Journal of Environmental Chemical Engineering 4 (2016) 3401–3408

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

An optimized biological approach for treatment of petroleum refinery wastewater

Milad Ebrahimi, Ph.D.[a,1,*], Hamidreza Kazemi, Ph.D.[a,1], S.A. Mirbagheri, Ph.D.[b], Thomas D. Rockaway, Ph.D.[a]

[a] Center for Infrastructure Research, Civil and Environmental Engineering, University of Louisville, Louisville, KY, USA
[b] Civil and Environmental Engineering, K.N. Toosi University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 23 June 2016
Accepted 26 June 2016
Available online 19 July 2016

Keywords:
Optimization
Contact stabilization
Petroleum refinery wastewater
Produced sludge
Removal efficiency
Return sludge
Aeration

ABSTRACT

Excessive sludge production is cost prohibitive and a major concern in biological treatment of petroleum refinery wastewater. Thus, it is essential to identify operational conditions for treatment systems that result in low sludge production of the system, while maintaining its high removal performance. This study assesses the feasibility of using contact stabilization process for secondary treatment of refinery wastewater through a step by step analysis. The mixed liquor dissolved oxygen (DO) and the rate of activated return sludge (RS) were selected as operational parameters governing the optimum performance of the system. A total number of 32 individual experiments were conducted on a pilot plant under four different aeration phases (DO) and eight RS percentages. The analyses investigated the biokinetic coefficients, observed removal efficiencies, and the amount of produced sludge to identify suitable operational conditions. The results indicated that the system had an optimum performance under applied aeration of 3.7 mg oxygen per liter of mixed liquor and 46% return sludge. This operational combination resulted in COD removal efficiency of 78% with daily biomass production of 1.42 kg/day.

1. Introduction

Petrochemical industries and petroleum refineries generate significant amounts of wastewater as crude oil is refined. This wastewater contains a complex set of oxygen-demanding materials and priority pollutants which, if untreated, would be released into the natural environment [19]. Common wastewater pretreatment methods employed by the industry include coagulation flocculation, adsorption, membrane, and chemical oxidation [4]. Generally, it is challenging to remove small suspended oil particles and dissolved elements by sole use of physical or chemical technologies. In this case, the processes that rely on the ability of microorganisms to use wastewater components for their metabolisms, are found to be more cost-effective and sustainable compared to physical and chemical oxidation processes [21].

The activated sludge biological processes are often employed to remove pollutants from the waste stream as a secondary treatment stage. [17]. Biological treatment of oily wastewater can be cost-effective, environmental friendly, and more compatible with existing plant facilities compared to other techniques [6]. However, these systems are typically associated with numerous operational challenges, including poor sludge settling properties, extra-cellular polymers generation, biological inhibition, prolonged sludge retention time, and extensive period of acclimation or start-up [18,19].

Excess sludge production, which is a byproduct of biological processes, raises a serious issue during the wastewater treatment. Treatment and disposal of considerably high produced sludge from the biological processes may even account for almost 60% of total associated costs and energy demand of the treatment plants [23]. Thus, the optimal design of biological treatment systems is essential to reduce the treatment costs of refinery wastewater. A significant number of previous researchers have worked to assess the improvements in pollutant removal efficiency for treatment of petrochemical as well as other industrial wastewater [5,7,12–16,20,21]. However, very few have sought an optimal condition for both maximizing the process removal efficiency and minimizing

* Correspondence to: J.B. Speed School of Engineering, University of Louisville, Louisville, KY, United States.
E-mail addresses: m.ebrahimi@louisville.edu (M. Ebrahimi), h.kazemi@louisville.edu (H. Kazemi), mirbagheri@kntu.ac.ir (S.A. Mirbagheri), tom.rockaway@louisville.edu (T.D. Rockaway).
[1] The first two authors made equal contribution in this work and are both equally considered as first author.

http://dx.doi.org/10.1016/j.jece.2016.06.030
2213-3437/

the amount of produced sludge and with considering a limited range of operational conditions [15,20].

To overcome the aforementioned shortcoming of previous research projects, this study identifies the conditions that lead to optimal performance of contact stabilization systems treating petroleum refinery wastewater. Specifically, the study focuses on conditions that maximize the removal performance and minimize sludge production of the system. To achieve this objective, a series of experiments were conducted on a pilot plant. The system was tested under a wide range of operational conditions and the results were studied through a systematic analysis. The findings from this work serve as a guide for secondary treatment of wastewater from petroleum refineries.

2. Materials and methods

2.1. Contact-stabilization process

The development of contact-stabilization process was based on the idea of increasing the capacity and improving the performance of activated sludge biological wastewater treatment systems [3]. In this method the raw wastewater is aerated and mixed with the bacteria, which is in contact with dissolved and insoluble organic matters, in the contact basin. During this bio-oxidation process, the dissolved organic matters are used by bacterial cells and the insoluble organic matters are adsorbed to external skin cells [14]. Some of the biological solid matters is settled in the secondary settling basin and subsequently wasted, while the remaining is returned to the stabilization basin for further bio-regeneration and stabilizing the organic matters received from the contact basin. It has been ascertained that competition between floc-forming and filamentous microorganism is strongly affected by the organic concentration during mixing of influent and return activated sludge [9]. Thus, through the optimization of return sludge to the contact tank, the high adsorption capacity of activated sludge is fully utilized and the volume of daily excess production from the system is decreased.

2.2. Pilot plant description

A pilot-scale biological treatment plant was constructed at Tehran petroleum refinery. The treatment process involved three distinct zones: contact, stabilization, and settling tanks, see Fig. 1. Detailed dimensions and volumes describing the pilot plant are presented in Table 1.

To prevent short-circuiting and turbulent flow in the basins, 50 cm × 60 cm partition sheets were installed at the inlet and outlet of the contact and stabilization tanks. An equalization basin, equipped with a diffuser and an air flotation unit, was installed up gradient of the pilot plant. Stone air diffusers were fixed at 10 cm above the bottom of the reactors. The air flow in the reactor ensured a mixing intensity, which simulated the mixing characteristic in an activated sludge process. The sludge was recycled from the settler and then returned into the stabilization tank by using a 3500 L/h pump. The pilot plant's operation (start and termination) was controlled by programming a logic control. A steady-state condition was assumed, when fairly constant biomass growth and permeate chemical oxygen demand (COD) were attained.

2.3. Wastewater

The feed wastewater for the pilot plant was obtained from the biological stage influent of Tehran's petroleum refinery treatment plant. The general characteristics of the influent wastewater are presented in Table 2.

2.4. Operational conditions

To achieve optimum treatment performance, a variety of operational parameters need to be adjusted. In this study, the mixed liquor dissolved oxygen (DO) and the percentage of return sludge (RS) from the settling tank to the stabilization tank, were selected as key operational parameters affecting the total sludge production and overall removal efficiency of the system. The dissolved oxygen in the contact tank affects the physical, chemical and biological potential synergic functions of microorganisms in the mixed liquor to adsorb pollutants [10]. The return sludge parameter impacts the growth rate of organisms from the stabilization tank to maintain a specific level of food to microorganism ratio in the contact tank [8]. Thus, it was hypothesized that minimum sludge production and maximum performance efficiency of the system would be achieved by changing the return sludge rate and oxygen supply of the aeration basin.

The pilot plant was operated for a period of six months. The operation was conducted at fixed inflow rate of 700 L/h and under different DO concentrations and RS percentage values. In start-up, the system was maintained at a constant hydraulic retention time (HRT) of 0.65 h and 5.43 h for contact and stabilization tanks, respectively. Each individual experiment was conducted for four days and a minimum time of one week was selected for the mean cell residence time (MCRT) between subsequent test series, to ensure steady state conditions. The experiments were conducted under four different aeration phases and eight different RS percentages ($n = 32$), see Table 3.

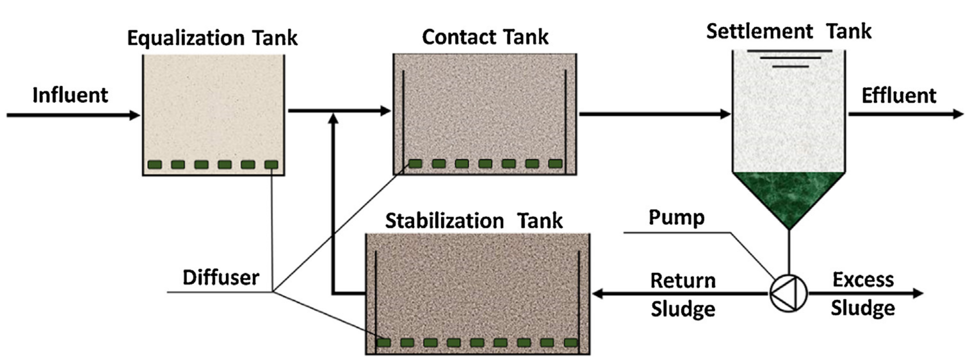

Fig. 1. The Process of the Contact Stabilization Pilot Plant.