Upgrading a textile wastewater treatment by hollow fiber membrane

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A membrane bioreactor has been tested in parallel with a full-scale activated sludge wastewater treatment plant fed on the wastewater from a textile factory. The possibility to upgrade the final effluent for internal reuse was investigated. The research was related to full-scale plant located in a textile factory at Misr-spain Company for polyester textile which located in Shobra-El-khema. The activated sludge wastewater treatment plant is an extended aeration system. The KMS unit is a bench Hollow Fiber Membrane (HFM) submerged in a 40 L tank. Performance of the HFM was evaluated in removal efficiency of COD about 99%, SS 100%, NH_3 and PO_4 more than 90%.

يهدف هذا البحث الى دراسة خصائص المخلفات السائله الناتجه من صناعة النسيج فى محطة المعالجه المقامه بمصنع مصر اسبانيا بشبرا الخيمه والتى سبق ان تم عمل دراسه بحثيه عليها بنظام المعالجه البيولوجيه بالتهويه المطوله، وذلك باستخدام الاغشيه الدقيقه (HFM) مقاس (0.4 micron) من طراز KMS وذلك بهدف دراسة امكانية الحصول على مياه معالجه بدرجه اكثر نقاء من المعالجه التقليديه المستخدمه حاليا. وقد تم عمل الجهاز وتشيغيله على مدى ثلاثة اشهر وتحليل العينات اسبوعيا بقياس COD وBOD و TSS وNH_3-N وNO_3-N وPO_4 وsulfide وكانت النتائج مشجعه، حيث كانت ازالة COD اعلى من ٩٩% و TSS ١٠٠% وNH_3-N اعلى من ٩٠% و PO_4 حوالى ٩٠%. وهذه النتائج توضح ان استخدام (HFM) يجعل من الممكن استخدام المياه فى الاغراض المختلفه فى نفس مجال صناعة النسيج وليس فقط لتلبية متطلبات قانون البيئه للصرف على شبكه الصرف العموميه اوالصرف على المسطحات المائيه. باللاضافه الى ماسبق فان المياه الناتجه من هذا النظام يمكن تنقيتها بشكل كامل باستخدام النانو فلتر (وحدات التناضح العكسى RO) للحصول على مياه تصلح لكافة الاغراض. ولكن هذا النظام لايصلح الاللتصرفات الصغيره وفى الحالات ذات الاهميه الطارئه فى الاماكن التى تندر فيها مصادر المياه وليس فى جميع الاحوال.

Keywords: Textile wastewater, Hollow fiber membrane, Bioreactor, Reuse, Fiber module

1. Introduction

Much of the wastewater generated by the textile industry is derived from wet finishing processes such as scouring, dyeing, printing, etc. which generate large volumes of wastewater with contaminants. Lubello C, and Gori R. reported that HFM technology demonstrated to be effective for textile wastewater reclamation, leading to an improvement of pollutants removal [1]. Baumgarten S, et al. demonstrated that using a membrane bioreactors for the treatment of wastewater from the chemical and textile industries was absolutely necessary, in particular if the technology is to be used for new applications [2].

Wastewater reuse, combined with the recovery of process chemicals, whenever possible, should be applied to reach a more sustainable management of textile industry. A Hollow Fiber Membrane (HFM) was operated in parallel with a full-scale activated sludge WasteWater Treatment Plant (WWTP) on the effluent of a polyester textile finishing factory. The preliminary results related to the comparison of their performance are presented in this research. Rofail M. and Seif H. reported that in the same location a WWTP gave poor results with the biological treatment, just to satisfy the Egyptian law to discharge on to sewerage, not to be reused [2]. The comparison between the two systems was based on removal efficiency of COD, and the quality and constancy of the effluent, in view of a possible recycle within the factory. The preliminary results related to the comparison of their performance are presented in this article.

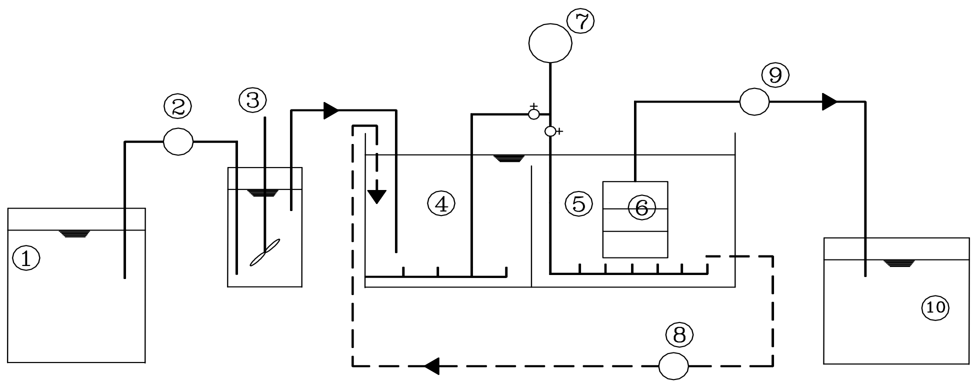
2. Materials and methods

The wastewater used during the tests is discharged from a textile factory which processes polyester fabric (desizing/scouring, dyeing and finishing) woven elsewhere. Scouring is performed with hot water and surfactants to remove the soluble polyester-based size used in weaving and the oils used in spinning. Dyeing is carried out with disperse dyes, and finishing involves several different processes (thermal fixing of the fibre plus antistatic, softening, waterproofing treatments, etc). The COD concentration of the wastewater during the period of the tests (September-November 2006) ranged from 2500 to 3100mg/L

The wastewater is treated in a biological Activated Sludge (AS) extended aeration (WWTP located at the factory and discharged to a public sewer prior to further treatment. The treatment steps are: neutralization and equalization, extended aeration and secondary settling of aerobic digestion of the wasted sludge.

The membrane used during the tests is a KMS, Hollow Fiber Membrane. The membrane module is a vertical bundle of hollow fibers, outer diameter=650 micron, inner diameter= 410micron and thickness= 120micron, which are potted into two ABS heads. The module is submerged into a bioreactor tank (Volume = 40 L). Air is provided by a blower at the base of the module. The fibers are aerated to maintain an adequate turbulence and control fouling. The cleaning method is the forward flush, followed by a forward flush with air and a back flush. The permeate water is extracted by suction from the hollow fibers or is pumped back (during backwashing), to clean the membrane surface by a volumetric (two heads) pump. An additional air diffuser (porous disc) was placed on the bottom of the tank to fulfill the oxygen requirements of the biomass. Dissolved Oxygen (DO) concentration in the mixed liquor was always maintained in the range 2-5 mg/ L. Fig. 1 shows the schematic diagram of the setup.

The feed was provided continuously by a peristaltic pump (model315, Watson Marlow Bredel, Falmouth, UK). During the research, batches of neutralized / equalized wastewater were loaded into a tank (V = 100 L), to make a constant feed (COD variations less than 5%) lasting several days.



1	– Feed tank 40 liter volume	7	– Blower for aeration
2	– Feeding pump	8	– Recycling pump
3	– pH adjustment	9	– Two heads (Pump suction and back wash of HFM)
4	– Aerobic department		
5	– Membrane department	10	– Treated water to be reused
6	– Membrane (HFM)		

Fig. 1. Schematic diagram of bench scale set-up.

3. Analytical methods

The selected parameters were: pH, BOD, COD, TSS, TDS, NH_3-N, NO_3-N, PO_4 and color of the influent, effluent of WWTP. So that pH, BOD, COD, TSS, TDS, NH_3-N, NO_3-N were analyzed periodically for the effluent of HFM once or twice a week. The pH was measured using a digital pH meter (Horiba D-12). The chemical oxygen demand (COD) was measured according to the HACH potassium dichromate method approved by USEPA (Cat. 21259-15, 0-3000 ppm). The ADMI color value was determined spectrophotometrically, using a spectrophotometer with a narrow (10nm or less) spectral band and an effective operating range of 400 to 700 nm. The other parameters were measured according to standard methods for examination of water and wastewater, 20th edition [4]. E. coli and total coliform were measured several times (five times) just to observe if it is available in the effluent of HFM, but was not recorded periodically.

4. Results and discussion

Table 1 shows the raw wastewater characteristics at WWTP and analysis of the effluent of HFM. To compare the performance between WWTP and HFM for the upgrading study, the quality of treated wastewater was followed between the effluent of both systems.

Fig. 2 shows the relation between different results of pH, COD, BOD, and DO in the influent and effluent of WWTP and then the effluent of HFM. The pH values in the effluent of WWTP and HFM are mainly the same. Considering the average values of the 12 samples results, COD decreased from 213 to 11.92 mg/L, BOD decreased from 121.17 to 2.58mg/L and DO increased from 4.39 to 5.45mg/L.

Fig. 3 shows the relation between different results of TDS, SS, NH3-N and PO4 in the influent and effluent of WWTP and then the effluent of HFM. Considering the average values of the 12 samples results, TDS decreased only from 305.17 to 218.17 mg/L, SS decreased from 12.10 to 0.00 mg/L, NH3-N decreased from 4.11 to 1.26 mg/L and PO4 decreased from 11.03 to 2.32mg/L.

Table 1

Raw wastewater characteristics of the influent to WWTP and the effluent of HFM

Parameter		Average
pH	Inf. raw WW	8.37
	Eff. of HFM	7.21
COD mg/L	Inf. raw WW	2650.00
	Eff. of HFM	11.92
BOD mg/L	Inf. raw WW	1693.42
	Eff. of HFM	2.58
DO mg/L	Inf. raw WW	2.16
	Eff. of HFM	5.45
TDS mg/L	Inf. raw WW	1164.58
	Eff. of HFM	218.17
SS mg/L	Inf. raw WW	178.42
	Eff. of HFM	0.00
NH_3-N mg/L	Inf. raw WW	13.02
	Eff. of HFM	1.26
PO_4 mg/L	Inf. raw WW	22.23
	Eff. of WWTP	2.32
NO_3-N mg/l	Inf. raw WW	13.83
	Eff. of HFM	4.68
Sulfide mg/L	Inf. raw WW	19.72
	Eff. of WWTP	1.17
Oil and grease mg/L	Inf. raw WW	26.35
	Eff. of WWTP	0.00
Color NTU	Inf. raw WW	185.33
	Eff. of HFM	4.2

All units are in mg/L except pH and color. WWTP=Waste Water Treatment Plant,
HFM= Hollow Fiber Membrane. NTU=Nephelometric Turbidity Unit

Fig. 4 shows only the relation between different results of NO3, and Oil and Grease in the influent and effluent of WWTP and was not analyzed in the effluent of the HFM. NO3 decreased from 13.83 to4.68 mg/L, Sulfide decreased from 19.72 to 1.17 mg/L, but Oil and Grease was removed completely.

Fig. 5 shows also that Color was removed very efficiently by the HFM. The average abatement of absorbance was 96.5% at 426 nm and 98.7% at 660 nm. Lower, but still significant abatement. were measured with reference to the absorbance measured on the filtered influent. These values are comparable with the ones obtained by Rozzi et al. (2000) in the permeate of a ZeeWecd@ microfiltration module fed with the mixed liquor of a centralized WWTP treating textile influent [5].

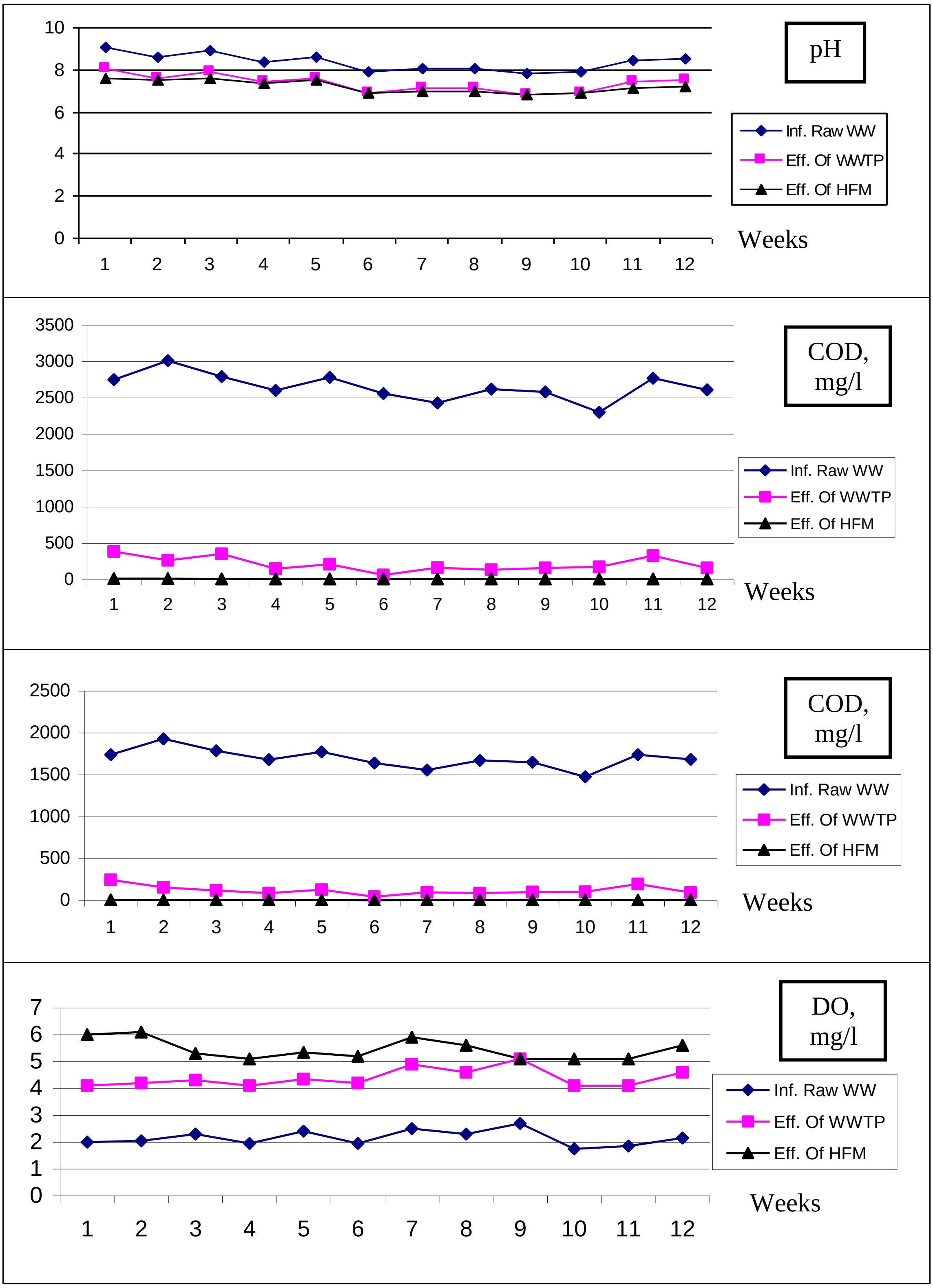


Fig. 2. Values of pH, and concentration of COD, BOD, and DO in mg/L of influent and effluent of WWTP and then the effluent of HFM versus weekly sampling periods.

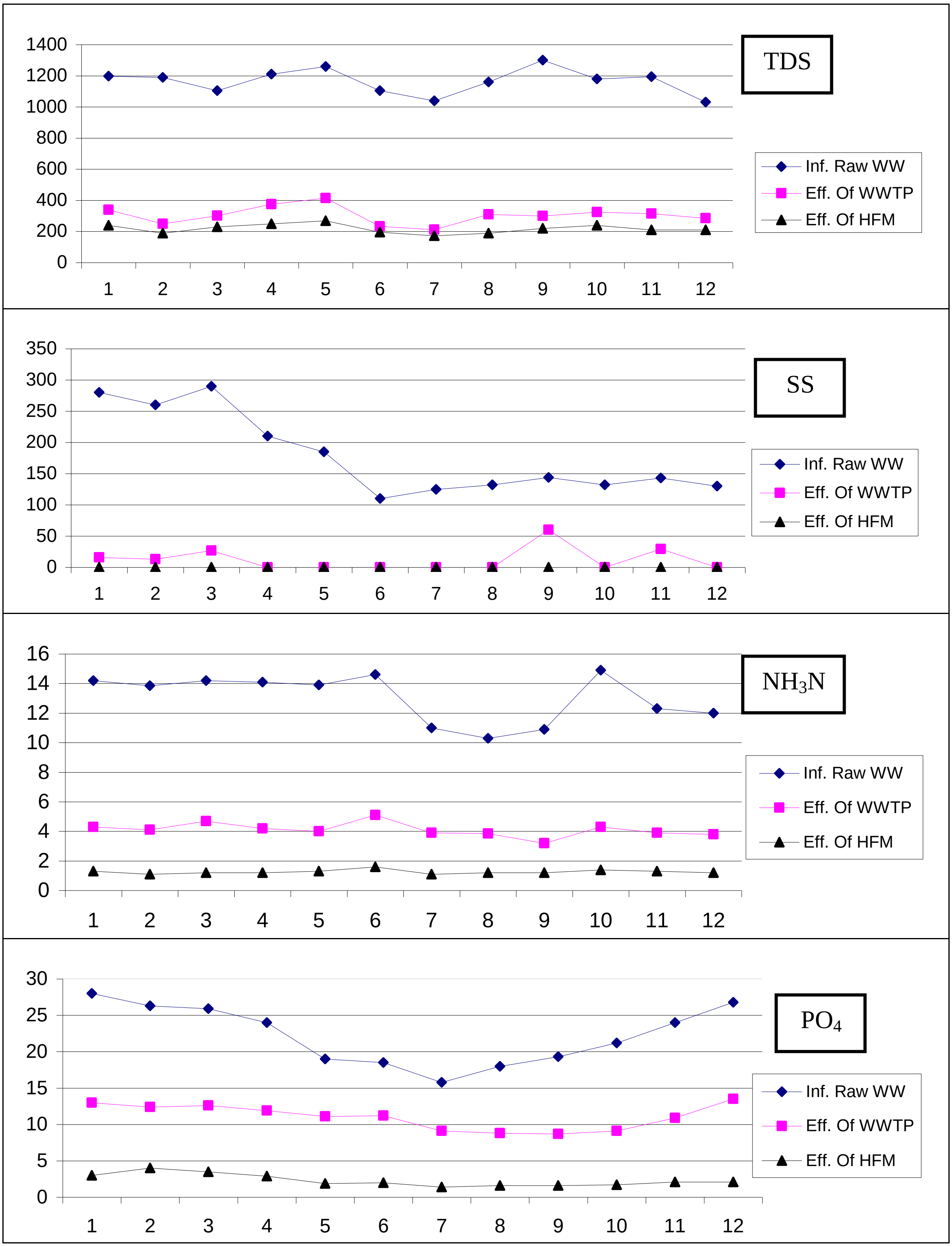


Fig. 3. Concentration of TDS, SS, NH_3-N, and PO_4 of influent and effluent of WWTP and then the effluent of HFM versus weekly sampling periods.

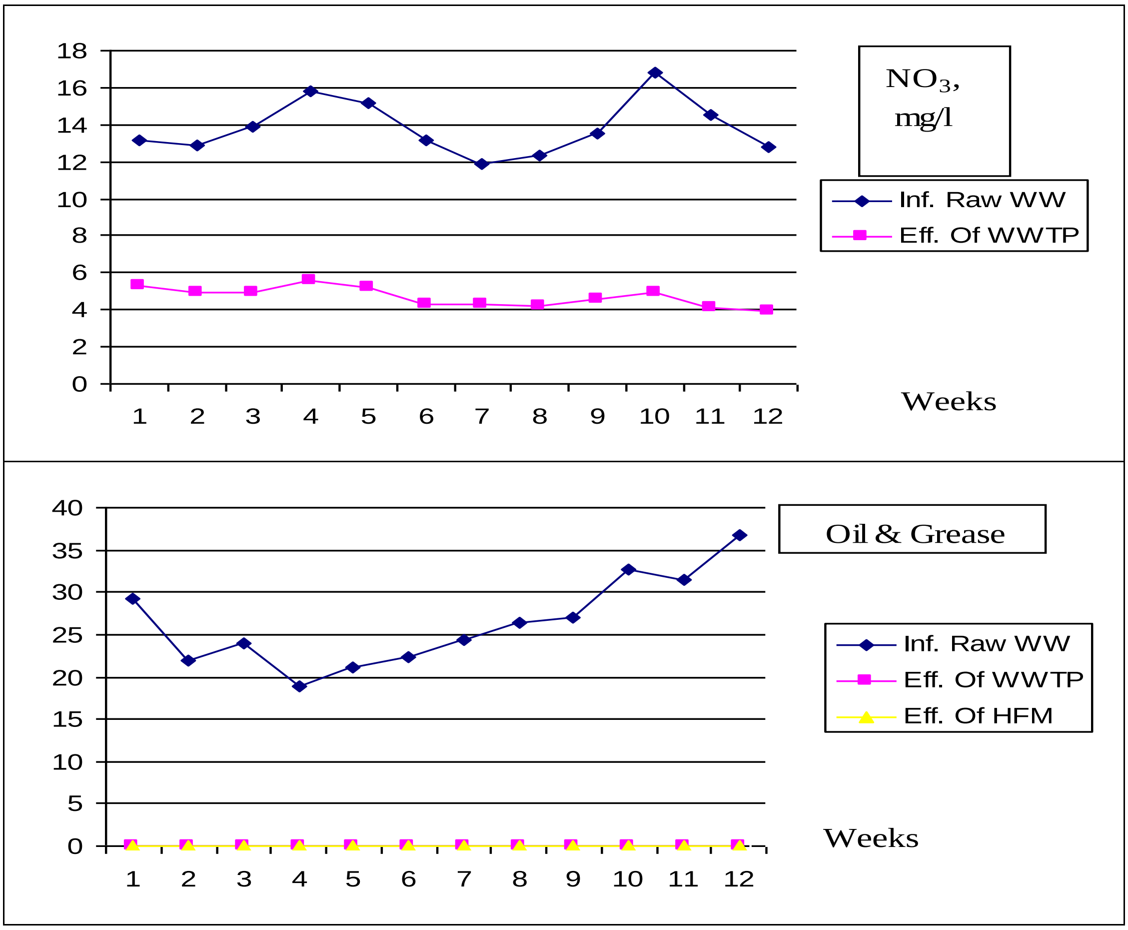


Fig. 4. Concentration (mg/L) of NO_3 and oil and grease of influent and effluent of WWTP and then the effluent of HFM versus weekly sampling periods.

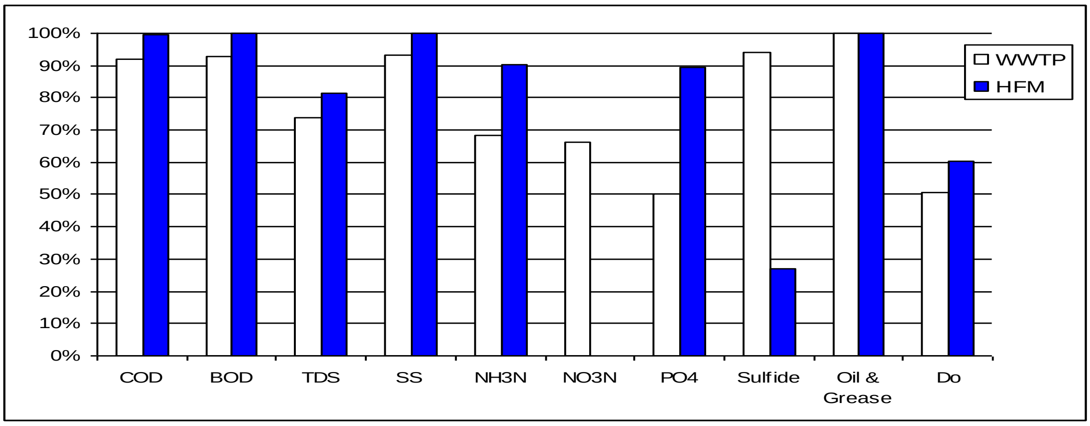


Fig. 5. Average removal efficiency of different parameters for effluent of WWTP the effluent of HFM.

The presence of microorganisms indicators of pathogenicity is a very important issue for water reuse. The draft of the Egyptian law on water reuse now in discussion for instance, requires a maximum of2 CFU/IOO mL for E. coli for any kind of reuse. For this reason, the evaluation of the removal efficiency of the HFM on three of the most common indicators: total coli forms, faecal coliforms and E. coli were considered to be very important. Five analyses, were made during the experimental period on the influent and the permeate. The total and faecal coliforms were not completely removed, even though a very high log abatement (almost four orders of magnitude) was achieved. On the contrary, in three out of the five samples, E. coli were completely removed from the influcnt, possibly because their concentration was much lower, and the abatement was "only" close to three orders of magnitude.

The results indicated many advantages of this system such as effective highly treatment, high nitrogen removal up to 90%, low COD residuals and high bacteria removal without disinfection. The removal of organic matter in this system was efficient and at a high-level. The COD and BOD removal was more than 99%, fig. 5. The TDS removal was more than 80%, and residual TDS were almost constant throughout the experimental period. More than 90% of the nitrogen was removed, and the effluent nitrogen concentration was less than 1.3 mg/l. In the beginning of the experiment, nitrogen removal was not stable because of a longer aeration time, and in some later periods it dropped due to the decrease of organic loading associated with the membrane clogging. Suspended solids in permeate water were analyzed occasionally in the permeate as a control, and their concentration was always found to be less than 12 mg/L.

Application of the system as an easily installed temporary wastewater treatment plant and, totally, the system operated well throughout the experimental period. Thus, the proposed system is technically adequate as an easily installed temporary wastewater treatment plant. The cost is the most important factor for the temporary plant, it was estimated for this system compared with the conventional temporary wastewater treatment system. The construction cost, cost of moving, setting and dismantling, final disposing cost of the plant and operation and maintenance (O/M).

The results of estimations and comparisons have indicated that construction cost of the proposed system is lower than the conventional system but the O/M cost is higher than the conventional system in all aspects. Considering the subsidies to the construction, the proposed system seems inalterable to the conventional system except in the case of a very small plant of flow rate about 100 m^3/day or less. According to this high operation cost, which is the result of the high membrane operation cost which includes the replacement cost and periodical cleaning cost. So the key to the practical use of this system is the drastic procedure of a surface deposit control method to prolong the washing intervals and lower the cost of the membrane module.

4.1. Advantages of application of the system to other cases

1. The effluent quality from the system is so good and safe without disinfection.
2. It will be better to use this system in small communities and small flow rates of wastewater.
3. It might be useful in preventing the spread of infectious bacteria and protozoa.
4. Installation is easy and it can be operated without sludge draw out for at least six months.
5. The system is suitable as an emergency plant in a natural disaster, or as a temporary treatment plant at a large event such as the popular games or exposition at rural areas.
6. It is possible to use it as an on-site water reclamation facility, because the efl1uent quality matches the criteria for aesthetic water, sprinkling water and flushing water, without disinfection (such as south of Sainai and red sea).
7. Taking into account experimental results previously obtained with a Zee Weed hollow fibres module can be used as simple microfiltration unit of the secondary effluents of a WWTP fed on prevailingly textile effluents [5]. The permeate of the HFM could be directly fed to a nano filtration or RO module to

produce a water suitable for any textile process.

5. Conclusions

1. On the basis of the experimental data obtained on the hollow fiber KMS membrane bioreactor, the application of this process for the production of purified water to be reused in a textile factory is feasible.
2. The HFM provided an excellent and quite constant COD removal efficiency, average COD removal during the whole experimental period was close to 99%, and average COD value in the permeate were 11.9 mg/L.
3. Taking into account a preliminary investigation carried out at the factory the residual SST, COD and absorbance of the permeate water make it suitable for reuse in some operations of the dyeing cycle such as the first washing.
4. Compared to the existing extended aeration WWTP, the HFM makes it possible to obtain higher COD (99%) and color removal, besides a much higher removal efficiency for suspended solids and microorganisms.
5. Taking into account experimental results previously obtained with a hollow fiber module can be used as simple microfiltration unit of the secondary effluents of a WWTP fed on textile effluents, the permeate of the HFM could be directly fed to a nano filtration or RO module to produce a water suitable for any textile process or human uses.

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