Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.883173

54 (2015) 37–43
April

Taylor & Francis
Taylor & Francis Group

Influence of support media on COD and BOD removal from domestic wastewater using biological treatment in batch mode

Y. Salama[a,b,*], M. Chennaoui[a], M. Mountadar[b], M. Rihani[a], O. Assobhei[a]

[a]*Laboratory of Marine Biotechnology and Environment (BIOMARE), Faculty of Science, University Chouaib Doukkali, BP 20, 24000 El Jadida, Morocco*
Email: salama.youssef@gmail.com
[b]*Laboratory of Water and Environment, Faculty of Science, University Chouaib Doukkali, BP 20, 24000 El Jadida, Morocco*

Received 31 January 2013; Accepted 15 December 2013

ABSTRACT

The objective of this work is to study COD and BOD_5 reduction of domestic wastewater using biological denitrification provided by anaerobic flora attached to different support media (pouzzolane irregularly shaped, foam (polyurethane) cube-shaped, two different types of PVC (polyvinyl chloride), PET (polyethylene terephthalate), and PS (polystyrene)) Under optimum conditions, maximum reduction and maximum COD and BOD_5 reduction achieved using PVC1 and PVC2 were 64.33 and 58.93%, and 80.1 and 72.1%, respectively. Results showed that PVC offered potential benefits for COD and BOD_5 removal from wastewater. Results showed that PVC promotes bacterial adhesion and biofilm formation compared to other support media and offered potential benefits for COD and BOD_5 removal from wastewater.

Keywords: Batch mode; BOD; COD; Denitrification; Wastewater treatment

1. Introduction

The management of domestic wastewater has become a big problem particularly with improvement in living standard of people. For this, sufficient capacity is not available for handling this domestic wastewater in Morocco. Bulk of this wastewater is either discharged in open channels or accumulates in low-lying areas or flows through natural open drains. Some affluent people, however, use individual captive wastewater storage wells.

It is well known that the wastewater from domestic origin typically contains pathogens, suspended solids, nutrients (nitrogen and phosphorus), and other organic pollutants [1]. For curtailing the environmental and health hazards, these pollutants need to be brought down to permissible limits for safe disposal of wastewater [2,3]. Therefore, removal of the organic contaminants and pathogens from wastewater is of paramount importance for its reuse in different activities [4,5].

The conventional wastewater treatment technologies as adopted in industrialized nations are expensive to build, operate, and maintain [6–8]. Also to comply with the stringent regulations and to restore safe environment, it has become imperative to find less costly and easily adaptable treatment technologies.

*Corresponding author.

Research efforts are going on [9,10] for the development of treatment technologies suited to small, medium, and large communities. The immersed bacterial bed was colonized by anaerobic denitrification heterotrophic flora can be a biological treatment system that is both effective and beneficial [10]. Zaouche and Hamdani [9,11] used an immersed bacterial bed reactor in the treatment of wastewater in food industry. This type of reactor is considered more stable for the treatment of a series of wastewaters rich in organic matter soluble or partially soluble, with 99.99% removal of nitrate and 91% of the organic load of effluent slag [10]. In the present study, this kind of reactor has been used to treat domestic wastewater.

Our study aims to the biological treatment of domestic wastewater in a submerged bacterial bed in batch mode with six types of support media. After determining the physico-chemical characteristics of the raw domestic effluent and performing its pretreatment by the passing through a settling tank, we evaluated the purification performance of the denitrifying biomass by measuring temperature, pH, BOD_5, and COD of the raw and treated water taken from each Erlenmeyer and the biomass formed on the support media.

2. Materials and methods

2.1. Studied zone

The origin of the poured residuary water in the sea of El Jadida comes from the domestic and industrial sources (95 and 5%). Samples of wastewater were collected from the main collector of El Jadida city in Morocco and stored at 4℃ (Fig. 1).

2.2. Analytical methods

The support media used in the present study are presented in Table 1.

The pH and temperature of the wastewater samples were measured at collection site. Electrical conductivity, total suspended solids, BOD_5, most probable number (MPN), and COD were analyzed in laboratory according to the methods prescribed in AFNOR handbook [12].

COD is used as a general indicator of water quality and is an integral part of all water quality management programs. Additionally, COD is often used to estimate BOD (biochemical oxygen demand) as a strong correlation exists between COD and BOD; however, COD is a much faster, more accurate test. In both cases, the oxygen-consuming substances are mainly of organic origin. These substances should be reduced to a minimum in the wastewater treatment plant. In this paper, we have studied the removal of COD and BOD_5 only. The COD and BOD_5 of the wastewater samples were measured in laboratory before and after treatment with different types of support media.

At the end of the experiment, all Erlenmeyer flask were dismantled. The Erlenmeyer liquid and media were taken out to determine the concentrations of the physico-chemical parameters and distributions of attached biomass within the Erlenmeyer.

Care was taken while dismantling the reactors to minimize mixing of suspended solids or shearing and sloughing of attached biofilm.

2.3. Extraction yield of EPS from each media type

Microbial EPS are biosynthetic polymers (biopolymers). EPS were defined (GEESEY 1982) as "extracellular polymeric substances of biological origin that participate in the formation of microbial aggregates". Another definition was given in a glossary to the report of the Dahlem Workshop on Structure and Function of Biofilms in Berlin 1988. Here, EPS were defined as "organic polymers of microbial origin which in biofilm systems are frequently responsible for binding cells and other particulate materials together (cohesion) and to the substratum (adhesion)".

The biochemical composition of the EPS predominantly consists of proteins and polysaccharides.

A tong was used to extract the raschig rings individually from the Erlenmeyer flask.

The remaining liquid was gently stirred and withdrawn to determine physico-chemical parameters.

EPS was extracted by physical methods: Sonication at 40 W for 2 min [13]. The EPS composition in terms of carbohydrates and proteins was measured by the phenol sulfuric method with glucose as a standard [14] and Biuret method [15], respectively.

2.4. Batch mode treatment of wastewater samples

All the experiments were carried out at ambient temperature (25℃) in batch mode. The batch experiments were run in different flasks each of 250 ml capacity.

Eighteen flasks of 250 mL packed with different support media were used to evaluate removal efficiency of BOD and COD.

The development of biofilm on these different media was followed in 250-ml Erlenmeyer flasks (with three replicates) containing the medium and the nutrient medium inoculated with denitrifying flora diluted 1/20. The anaerobic condition is ensured by

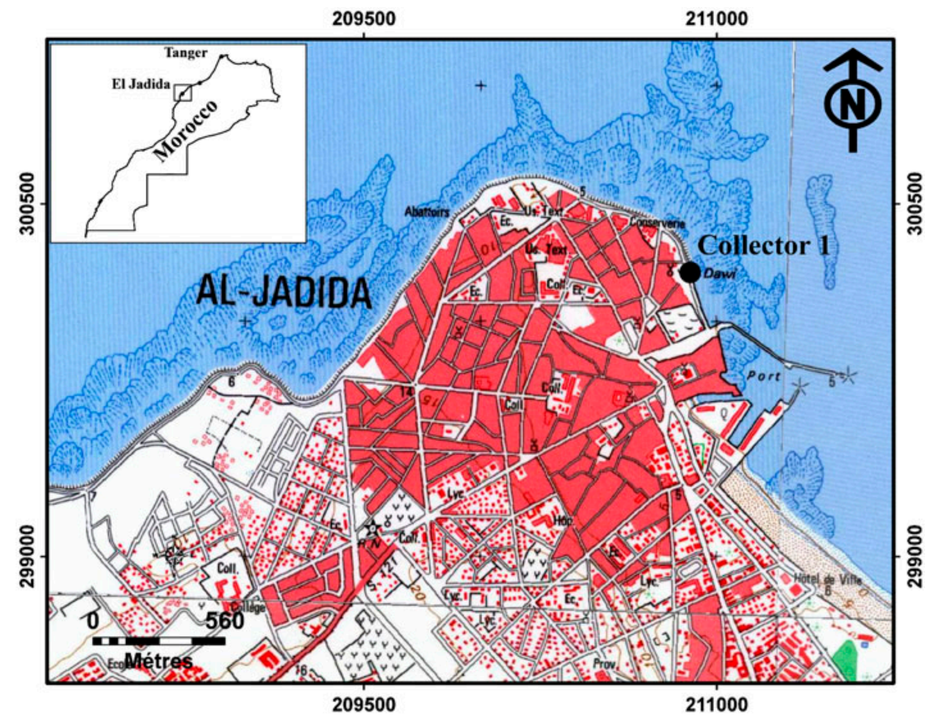

Fig. 1. Location of sampling sites in study zone: Collector 1 (SIDI DAWI collector).

Table 1
Characteristics of support media

						
Materials	Pouzzolane	PVC I	PVC II	Foam	PET	PS
Surface texture	Rigorous	Striated	Smooth	Rigorous	Smooth	Rigorous
Outside diameter (mm)	–	25	17	–	2	–
Height (mm)	12	12	25	18	30	20
Thickness (mm)	–	2	2	–	1	–
Specific surface (m^2/m^3)	115	99	187	292	957	324
Equivalent pore diameter (mm)	3.5	20	11	1	2	2

keeping the media submerged. Denitrifying biomass was allowed to develop in the media for 43 d with the monitoring of the denitrification and the addition of KNO_3.

3. Results and discussion

The domestic wastewater was polluted with organic load plus dissolved and suspended matter as shown in Table 2. Organic load was reflected in terms of COD, BOD, and most probable number (MPN). We were concerned only with COD and BOD reduction into different flasks with support media studied.

The color of the effluent was turbid and yellow.

The physico-chemical properties of the wastewater collected from the studied zone are depicted in Table 2. Organic load is reflected in terms of the COD and the BOD_5 values.

Table 2
Physico-chemical analysis of domestic wastewater and Moroccan project standards permissible limits

Parameters	Averages values	Maximum permissible limits (Moroccan project standards)
pH	7.4	6.8–8.5
Electrical conductivity (EC) (mho/cm)	5.12×10^{-4}	1×10^{-3}
Temperature (°C)	21.28	16–32
Total suspended solids (TSS) (mg/L)	1,365	500
Chemical oxygen demand (COD) (mg/L)	989.7	100
Biochemical oxygen demand (BOD_5) (mg/L)	654.5	20–30
MPN (Coliform cells/100 mL)	5×1.0^{10}	1.5×10^{7}

The analysis of theses effluents showed that some physical and chemical parameters exceeding the standards of reject. The concentration of the COD is estimated between 989.7 and 1,021 mg/L, while concentration of the BOD_5 is limited between 533.2 and 723 mg/L. The values of the COD and BOD_5 are higher than the discharge Moroccan project standards (100 and 30 mg/L).

For BOD_5/COD higher than 0.4, the wastewater biodegradability is high, and consequently the biological process is the most suitable for the treatment of these effluents [16]. However, at BOD_5/COD ratios lower than 0.30, physical–chemical processes are usually more effective than biological treatments [17].

The values of BOD_5/COD ratio were between 0.65 and 0.70 with an average of 0.66.

These values are in the good range of activity of the micro-organism and are favorable for a biological treatment.

The COD and BOD_5 concentrations were very high compared to their permissible limits, for irrigation and horticultural uses as prescribed by Moroccan project standards for wastewater parameters as shown in Table 1. The wastewater was treated under batch mode operation with different support media (pouzzolane, foam, PVC1, PVC2, PET, and PS) and COD and BOD_5 concentrations were measured before and after treatment with each type of support media. The important operating parameters taken into consideration for the present study were: treatment time, pH of the medium, and initial COD/BOD_5 concentration of the wastewater.

3.1. pH

The measure of temperature, pH, and dissolved oxygen were achieved *in situ*. During operation of erlenmyers, we noticed an increase in pH with time (Fig. 2). This pH increase is explained by the formation of OH ions in the process of denitrification. OH ions are released into the external environment, which promotes an increase in pH [18]. The pH of the culture medium is a vital factor that governs denitrifying biofilm growth and exopolysaccharide production. This parameter determined the morphological changes of the cells. The extreme pH profiles of the medium (pH 2.0–3.0 or pH ≥ 10) inhibited not only the process of microbial growth but also the biosynthesis of extracellular polymers [19,20].

The process of heterotrophic denitrification process is [21]:

$$5CH_3OH + 6NO_3^- \rightarrow 3N_2 + 7H_2O + 5CO_2 + 6OH^-$$

The degradation mechanism for the denitrification process could be deduced from the pH variation. Indeed, the results of the analysis of the evolution of pH allowed classifying the support media for the rate of biodenitrification:

$$\text{PVC1} > \text{PVC2} > \text{Pouzzolane} > \text{PS} > \text{PET} > \text{Foam polyurethane}$$

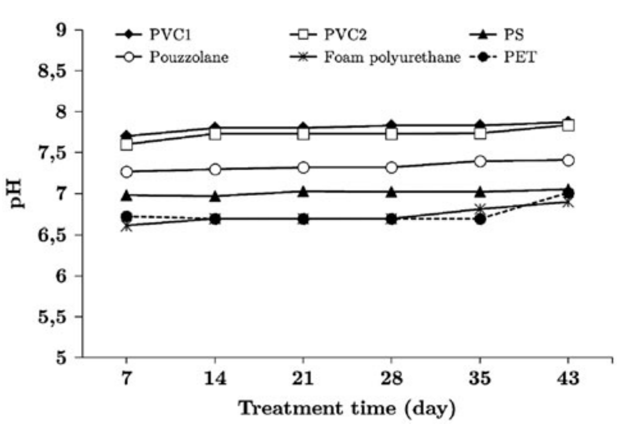

Fig. 2. pH evolution according to the time (initial pH is 6.1).

Reduction of physicochemical parameters of pollution is better with the increase of temperature (25–35˚C) according to [22,23].

3.2. Biomass formed on support media

Bacterial growth and production of EPS was closely correlated. In this study, the tracking evolution of EPS was produced by the extraction of EPS and a quantitative analysis of carbohydrates and proteins constituting the EPS.

Extraction of extracellular polymeric substances (EPS) was used to follow the evolution of bacterial growth on each media type. Carbohydrates and proteins are usually found to be the major components of EPS [24,25]. The extracellularly secreted proteins determine the microbial attachment process to different solid surfaces [26,27].

The effect of support media on biomass growth was evaluated by measuring protein and carbohydrate components of EPS. The results are presented in Figs. 3 and 4.

We noticed at the beginning of the experiment, all media have presented a significant increase the percentage of EPS. After 28 days, the concentration of EPS becomes stable and decreases gradually after 35 d.

From the results, for media of PVC1 and PVC2, the rate of carbohydrates/protein characterized from EPS was higher compared to other support media. For media of PVC1 and PVC2, the rate of carbohydrates/protein characterized from EPS was higher compared to other support media. The lowest amount of EPS was observed in the Erlenmeyer flask with media PET.

The analysis of main components of EPS: proteins and carbohydrates have shown that the type of the support have an important role in growth and biofilm formation.

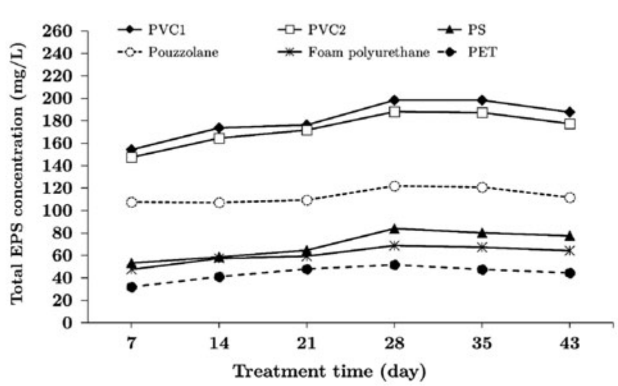

Fig. 3. Change of total EPS concentration at various support media.

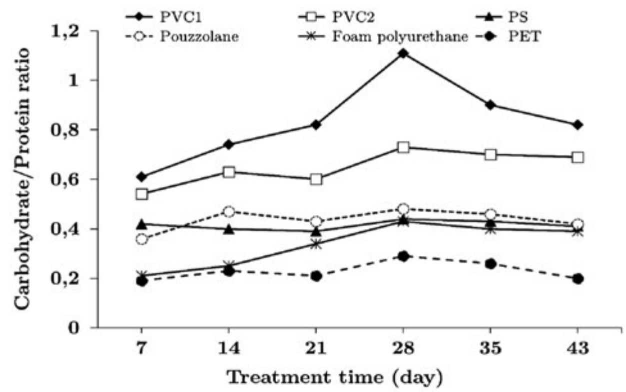

Fig. 4. Variations of carbohydrate to protein ratio of EPS.

Indeed, the results of the analysis of ratio of carbohydrates to protein in the EPS allowed us to classify media according to their ability to promote the formation of microbial biofilm:

PVC1 > PVC2 > Pouzzolane > PS > Foam polyurethane > PET

3.3. Performance of COD removal

COD was studied during the biological treatment to monitor the degradation of organic matter and the effectiveness of this treatment.

Fig. 5 shows that COD is reduced especially in the treatment with PVC1 media to 67.76%, and the treatment with the PVC2 reduced 60.4% of COD for 35 d. But under the same conditions, other different support media have reduced the COD with just 49.27, 30.32, 28.33, and 19.55% in the erlenmeyer with pouzzolane, PS, foam, and PET, respectively.

This indicates that the specific type of support media PVC1 is most effective in the treatment of domestic wastewater under these conditions.

These results confirm the work of Picano [28] has obtained a COD removal efficiency of 68% in anaerobic fixed-bed reactor with support media of PVC.

After 35 d, the COD removal efficiency decreases gradually in all Erlenmeyer. This decrease is proportional with the decrease in bacterial growth observed in Figs. 3 and 4, and this amounts to the impoverishment of substrate in the middle.

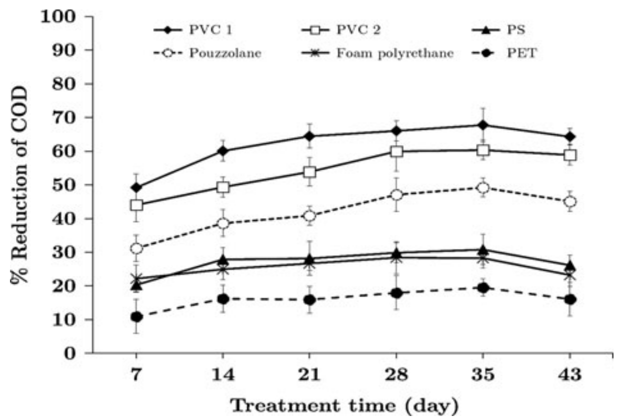

Fig. 5. COD removal efficiency for various supports (initial COD concentration: 1,102 mg/L).

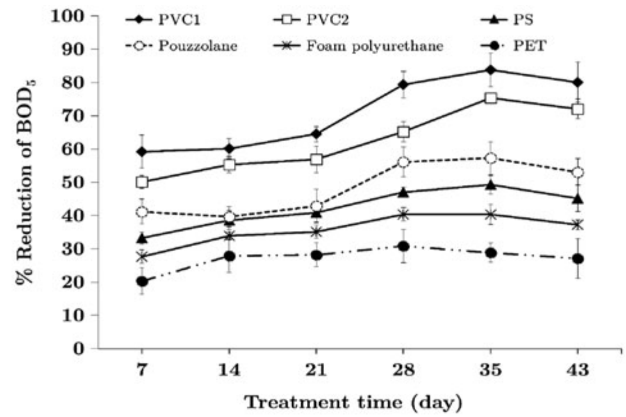

Fig. 6. BOD_5 removal efficiency for various supports (initial BOD_5 concentration: 506 mg/L).

3.4. *Performance of BOD_5 removal*

Effect of percentage COD and BOD_5 reduction was studied as a function of treatment time with different support media as shown in Fig. 6. The percentage reduction of BOD_5 with foam, pouzzolane, PS, and PET was 37.21 and 53.09%; 45.22 and 27.1%, respectively, after a treatment time of 43 d, whereas the maximum reduction of BOD_5 with PVC1 and PVC2 was 79.33 and 65.19%, respectively, after a treatment time of 28 d. As the treatment time progressed, the rate of removal became more stable and then decreased. Difference between the disposal capacities could be attributed to the difference in the quantity of the biofilm that colonizes the surface of each media type.

The denitrification process that ensures the anaerobic flora in different erlenmeyers is one of the two forms of nitrate reduction. When nitrate is reduced through bacterial activity, oxygen is removed from nitrate. Facultative anaerobic bacteria reduce nitrate to degrade soluble cBOD when free molecular oxygen is not available. This is referred to as denitrification or dissimilatory nitrate reduction, because the nitrogen in nitrate is not incorporated into cellular material; that is, nitrogen leaves the bacterial cell in molecular nitrogen (N_2) and nitrous oxide (N_2O).

The use of free molecular oxygen provides the bacteria with more energy for cellular activity, growth, and reproduction than does the use of nitrite ions or nitrate ions.

Bacterial degradation of cBOD is "respiration". Respiration may be aerobic (oxic) or anaerobic [21]:

$$C_5H_{10}O_5 + 4NO_3^- + 4H^+ \rightarrow 5CO_2 + 7H_2O + 2N_2$$

4. Conclusions

During this study we have tested a biologic treatment for an urban wastewater.

The evaluation of the polluting load has lead to determinate the physical and chemical parameters which influence the biological treatment. The results of the analyses of the chemical parameters of pollution permitted us to note that these urban waters passed the permissible standards.

The biologic treatment applied to these waters permitted to decrease the polluting load of which the retention of elimination of the pollution parameters.

The obtained results suggest that the effluent is suitable to this type of treatment.

The use of six types of support for membership of the biofilm was found that the type of support plays an essential role in bacterial growth and the efficiency of biological treatment of wastewater.

Laboratory results in the present study suggest that media type play a significant role in the performance of anaerobic biofilm. To optimize the retention of biofilm attached on the media surfaces and the suspended biomass trapped within the interstitial void spaces, support media of PVC type have the best performance of wastewater treatment.

Acknowledgements

This study is cofinanced by the Hassan II Academy of Science and Technology of Rabat, Morocco. The authors express their thanks to all members and PhD students of the Lab of Marine Biotechnology and Environment (BIOMARE) in the Faculty of Science for their support and for providing the equipment. We would also like to give our thanks to all the colleagues from

Lab of Water and Environment who provided a lively atmosphere all throughout the research.

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