PERFORMANCE COMPARISON OF TRICKLING FILTER MEDIA FOR A MUNICIPAL WASTEWATER TREATMENT FACILITY

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Abstract

Proper treatment of a municipality's wastewater is an important part of any successful society. This work is part of an on-going research opportunity for undergraduate engineering technology students as part of an independent research course. Students participating in this applied research opportunity gain real-world experience with green projects. This project focused on the use of two media types in the existing trickling filters at a 1.04MGD wastewater treatment facility. Data were collected by undergraduate engineering technology students from the monthly discharge monitoring reports and then analyzed and evaluated to assess the difference in final total ammonia nitrogen effluent levels at the point of discharge. Preliminary data suggest that upgrading to the new cross-flow media in one of the existing trickling filters may provide additional reduction in the total ammonia nitrogen effluent levels.

Introduction

As part of an on-going effort by the School of Engineering Technology at Youngstown State University to provide an opportunity for undergraduate engineering technology students, the authors developed a plan for the students to work with faculty on an applied research project. Students taking ENTC 4895 Independent Engineering Technology Projects learn to integrate theory and practice through a supervised research experience. Students are involved in project formulation, field and laboratory research, quantitative methods for the collection, analysis, and interpretation of research data, and the culmination of the project with the preparation of a written report and an oral presentation at a national or regional meeting or at the university's QUEST – a forum for student scholarship held each spring semester.

The introduction of applied research opportunities for undergraduate students presents unique challenges in the implementation and coordination of the project [1-3]. A 2002 study [4] indicates that educational institutions continue to face challenges in the implementation of undergraduate research opportunities into the undergraduate curriculum.

Project Overview

Trickling filter systems for a wastewater treatment facility can be an efficient filtration method to remove pathogens from wastewater. Typical trickling filter systems rely on a biofilm consisting of living mixed microbial cultures that attach to solid materials in a fixed environment and consume toxins in the wastewater [5]. A larger surface area, allowing for greater contact time along with the presence of oxygen, creates favorable conditions for biofilm growth. The type of filtration media used for biofilm growth can influence the total ammonia-nitrogen effluent levels, which is the main focus of this study.

Nitrogen plays an important role in the structure and make-up of all living organisms. In the aquatic environment, nitrogen exists in the inorganic forms of nitrate, nitrite, ammonia, and nitrogen gas, in addition to many forms of organic nitrogen [6]. Aqueous ammonia can be toxic to fish and other aquatic organisms at relatively low concentrations. Therefore, ammonia must somehow be controlled, converted to a non-toxic form, or removed from the wastewater.

This study focused on an existing Municipal Wastewater Treatment Plant's (WWTP) efforts to upgrade their plant processes in order to maintain compliance with the ammonia nitrogen effluent limitations in the National Pollutant Discharge Elimination System (NPDES) permit. The WWTP has periodically failed to meet certain organic and hydraulic effluent limits set forth in the existing NPDES permit. A new NPDES permit has been issued for the WWTP with more stringent effluent limits which require multiple plant modifications. The initial plant modification involved the installation of new trickling filter media in one of the two existing tricking filters. In June, 2010, rock media was replaced with a new 60º cross-flow media, and was fully functional by October, 2010. Data were collected from the WWTP's Discharge Monitoring Reports (DMRs) and used to identify the impact the new cross-flow media had on the total ammonia-nitrogen concentration levels in the effluent.

Plant Description and Process Modifications

The existing WWTP (see Figure 1) is a secondary treatment plant utilizing the trickling filter process and permitted to process 1.04 million gallons per day (MGD) with an average daily flow of 0.6 MGD.

The WWTP's existing Biological Treatment Process begins with sewage flow from the main interceptor line into the headworks of the WWTP. The sewage influent then passes through the comminutor and primary screening units and into a splitter box before being distributed into the two primary clarifiers. Effluent from the primary clarifiers is then distributed (via a splitter box) into the two trickling filters, which are operated in parallel.

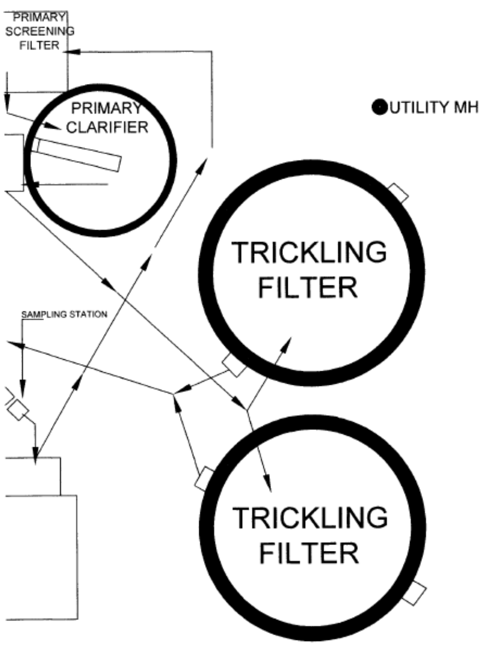

Figure 1. Trickling Filter Schematic and Flow Path

Effluent from the trickling filters is split into two waste streams, one of which is discharged to the secondary wet well with the second being sent to the raw sewage wet well to be recycled. Trickling filter effluent is pumped from the secondary wet well into final clarifiers. Effluent from the final clarifiers then proceeds to the chlorine contact tank for disinfection and discharge into the receiving stream. Sludge from both the primary and final clarifiers is then pumped to the anaerobic digester. Finally, the digested sludge is pumped from the anaerobic digester to the sludge drying beds and then to a landfill.

This WWTP requires plant process modifications to address the permit violations and more stringent parameters set in the updated NPDES permit following the Clean Water Act of 1977 [7]. More specifically, these new limitations are made effective August 1, 2010, for total Residual Chlorine and July 1, 2013, for total Ammonia-Nitrogen. The reduction in total ammonia-nitrogen can be seen in Tables 1a and 1b.

Table 1a. Ammonia-Nitrogen Permit Levels

August 1, 2010-June 30, 2013			
	NPDES Effluent Limitations		
	Mass Units (lbs/day)	Concentrations (mg/L)	
Discharge Parameter	Average Monthly	Average Monthly	Instantaneous Maximum
Ammonia-Nitrogen			
05/01-10/31	41	5	10
11/01-04/30	124	15	30

Table 1b. Ammonia-Nitrogen Permit Levels

July 1, 2013-July 31, 2015			
	NPDES Effluent Limitations		
	Mass Units (lbs/day)	Concentrations (mg/L)	
Discharge Parameter	Average Monthly	Average Monthly	Instantaneous Maximum
Ammonia-Nitrogen			
05/01-10/31	37	4	8
11/01-04/30	110	12	24

In June of 2010, the trickling filter containing rock media was temporarily shut down, the rock media removed, and replaced by 60º cross-flow media. Combining high surface area with maximum mixing/redistribution points per unit volume of media, cross-flow media facilitates superior process performance in the treatment of wastewater. Each sheet in a module is completely corrugated at a 60° angle from horizontal and assembled in a cross-corrugated pattern with adjacent sheets, creating a minimum 95% void-to-volume ratio. The modules are fabricated from rigid, non-flammable PVC sheets, which are UV-protected, resistant to rot, fungi, bacteria, acids, and alkalis commonly present in municipal wastewater [8]. The new cross-flow media replaced an existing rock media which had a minimum 50% void-to-volume ratio. The second trickling filter contained the random-dump (plastic) media that has a 95% volume-to-void ratio [9].

After the rock media was removed, a one-foot riser was installed off of the base of the tank to prevent clogging and to allow for greater oxygen circulation. The cross-flow media was assembled in modules and cut to fill the remaining tank volume, after which a grate was placed on the uppermost layer to protect the media. Installation can be seen in Figure 2. The project was completed in October, 2010, after the initial seeding acclamation period; the new trickling filter media was then fully operational.

Figure 2. Cross Flow Installation

Analysis

The existing WWTP had trouble meeting the total ammonia-nitrogen effluent limitations of the NPDES permit, particularly during the dry season (May 1 – October 31). The DMR's ammonia-nitrogen monthly averages for trickling filters utilizing rock- and random-dump media were 8.80mg/L for the dry season and 9.14mg/L for the wet season (see Table 2).

Table 2. Media Comparison Results

Media Comparison Results	Rock and Dump Media		Dump Media		Dump and Cross Flow	
	Avg	Med	Avg	Med	Avg	Med
Ammonia-Nitrogen						
5/01-10/31	8.80	8.69	12.05	13.00	N/A	N/A
11/01-04/30	9.14	9.14	N/A	N/A	7.78	7.35

The NPDES permit levels during the dry season were 5 and 15mg/L, respectively (see Table 1a). During the months when the WWTP only operated with only one trickling filter containing the random-dump media, the data revealed a spike in ammonia-nitrogen concentrations, as can be seen in Figure 3 for September, 2010. After the new cross-flow media was installed in the second trickling filter and put back into operation, the spike in total ammonia-nitrogen levels continued as the new cross-flow filter media was seeded, allowing the biofilm to grow and mature on the media. Figure 3 displays the actual total ammonia-nitrogen monthly averages along with the permitted levels. Table 2 summarizes the DMR's monthly averages for the various combinations of trickling filter media utilized during this research project. As indicated in Figure 3, this study was limited to a comparison of the data for the wet season (11/01–04/30) based on limited data available on the performance of the trickling-filter media combination of one filter with random-dump media and one filter with the cross-flow media.

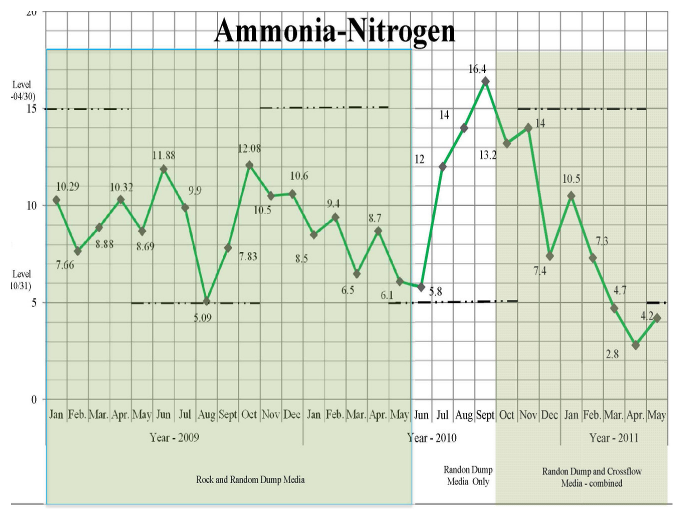

Figure 3. Actual Ammonia-Nitrogen Effluent Levels

From January 2009 through May 2010, there were two trickling filters in operation, one with rock media and one with random-dump media. The average total ammonia-nitrogen concentration for the wet season was 9.14mg/L (see Table 2). From June 2010 through September 2010, there was only one trickling filter in service which had the random-dump media only. The total ammonia-nitrogen concentrations during the dry season (5/01–10/31) averaged 12.05mg/L (see Table 2). From October 2010 through April 2011, both trickling filters were in operation with one filter with random-dump media and one filter with cross-flow media. The total ammonia-nitrogen effluent concentration during the wet season (based on available data) was 7.78mg/L (see Table 2).

The data suggest that the new WWTP process with the two trickling filters, one with random-dump media, and one with cross-flow media, had reduced the average monthly total ammonia-nitrogen effluent concentration from 9.19mg/L to 7.78mg/L.

Summary and Conclusions

This research project provided an opportunity for two senior-level undergraduate Civil and Construction Engineering Technology students to evaluate an existing WWTP, collect and analyze data with regards to modifications to the trickling filter media, and to evaluate the impact of the flow media to address total ammonia-nitrogen effluent concentrations levels. Based upon the limited data from the upgraded trickling-filter media, they suggested that the use of the cross-flow media made a positive impact on lowering the ammonia-nitrogen effluent concentrations from the WWTP. However, additional data collection and analysis will be required to fully evaluate the impact of cross-flow media on the ammonia-nitrogen effluent concentrations.

As part of the actual WWTP evaluation, four Biological Treatment Process Alternatives were being considered for this facility. These included:

- Two-stage (Series Operation) trickling-filter process;
- Two-stage trickling-filter/moving-bed bioreactor (MBBR) process;
- Two-stage trickling-filter/ICEAS sequencing-batch reactor (SBR) process; and
- Single-stage ICEAS SBR process.

Future research will involve the evaluation and monitoring of the WWTP facility's compliance with the NPDES permit limits as upgrades and modifications are made to the facility. This future research will focus on the determination of correlation between rainfall intensity and flow rate, rainfall intensity and ammonia-nitrogen concentration, and determination of peaking factors.

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