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Biological tannery wastewater treatment using two stage UASB reactors

Mahmoud A. El-Sheikh [a,*,1], Hazem I. Saleh [a], Joeseph R. Flora [b], Mahmoud R. AbdEl-Ghany [c]

[a] Sanitary & Env. Eng., Menoufiya University, Shebeen Elkom, Egypt
[b] Sanitary & Env. Eng., University of South Carolina, SC, USA
[c] Env. Eng., National Water Research Center, Cairo, Egypt

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ABSTRACT

Wastewater discharged from tannery industries is highly complex, concentrated, and toxic. In view of the varying nature of discharged wastewater and the numerous small industries in Egypt, there is a need for highly efficient treatment processes that are simple to operate and have low/reasonable construction and operation costs. This study investigated the possibility of applying innovative low cost biological treatment using upflow anaerobic sludge blanket (UASB) in providing adequate treatment for tannery wastewater. The anaerobic treatment application was thus evaluated through using two stage UASB reactors connecting in series, each with volume of 94 l. Five hydraulic retention times (HRT) were used along the experimental works, which lasted for a year, starting by HRT of 24 h then 18, 12, 8 and finally 5 h for each UASB reactor. The proposed process at 12 h HRTs could pre-treat the tannery wastewater to be disposed to the municipality sewers. The study created best fit equations to predict the efficiency of the system.

1. Introduction

The tanning and finished leather industry constitute the fifth largest industrial sector in Egypt where it is estimated that over 65% of such industries are owned by small businesses. Egyptian leather tanning is almost completely a wet process from which a large volume of liquid waste is continuously generated. Tanning is a process where the addition of a tanning agent (chromium salts, aluminum, zirconium, vegetable extracts of mimosa or quebracho tree, etc.) stabilizes the skin structure by forming transverse bonds among its fibers. The tanning processes consist of three sequential processes (beam–house, tan–yard and finishing). The tanning agent blocks carboxylic or amine groups and joins the proteinic colloid, thus increasing the cross linking of collagen fibers. Through this method, the leather is turned into a durable material [1]. The tanning process and the effluents generated have already been reported in many literatures [2–4]. Wastewater discharged from this industry is highly complex, concentrated, and toxic. Tannery wastewater can cause significant pollution unless treated prior to discharge. These pollutants are expressed in terms of chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and total Kjeldahl nitrogen (TKN), as well as sulfur, phosphorus, and chromium compounds.

In view of the varying nature of discharged wastewater and the numerous small industries, there is a need for highly efficient treatment processes that are simple to operate and have low/reasonable construction and operation costs. A review of the technical literature indicates that many processes have been investigated for tannery wastewaters, ranging from the simple to the advanced complicated methods. These methods include biological treatment (aerobic and anaerobic treatment), physico-chemical treatment, ion exchange, membrane filtration, and electrochemical systems [5–14]. Esmaeili et al. [15] reported that chromium precipitation is a relatively simple technique in which chromium and other metals are precipitated as highly insoluble hydroxides. Song et al. reduced COD and TSS by using chemical precipitation. Aluminum sulfate and ferric chloride were used as a coagulant material. COD and TSS removal efficiencies were 30–37% and 38–46% respectively. Ozone and ultraviolet (UV) radiation technologies were also used to remove pollutants in the tannery effluents [16–19]. However, the high cost of ozone still remains an important drawback of these processes.

Electrochemical oxidation was investigated for final tannery wastewater treatment showing complete mineralization of vegetable tannery wastewater [20]. Pre-treatment of tannery wastewater using two systems, electrolytic and physico-chemical systems, showed poor efficiencies for the electrolytic system and significant removal of pollutants with the physico-chemical system [1]. Szpyrkowicz et al. [21] used a combination of electrochemical and biological processes for tannery wastewater treatment. Song et al. [22] also developed an up-flow anaerobic fixed biofilm reactor (UAFBR) to treat tannery wastewater and obtained good COD and TSS removals even under conditions of temperature shock. Lefebvre et al. [23] studied anaerobic

* Corresponding author.
E-mail address: mshafy2@yahoo.com (M.A. El-Sheikh).
[1] On leave to Faculty of Engineering, University of Tabuk, Saudi Arabia Tabuk, Saudi Arabia, P.O. 741.

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digestion of tannery soak liquor using an up-flow anaerobic sludge blanket (UASB) and achieved 78% COD removal at an organic loading rate (OLR) of 0.5 kg COD/m^3/d, a hydraulic retention time (HRT) of 5 days, and a total dissolved solids (TDS) concentration of 71 g/l.

Some of the above processes may not be economically feasible because of high costs and expertise required to implement and sustain the operation of such processes. Many of these processes may not necessarily be applicable to Egypt because of the high amounts of chromium, ammonia, sulfides, chemical oxygen demand and total suspended solids present in the discharged wastewater.

The objectives of this study are to perform laboratory tests to identify several series of biological processes using two UASB reactors connecting in series for the optimum treatment of Egyptian tannery wastewaters. This study also tested the efficacy of the selected process in a pilot scale system operated in the field, and evaluated costs associated with the operation of the pilot scale system. The ultimate goal of this study is to provide the tannery industry with a blueprint for operating a sequencing biological system that is easy to implement across different scales of tanning industries in Egypt.

2. Experimental works

Experimental works were carried out in Piel Color Tannery located at Mobarek Industrial Zone in El Menofiya Governorate (approximately 70 km north of Cairo), Egypt. The Piel Color Tannery is considered as one of the biggest tanneries in Egypt. In this tannery, three processes are adopted to tan hide namely beam-house, tan-yard and finishing processes. Production of wastewater in the tannery is about 1500–2000 m^3 per day.

A biological treatment using two stage upflow anaerobic sludge blanket (UASB) reactor was used to biologically oxidize the organic carbon to carbon dioxide and cellular material. The built pilot system consists of tanks manufactured from PVC material and carried on steel elements as to ensure good fixation of different units. The tanks included sedimentation tank, pH equalization tank, storage tank, first stage UASB reactor, and second stage UASB reactor (all are connected in series). Testing was performed in five operating phases evaluating the hydraulic retention time and system response to such changes. These impact the hydraulic and organic loadings of the UASB reactors which are the main core of the biological treatment units dealing with the considerably high chemical oxygen demands in the wastewater.

The two UASB reactors from UPVC material were installed with a diameter of 20 cm and a height of 325 cm (each) to maintain upflow velocity to the level required in anaerobic upflow reactors. The volume of each reactor was 94 l (Fig. 1). A gas–liquid–solid (GLS) separator device from UPVC was installed at the top of the reactor comprising an inverted cone and a horizontal circular baffle, with a 1.5 cm overlap between them (on the horizontal projection) in order to entrap floating solids to minimize their concentration in treated effluent. The inverted cone was connected to a vertical pipe for collecting biogas. In addition, five sampling ports were installed every 55 cm along the reactor height in order to investigate variations occurring in wastewater along the reactor. The wastewater entered the reactor from the bottom through lower cone and the treated effluent was collected by a pipe attached with internal weir above the GLS separator.

The main characteristics of raw tannery wastewater were as shown in Table 1. This raw wastewater has pre-treated through physico-chemical treatment [1] before entering the two stage UASB reactors. The characteristics of the wastewater entering the UASB reactors will be discussed in the next paragraph (Results and discussions).

The two stage UASB was continuously operated for 52 weeks. Five operational hydraulic retention times of 24, 18, 12, 8 and 5 h (5 phases) were applied. The temperatures varied between 17 and 38 °C in the morning and between 7 and 25 °C in the evening. The process started up with HRT of 24 h for an operational period of three months. Before utilizing the anaerobic treatment by the two stages UASB, the equalization tank (600 l) was used for reducing the pH value to meet

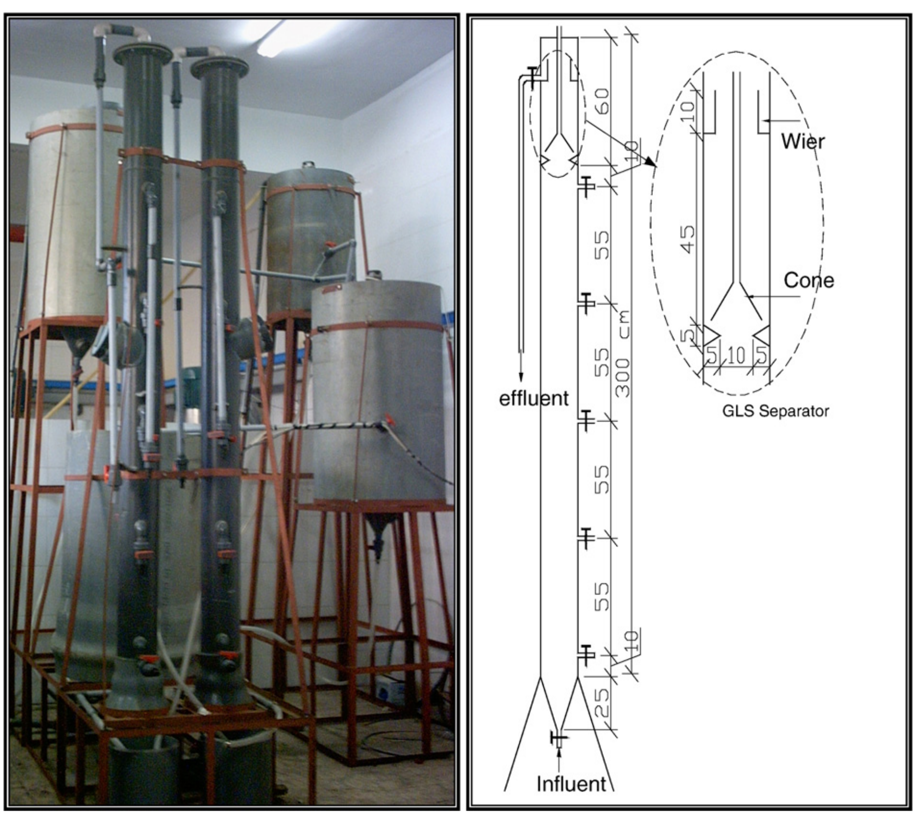

Fig. 1. Dimension of the used UASB reactors and photo of the used system.