater and two different co-substrates (HRT 5 days) (3rd system)

Previous chapter indicated that municipal mixture ratio and added glucose as a co-substrate in the polyester wastewater does not have a substantial change in COD removal efficiency. Therefore in this part, distinct effects of glucose and lactose as co-substrate, called 3rd system, were researched in the reactors. Mixed wastewater charges including 30% of municipal wastewater with real polyester textile wastewater are studied for the treatability in two UASB systems.

Even with the feeding of two different co-substrates such as glucose and lactose, Fig. 4 indicates that ratios of the COD removal efficiencies in both reactors decreased during the trial. For example, the efficiencies in the both effluents decrease consistently between beginning time and 265th hours in the trial approx. from 75% to 50%. This result is also similar the previous trial (Fig. 3).

In both reactors, it was observed that values of pH, alkalinity and VFA were almost parallel during the 735 hours trial period. The values of VFA in the effluents of mixed wastewater with glucose reactor and with lactose reactor are measured 700 mg/L and 900 mg/L, respectively. This change in parameters may be caused by instability, even though the values were under the limits for anaerobic systems.

4.5 General evaluation of polyester wastewater and cotton wastewater

In this section, anaerobic treatability of polyester wastewater with domestic wastewater is compared the treatability of cotton wastewater in the same condition. This last process of cotton is changed depending on the type and amount of cloths in the batch process. Used cloth types are knit, viscose rayon, cotton, polyester, polyamide knit fabrics together with cotton/polyester, polyester/viscose rayon and viscose rayon/knit blends. The type used most is cotton knit fabrics cloths (60%).

The characteristic of each raw wastewater sample is given in Table 1. Table 1 shows that the raw polyester wastewater has a high COD, TKN, TSS concentration than other textile wastewaters. Table 2 reveals that total dissolved COD ratios of real cotton textile wastewater and raw polyester textile wastewater has almost similar ratio, 82% and 84% respectively. On the other hand, the total COD consisted of inert microbial products and ratio of inert COD in the influent of polyester wastewater have founded two times bigger ratio than cotton last process wastewater textile wastewater. The fractions of easily biodegradable and rapidly hydrolysable are found high ratio the cotton wastewater (72%) than the polyester wastewater (64%). The total active biomass and the total particular biodegradable COD of both textile wastewaters are found to be equal after the measurements. The particular inert fraction of influent COD for both textile wastewaters and particulate inert microbial products are measured almost same ratio, 15% for cotton wastewater and 13% for polyester wastewater. Because the inert part is not biodegradable, this COD fraction is measured as the same value in effluent water. Total (particular and soluble) inert COD and total (particular and soluble) inert microbial product are measured as 25% for the cotton and 33% for the polyester wastewater. Therefore, 75% of COD in cotton wastewater and 66% of COD in the polyester wastewater are biodegradable in the process. The fraction of total COD in municipal wastewater was obtained to be 35%. Total particulate COD for the municipal wastewater was found to be 65%.

COD Fractions	Polyester process wastewater		Cotton process wastewater (From Sapci (2002))		Municipal wastewater	
	Total (mg/L)	Fraction (%)	Total (mg/L)	Fraction (%)	Total (mg/L)	Fraction (%)
C_T	3218	100	1757	100	925	100
ST1	2708	84	1440	82	325	35
SI1+SP	636	20	180	10	231	25
SS1+SH1	2072	64	1260	72	94	10
XT1	510	16	317	18	600	65
XH+XP	409	13	265	15	403	44
XH1+XS1	101	3	52	3	197	21

CT: total COD in the influent, ST1: total dissolved COD, SI1: inert COD in the influent, SP: dissolved inert microbial products, SS1: easily degradable COD, SH1: rapidly hydrolysable COD, XT1: total particulate COD, XH: particulate inert COD in the influent, XH1: active heterotrophic biomass, XP: particulate inert microbial products, XS1: particular degradable COD.

Table 2. COD fractions of textile industries wastewater and municipal wastewkoater

The fraction of total biodegradable and active biomass was found to be 31% for the used municipal wastewater. On the other hand, Cokgor et al. (1998) reported that the total ratio of total biodegradable COD and COD of active biomass were found to be 94 % for municipal wastewater having a COD concentration of 670 mg/L, and 93% for municipal wastewater having a COD concentration of 315 mg/L. This difference may be caused by several chemicals, such as cleaning materials, having high COD values and also anaerobic granular sludge.

4.6 Comparison of anaerobic treatability between polyester wastewater with municipal wastewater (1^{st} system) and cotton last process wastewater with municipal wastewater (4^{th} and 5^{th} system)

After the acclimatization period, the process are fed the different ratios mixed wastewaters, 45, 30 and 15 % diluted polyester wastewater with municipal wastewater, operate for 504 hours, and fed under batch mode for period 24 hours (HRT 5 days) which is called as 1^{st} system. For the previous study (Zengin & Aydinol, 2007), 3 different dilution rates of municipal wastewater (40, 30 and 15%) and raw cotton textile wastewater are used which is called here as 4^{th} system. The 4^{th} system was run according to HRT of 4.5 days. 1^{st} and 4^{th} systems were employed on the same conditions (except HRT), such as temperature, reactor type.

Values of alkalinity, SS and pH in effluents of both system exhibited similar behavior and they founded optimum range of literature required for successful operation of digester (Metcalf & Eddy, 2003, Kalogo et al., 2001). Therefore, during the trial periods, buffer material was not used because there is neither decrease in alkalinity nor increase in VFA.

During the first 145 hours period at the 1^{st} system, COD removal efficiency is drastically decreased from 30 to 5 % for each reactor and after the 145 hours it did not show any differences. On the other hand, even though COD removal efficiency was found unstable at the same period for 4^{th} system, COD removal increased after the first 145 hours. The three reactors containing 40, 30, and 15% of municipal wastewater in the 4^{th} system showed similar COD removal efficiencies of 53, 46 and 40%, respectively. As a result, it was observed that the municipal wastewater rate in both the polyester wastewater and the cotton wastewater

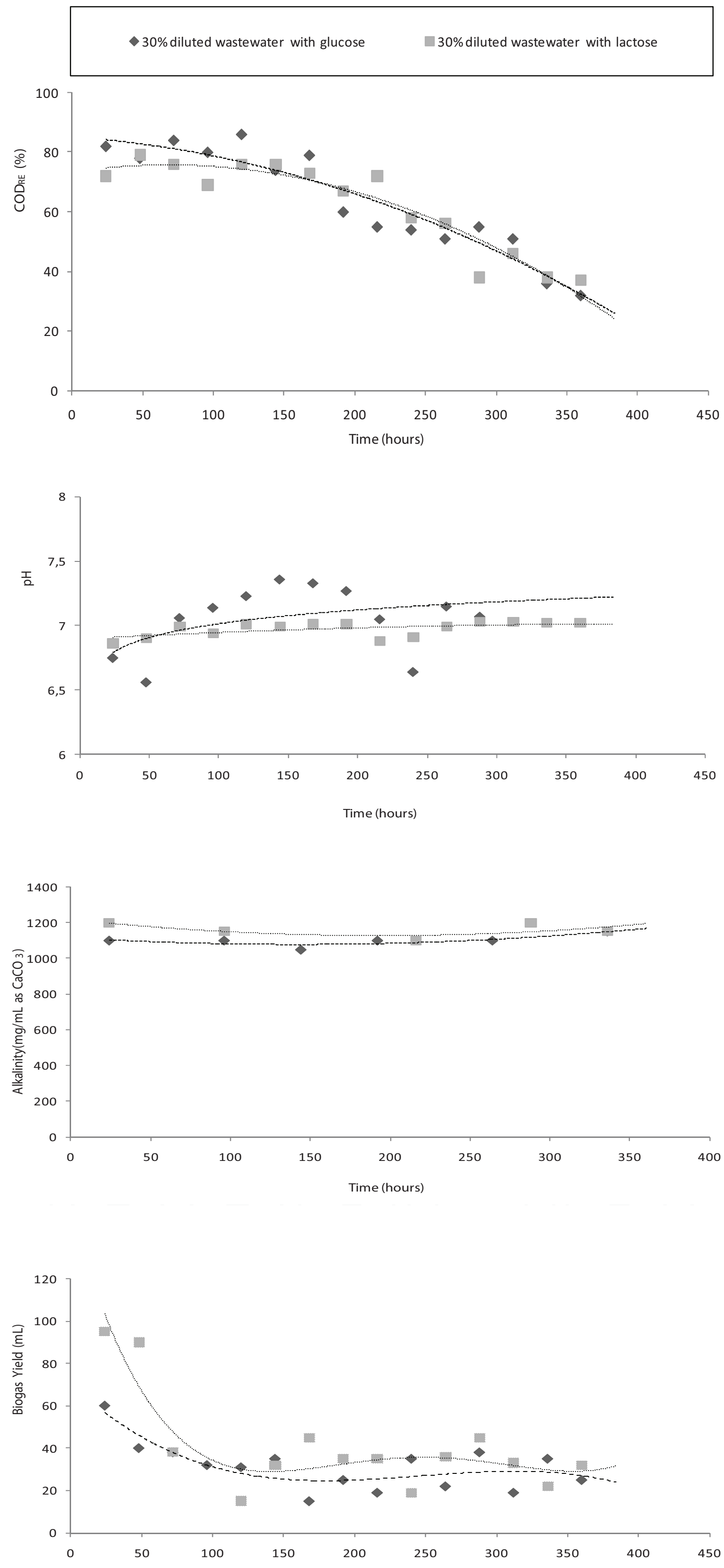

Fig. 4. Mixed wastewater charges including 30 % of municipal wastewater with two different co- substrates (glucose and lactose)

did not have a substantial change in COD removal efficiency. On the other hand, when the ratio of municipal wastewater in 4th system was increased, COD removal efficiency slightly increased (COD of effluent wastewater 630-635 mg/L) for the cotton wastewater treatment. Additionally, when the 3 reactors were fed with same mixed wastewater (40, 30, and 15 % diluted cotton wastewater) under 9-days batch mode (HRT) (5^{th} system), they showed a parallel COD removal efficiency but also this efficiency was slightly higher than 4^{th} system. Therefore, it can be said that different HRTs did not affect COD removal efficiency for cotton textile wastewater treatment.

4.7 Comparison of anaerobic treatability between polyester wastewater and municipal wastewater with co-substrate (2^{nd} system) and cotton last process wastewater and municipal wastewater with co-substrate (6^{th} and 7^{th} system)

Results of anaerobic treatability of both 2^{nd} system (mixed wastewater charges including 45, 30 and 15% of municipal wastewater with real polyester textile wastewater) and 6^{th} system (60, 45 and 30% of municipal wastewater with real cotton textile wastewater) are evaluated according to COD removal efficiency as a result of that the effects of co-substrate were determined. 3rd system indicates that using glucose or lactose as a co-substrate give similar result in effect of treatability. Therefore, in this part of the study, glucose is chosen as a co-substrate. HRT of 2^{nd} and 6^{th} system are run 5 and 4.5 days, respectively.

It is observed that values of pH, alkalinity, VFA, and COD removal efficiency in effluents of the both systems are found almost similar for the whole study period (Table 3). Buffer material was not added during the studies because of that the values of alkalinity and pH were under the limits for anaerobic systems. Biogas productions of both systems also showed fluctuations. Therefore, it can be concluded that municipal mixture ratio and added glucose as a co-substrate does not have a substantial change in COD removal efficiency for neither the polyester wastewater treatment under 5 days nor the cotton textile wastewater treatment under 4.5 days. However, when HRT was increased, the ratio of COD removal efficiency increased in the 7^{th} system. Therefore, it can be said that HRT are important in the treatment systems, in case of cotton wastewater as a feed source for anaerobic digester.

5. Conclusions

Anaerobic treatability of a real polyester textile wastewater diluted with municipal wastewater under various operating conditions is investigated in 3 UASB reactors. The main findings obtained can be outlined as follows:

- Firstly, values of alkalinity, SS, VFA and pH in each experiment are founded optimum range of literature required for successful operation of the reactor. Although it is observed that values of the process parameters in the effluents are almost parallel for the whole study period, biogas production has some fluctuations. In the study, biogas fluctuations are caused by gas bubbles which could not overcome partial pressure. The bubble formation process and gas production rate in the bioreactors are greatly influenced by hydrodynamic conditions existing in the reactor.
- Secondly, even though the municipal wastewater rate is increased, the COD removal rates in each reactor are not increased during the 400 hours trial period. On the country the efficiency is slowly decreased.
- Thirdly, the 3 reactors containing polyester wastewater with 45, 30, and 15% of municipal wastewater and glucose (easily decomposable monosaccharide) showed

Table 3. Operating conditions and specific outcome parameters

System no	Type of textile ww	Rate of municipal ww (%)	Co-substrate	HRT (days)	OLR (kgCOD/m3/d)	COD_{RE} (%)	pH	VFA (mg/L)
1	Polyester	45	Not added	5	0.411±0.01	5	7.05±0.4	465±87
	Polyester	30	Not added	5	0.498±0.005	5	7.05±0.6	467±65
	Polyester	15	Not added	5	0.567±0.005	5	7.35±0.8	475±40
4	Cotton	40	Not added	4.5	0.175±0.02	53	7.1±0.6	565±85
	Cotton	30	Not added	4.5	0.175±0.02	46	7.35±0.8	565±65
	Cotton	15	Not added	4.5	0.224±0.06	40	7.35±0.8	575±50
5	Cotton	40	Not added	9	0.088±0.003	53	7.7±-0.2	565±25
	Cotton	30	Not added	9	0.089±0.007	50	7.7±0.1	585±15
	Cotton	15	Not added	9	0.087±0.016	46	7.7±0.2	570±40
2	Polyester	45	Glucose	5	0.319±0.05	~45	7.3±0.1	281±124
	Polyester	30	Glucose	5	0.314±0.03	~35	7.2±0.1	323±54
	Polyester	15	Glucose	5	0.408±0.14	~30	7.3±0.1	313±30
6	Cotton	60	Glucose	4.5	0.468±0.082	36	7.2±0.2	525±75
	Cotton	45	Glucose	4.5	0.494±0.077	28	7.2±0.3	475±25
	Cotton	30	Glucose	4.5	0.517±0.090	32	7.3±0.3	510±10
7	Cotton	40	Glucose	9	0.313±0.052	76	6.7±0.4	605±5
	Cotton	30	Glucose	9	0.313±0.051	75	7.0±0.1	610±110
	Cotton	15	Glucose	9	0.311±0.620	69	7.0±0.2	635±15

similar decaying COD removal efficiencies. Therefore, it can be concluded that municipal mixture ratio and added glucose as a co-substrate in the polyester wastewater does not have a substantial change in COD removal efficiency.

- Fourthly, even with the feeding of two different co-substrates such as glucose and lactose, the COD removal efficiencies in both reactors decreased continuously during the trial. This result can be concluded that during approx. 400 hours trial period, addition of either glucose or lactose in polyester wastewater does not affect positively on the performance of UASB reactor. However, addition of co-substrate (glucose) in cotton wastewaters had a positive effect on the COD removal efficiency. Therefore, it depends on the textile wastewater prosperities, not only physicochemical parameters but also biologic parameters should be investigated in lab condition before starting the treatment.

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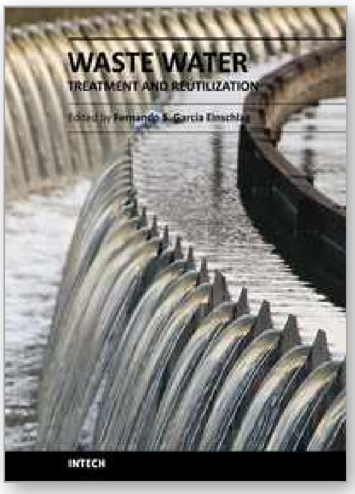

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The steady increase in industrialization, urbanization and enormous population growth are leading to production of huge quantities of wastewaters that may frequently cause environmental hazards. This makes waste water treatment and waste water reduction very important issues. The book offers a collection of studies and findings concerning waste water treatment, minimization and reuse.