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# The feasibility of using non-woven fabric as packing material for wastewater treatment

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**ABSTRACT**

The present study introduces a new technique using a combined up-flow anaerobic sludge bed (UASB) followed by innovative down-flow hanging non-woven fabric (DHNW) for the treatment of domestic wastewater. The aim of this work is to develop an innovative non-woven packing material that can be used to improve the performance of both UASB and DHNW and other similar techniques for the treatment of wastewater. The packing material could be produced from waste plastic bottles, thus considerable part of solid waste can be reduced, recycled and applied in wastewater treatment plant to produce treated reusable effluent. The primary treatment was carried out using packed and classical UASB reactor (in parallel manner). The quality of the packed UASB effluent was better than that of the classical UASB reactor. Consequently, the effluent of the packed UASB reactor was fed directly to the DHNW reactor. The source of wastewater was the domestic wastewater from Zeneen's wastewater treatment station. The hydraulic residence time (HRT) of the UASB reactors was 6 h. The performance of the combined packed UASB/DHNW showed reduction of COD, BOD and TSS from 349.6, 260.6 and 171.3 to 44, 24 and 27 mg/L, respectively. The fecal coliform (FC)count was reduced by 3 log units using the combined packed UASB/DHNW system. The results indicated that polyethylene terephthalate (PET) spun-bond non-woven fabric can offer a cost effective solution as well as durable and efficient packing material for wastewater treatment.

*Keywords:Domestic* wastewater; Spun-bondnon-woven packing materials; Plastic bottle recycling; UASB; Down-flow hanged non-woven reactor (DHNW)

## 1. Introduction

In the time being, Egypt suffers a sharp shortage of water for different uses, this fact might well be aggravated in the very near future as a result of constructing Al Nahda Dam of Ethiopia as well as drastic climatic changes [1]. Therefore, the need to save water consumption during various industrial processes is inevitable. Besides, the discharge of partially treated or even untreated sewage is a serious public health and environmental risk, leading to water resources, soil and air pollution and consequently affects all living organisms (plants, animals and humanity). Non-conventional water resources exist to meet part of the country's water requirements [2]. Treated wastewater is one of the non-conventional water resources existed to minimize the gap between supply and demands [3]. Sewage treatment by conventional means, including primary sedimentation followed by aerobic biological treatment, is very efficient, but at the high price of capital and running costs and require advanced technology [4]. The application of such expensive systems does not offer a sustainable solution for sewage

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treatment in less wealthy countries like Egypt. Low cost as well as low energy treatment has been proven to be an admirable technique and considered by several authors as the basis of sustainable waste management [5–9].

During the past few decades the UASB (as low cost and low energy) technique attracted the attention of several researchers for the treatment of wastewater in tropical and sub-tropical developing countries, where financing is generally scarce. However, the quality of UASB effluent doesn't meet the discharge standards. Consequently, post treatment is considered an option to get the benefits of that low cost technology [10–13]. Low cost post treatment techniques were used by several researchers [4,8,11,14]. Down flow hanging sponge (DHS) was evaluated as a post treatment for the UASB reactor effluent. The combined UASB/DHS system was found to be efficient for wastewater treatment [15–18].

The packing materials have been employed to improve the performance of both aerobic and anaerobic biological treatment techniques. It could be used for increasing the surface area and providing suitable surface for attaching the microorganisms. The performance of the treatment systems could be optimized by retention of biomass which degrade the dissolved organic load [19–22]. Several types of packing materials such as waste tire rubber and zeolite [23], wood charcoal [21], sponge or polyurethane were used in previous studies [17,19].

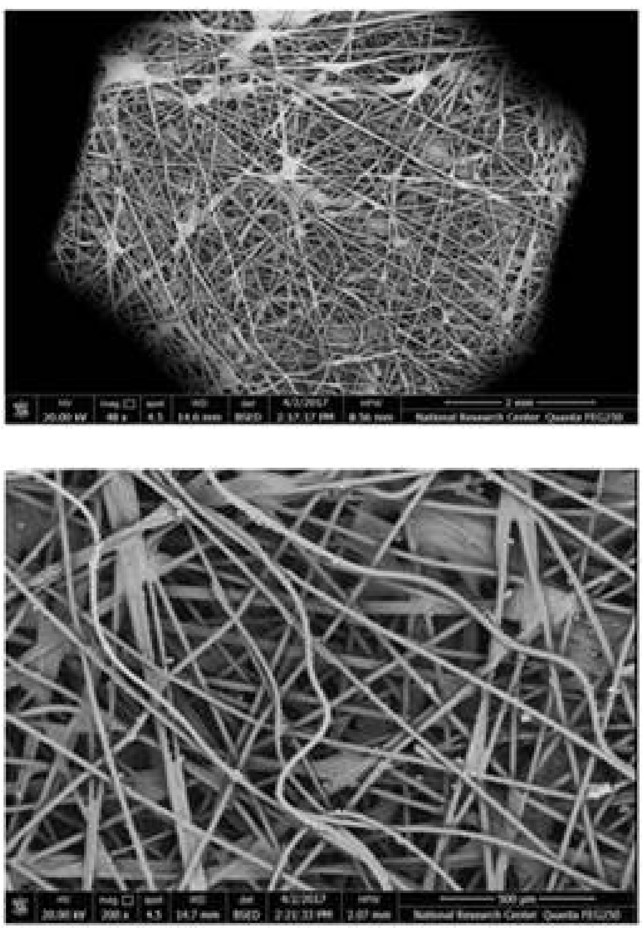

Fig. 1. SEM for the non-woven fabric used during the study.

The aim of this study is the use of non-woven sheets of polyethylene terephthalate (PET) (that could be produced from wasted plastic bottles) as packing materials in UASB/DHNW combined system for the treatment of domestic wastewater.

## 2. Materials and methods

### *2.1. Non-woven fabric*

The non-woven fabric (spun-bond webs) represents a new class of man-made product, with a property combination falling between paper and woven fabric with a random fibrous structure [24]. Spun-bonded non-woven fabrics have a wide range of applications in: i) Automotive ii) Civil Engineering iii) Sanitary and medical, and iv) Packaging. Heat-set spun-bonded web has been used with the following characteristics:

- Basis weights: 160 g/ m$^2$
- Web thicknesses: 0.79 mm
- Tensile strength:
  MD - 450 CD – 220 (N/5 cm)
- Elongation at break (%):
- MD - 57 CD – 64 (%)
- Water permeability of 100 cm WG: 0.60 (L/m$^2$·s)

### *2.2. Designing, manufacturing of the treatment units*

UASB reactor: The UASB reactor is the primary treatment step (Fig. 2) used throughout the study. The packing materials were held vertically in a zigzag (corrugated) shape. The

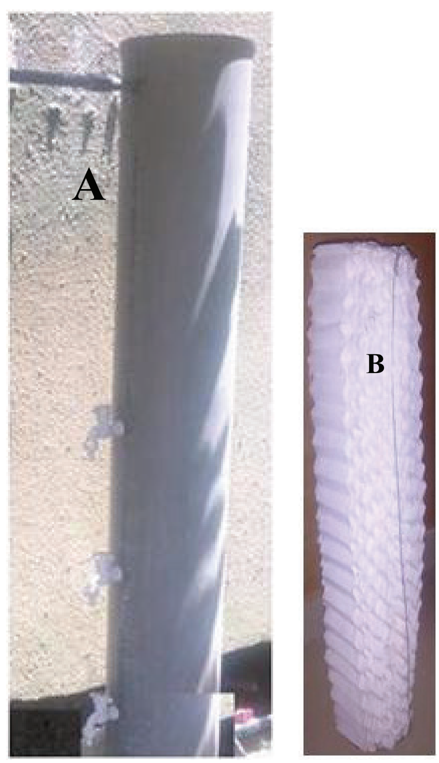


Fig. 2. A) The UASB reactor, B) the packing material.

operating conditions of the UASB reactors are presented in Table 1. The length of the packing material is only 0.8 m with diameter 0.24 m and fixed at the base of the reactor.

### 2.3. DHNW reactor

The effluent from the UASB reactor was fed directly to the post (secondary) treatment step using the DHNW reactor. The reactor design is shown in Fig. 3. The treatment units were fixed in Zeneen wastewater treatment plant.

Fig. 4 shows the sequence of the treatment train used in this work.

### 2.4. Characterization, selection and shaping of the packing materials

Non-woven fabrics were produced as sheets of different thicknesses, densities and porosities. Fig. 5 shows the packing material that was used in this study.

Table 1
Operating conditions of both classical and packed UASB reactors

| Parameter | Unit | Value |
|---|---|---|
| Length (m) | meter | 2 |
| Internal diameter (m) | meter | 0.25 |
| Effective volume (l) | liter | 98 |
| OLR | g/m$^3$/day | 1398.4 |
| HLR | m$^3$/m$^3$/day | 3.9 |

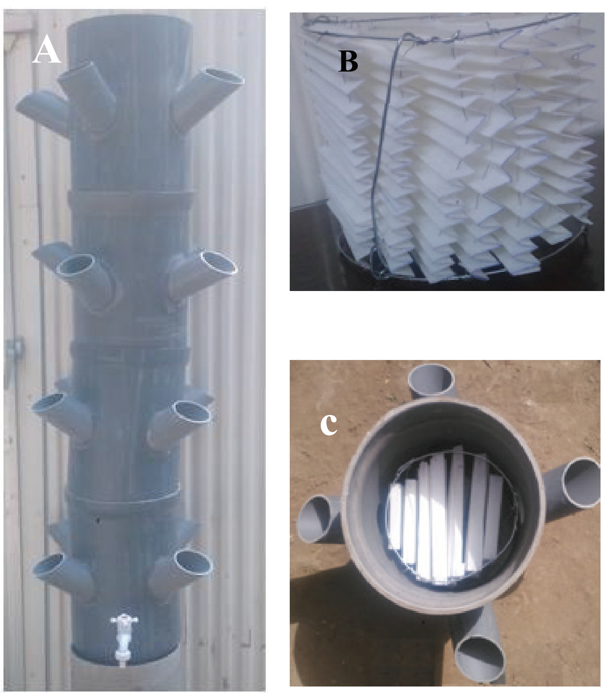


Fig. 3. A) DHNW reactor with four vertically fixed compartments. B) Packing material, C) Vertical view of one of the compartment containing the packing material.

### 2.5. Methods

The performance of the treatment system was evaluated during the study period. Complete physico-chemical and biological analyses were carried out for samples collected from the influent and effluent of each treatment unit. The physico-chemical analyses included: pH, ammonia-nitrogen ($NH_3$-N), total Kjeldahl nitrogen (TKN), total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), biological oxygen demand (BOD) and fecal coliforms. The analyses were carried out according to the American Public Health Association, Standard Methods for the Examinations of Water and Wastewater [25].

## 3. Results and discussion

Combining anaerobic and aerobic system in wastewater treatment can be considered as one of the recent and efficient technologies appeared in the treatment of wastewater (biologically) during the last few ducats. Such a combined technology is one of the possibilities to maximize the advantages of both anaerobic and aerobic techniques [4,13,26,27]. This integrated techniques found to be efficiently remove organic matter, nutrients, low energy with relatively short detention time and low specific production of excess sludge [28,29].

### 3.1. Characteristics of raw wastewater

The main characteristics of the influent raw wastewater used in this study are shown in Table 2. The concentration of organic load represented by COD and BOD was ranging from 298 to 410 and 207 to 305 mg/L with an average of 349.6 and 260.6 mg/L, respectively. The average concentrations of TSS, VSS, TKN and ammonia were 171.3, 148.5, 33.5 and 26.6 mg/L, respectively. According to Metcalf & Eddy, the influent wastewater used in this study is considered as medium strength [30].

### 3.2. Performance of the packed and classical UASB reactor

Raw wastewater was treated using packed and classical UASB reactors (in parallel pattern). The performance of both UASB reactors (packed and the classical) are depicted in Table 3. During the startup period of the reactor (two weeks) the decrease in the level of COD was observed in the effluent. The concentration of COD and TSS was reduced by 60% and 50% for the packed and the classical UASB, respectively. After achieving the steady state conditions, the level of COD was ranging from 79 to 178 and from 100 to 215 mg/L for both UASB reactors (packed and the classical), with an average value of 118 and 151 mg/L,respectively. At the same time, the level of BOD ranged from 41 to 125 and from 71 to 150 mg/L with corresponding average of 82 and 111 mg/L for packed and classical UASB rectors, respectively. These results are inconsistent with the results of Lew et al., [10] who reported no difference in performance of hybrid and classical UASB reactors. The presence of packing material increases the sold residence time consequently, enhancing the biodegradation of organic loads [31].

The level of TSS was reduced from 171.3 to 55.9 and 111 mg/L with a removal rate of 67% and 56% of the packed and

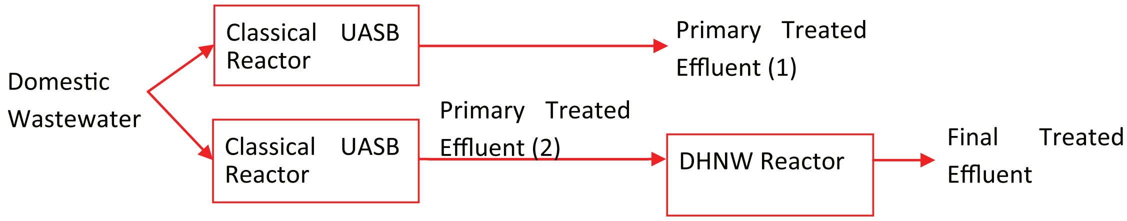


Fig. 4. Flow chart for the treatment train.

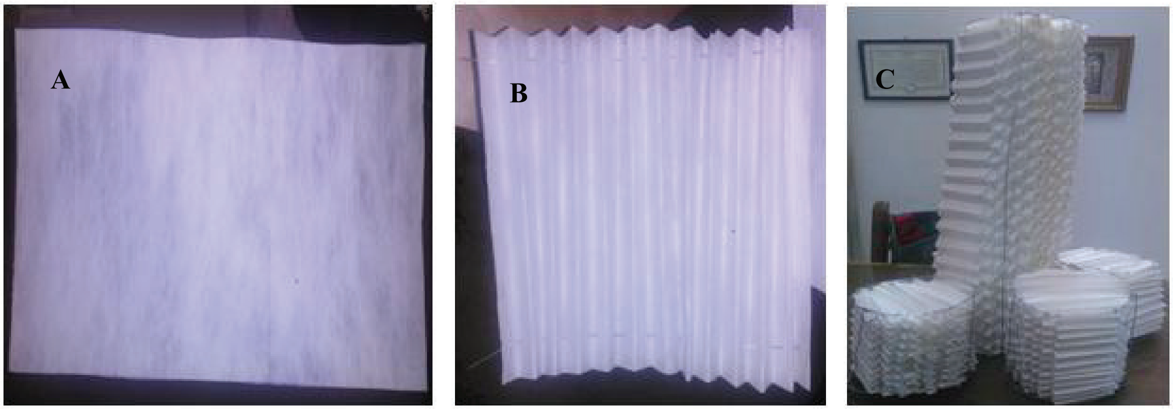


Fig. 5. Packing material (a) plane sheet, (b) corrugated sheet and (c) shaped modules.

Table 2
Raw wastewater characteristics*

| Parameter | Unit | Minimum | Maximum | Average |
|---|---|---|---|---|
| pH | | 7.3 | 7.4 | |
| COD | $mgO_2/l$ | 298 | 410 | 349.6 |
| BOD | $mgO_2/l$ | 207 | 305 | 260.6 |
| TSS | mg/l | 136 | 189 | 171.3 |
| VSS | mg/l | 107 | 187 | 148.5 |
| TKN | mg/l | 30 | 38 | 33.5 |
| Ammonia | mg/l | 22 | 31 | 26.6 |

* Number of samples = 19

Table 3
Characteristics of the packed and classical UASB effluents

| Parameter | Unit | Sewage water | Packed UASB | Classical UASB |
|---|---|---|---|---|
| pH | | 7.3–7.4 | 7.1–7.2 | 7.1–7.2 |
| COD | $mgO_2/l$ | 349.6 | 118 | 151 |
| BOD | $mgO_2/l$ | 260.6 | 82 | 111 |
| TSS | mg/l | 171.3 | 55.9 | 75.4 |
| VSS | mg/l | 148.5 | 48.9 | 64.4 |
| TKN | mg/l | 33.5 | 29.7 | 30.0 |
| Ammonia | mg/l | 26.6 | 28.8 | 28.0 |
| Nitrates | mg/l | 0.152 | 0.036 | 0.032 |
| Nitrites | mg/l | 0.010 | 0.005 | 0.005 |
| Fecal coliforms | MPN Index/100 ml | $3.7 \times 10^7$ | $3.7 \times 10^6$ | $5.3 \times 10^6$ |

* Number of samples = 19

the classical UASB, respectively. The total sludge weight in the packed and classical UASB is about 3.92 and 3.67 kg and the sludge residence time is 71.3 and 47 d, respectively. Consequently, the relatively good performance towards COD and BOD removal could be attributed to the relatively high sludge residence time (71.3 d) in the packed UASB reactor which facilitates the hydrolysis, transformation and degradation of organics in wastewater [19,26]. It can be noted that suspended solids settle, agglomerate and flow down the surface of the non-woven fabric, while the treated effluent is conducted upwards [32]. These results revealed that the use of the packing material improved the removal efficiency of the organic materials [32,33]. The performance of the reactor was higher than that obtained by Abou-Elela et al., [32], Picanco, et al., [33] and Lettinga [34] although they operated the UASB at relatively higher hydraulic loading rate. The TKN was reduced by 11 and 10.1% for both reactors (packed and classical), respectively. This may be attributed to particulate nitrogenous compounds removal, and/or conversion to ammonia [35].

On the other hand, the level of ammonia was slightly increased in both classical and packed UASB reactors during the period of study. The data showed that, fecal coliforms reduced from $3.7\times10^7$ to $3.7\times10^6$ and $5.3\times10^6$ in both packed and classical UASB reactors, respectively. The performance of the packed UASB reactor in term of FC removal was found to be higher than that of classical UASB by 30%. This may be attributed to the presence of the used packing material.

The obtained results were found to be in complying with that obtained by El-Gohary et al. [19]. They studied the treatment of the catalytically oxidized olive mill wastewater (OMW) with anaerobic treatment using two successive UASB reactors. The results indicated that the hybrid (packed) UASB reactor produced better effluent quality as compared with the classical reactor. This may be due to the presence of the curtain sponge (packing material) with active biomass in the sedimentation zone of the secondary treatment step (hybrid UASB reactor), which minimizes the washout of suspended solids, consequently enhancement of the efficiency of the reactor.

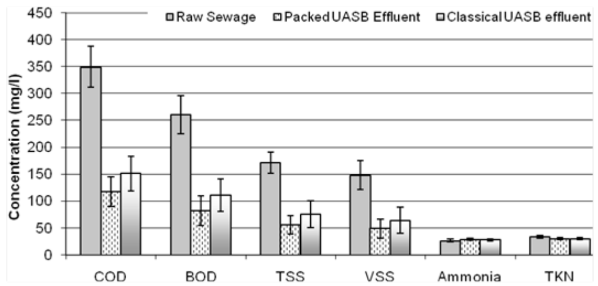


Fig. 6. Variation of sewage water characteristics (average of 19 samples).

### 3.3. Performance of the DHNW reactor

The DHNW was used as a secondary treatment step to improve the effluent of the UASB reactor. Fig. 7 shows the performance of the combined packed UASB/DHNW for the treatment of wastewater. Excellent COD removal was rapidly established after two weeks of operation. This is attributed to the temporary adsorption of organic constituents onto the fabric media [36]. The concentration of COD, BOD and TSS reduced from 118, 82 and 55.9 to 64, 41 and 30 mg/L, respectively.

The high performance of the DHNW for the removal of COD, BOD and TSS could be due to the high specific surface area and as a result, the low surface loading rate. The first step in the organic matter degradation in the DHNW system is the surface adsorption [17]. Furthermore, a biofilm is developed on the surface of the packing material where micro-organisms, biocatalysts the degradation of the organic matter [32]. After that, hydrolysis of the substrate takes place on the surface of non-woven fabric in the DHNW system due to the presence of the biofilm. This may increase the area of contact between wastewater and microorganisms, thus reduces the cost of the treatment processes.

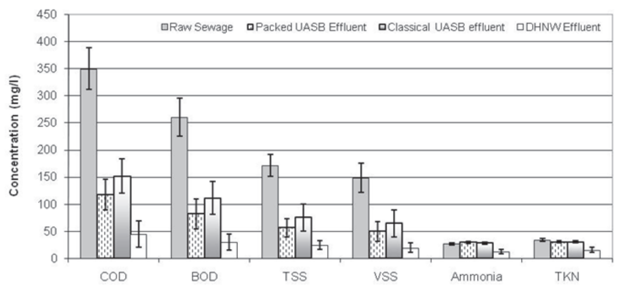


Fig. 7. Performance of UASB/DHNW combined system as well as the classical UASB effluents (average of 19 samples).

Fig. 8 shows the development of biomass on the surface of the non-woven fabric. It is clear that the fibers were not damaged and supported the biomass tightly.

In comparative work Mahmoud et al., [16] studied the treatment scheme consisted of hybrid UASB followed by DHS reactor. The study lasted for more than 140 days; the results revealed that the average removal values of COD (total), BOD (total), TSS and TN were 90, 78, 95, 96 and 72%, respectively. It was proven that the DHS reactor can withstand with higher organic loads. The DHS reactor efficiently removes both carbonaceous organic matter and nitrogenous compounds.

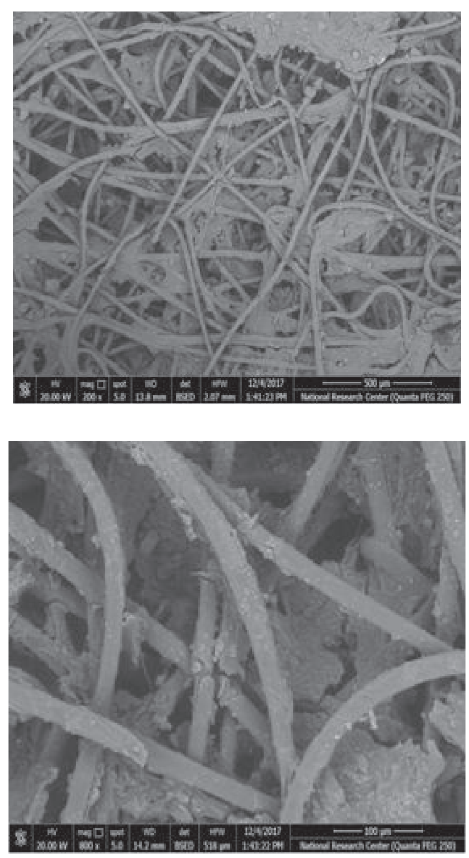

Fig. 8. SEM for the non-woven fabric after developing of biomass on its surface.

### 3.4. Effect of reusing Non-woven fabric

The polyethylene terephthalate (PET) plastic bottles constitute about 6.9% of the total municipal solid waste (MSW). In 2012, Egypt generated 89.03 million tons of solid waste [37]. According to the calculations conducted by Al-Jarallah and Aleisa [38] for the state of Kuwait, about 6.13 million tons/year of plastic bottles produced in Egypt. The low rate biodegradability of such waste causes the accumulation in the environment for a long time. One of the most important solutions is the reuse of such waste. This could give a value to great part of solid waste material produced worldwide.

## 4. Conclusions

- The study examined the use of non-woven fabric as packing material for both UASB and DHNW reactors.
- The results indicated that, the proposed packing material has a promising capacity as low-cost materials that could be used for the treatment of wastewater.
- This material easily shaped as corrugated sheets.
- The disinfection step could be used to meet the unrestricted irrigation for safe reuse of the treated effluent [39].


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