A critical review of monitoring approaches in anaerobic and aerobic systems: Application to anaerobic system in India's largest dairy company

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Abstract
Wastewater treatment (WWT) systems have become undeniable processes considering the seemingly large amount of water waste generated industrially and domestically. WWT systems are highly non-linear and dynamic processes influenced by a number of variables. Further they take place in a number of stages with different configurations and hence the focus on finding new methods of fault detection and monitoring for better process control has increased in the recent years. A lot of novel and improvisation methods on the same subject have been proposed. This paper reviews techniques on monitoring and diagnosis of WWT systems. Monitoring techniques are classified based on their approaches and their performances are compared based on its applicability to WWT systems. To further understand the utility of these monitoring techniques, we developed a model of the anaerobic digester unit in India's largest dairy company. The developed models was validated through experimental studies. This model serves to estimate various state of the system using Extended Kalman Filter (EKF), one of the popular soft sensing approaches, for monitoring the anaerobic system in Indian dairy company. Results from this approach indicate that the state estimation based approach can help monitor the anaerobic system by identifying: (i) inhibition of the process due to excess ammonia, (ii) inhibition due to accumulation of long chain fatty acids and (iii) inhibition of the process due to poor growth of methanogens

Keywords
State Estimation, Extend Kalman Filter, Dairy Industry, Anaerobic Systems

INTRODUCTION

Waste water treatment systems are highly complex, nonlinear, and dynamic. They involve number of stages with different process rates and factors that influence the functionality of the system (Gernaey et al., 2014). The sensitive physical, biological and chemical processes (that depend on temperature, pressure, nature of influents etc.,) increase the complexity of the overall process and pose difficulties in management WWT systems. However, it is important to continuously monitor and operate WWT plants under optimum conditions to satisfy the regulations set by pollution control bodies. Monitoring techniques typically identifies the variables that influence the operations, detect deviations from expected values, analyse the causes of discrepancies, trace the root of the cause and if required help implement corrective control actions. (Olsson & Newell, 1999).

Research and developments to strengthen the monitoring and diagnosis systems in WWT systems are continuing at a fast pace. The broad review of the developments in the field of WWT has been provided by a recent article (Olsson et al., 2014). However, the number of monitoring techniques used for monitoring of WWT systems are fast increasing and hence require a critical review of these for understanding the performance of these approaches. In this paper, we classify the monitoring techniques based on their approaches and compare their performances with emphasis on applicability to WWT systems. Also, we develop a experimentally validated of anaerobic system in India's largest dairy company and demonstrate the utility of Extended Kalman Filter (EKF), one of the popular techniques for monitoring and fault diagnosis.

Methods for simulation of ETP

The ETP (Figure 1) consists of 3 digesters which are fed in parallel from an equalization tank followed by two separate channels. The first channel moves to a UASB followed by an aeration tank and secondary clarifier. The second channel moves directly to an aeration tank followed by a settling tank. The supernatant from the clarifiers are stored in supernatant tank and then filtered in a Pressure sand filter. The entire ETP was modeled and simulated at steady state using the software SIMBA#.

Method for monitoring of WWT system:

Extended Kalman Filter, one of the commonly used non-linear model based state estimation approach was used to soft sense various variables in the anaerobic digester of ETP which is subsequently used for diagnosis of faults.

Key results & discussion

Results from this approach indicate that the state estimation based approach can help monitor the anaerobic system by identifying: (i) inhibition of the process due to excess ammonia, (ii) inhibition due to accumulation of long chain fatty acids and (iii) inhibition of the process due to poor growth of methanogens (Figure 2). EKF studies on the anaerobic digester system of the ETP reveal estimation approaches provides important clues that can be used by the operator to isolate the faults in ETP

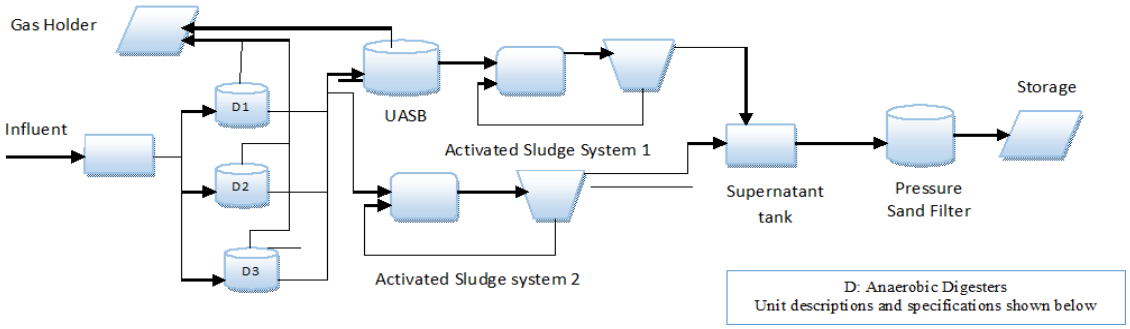

Figure 1: Process flow diagram of WWT plant at dairy unit

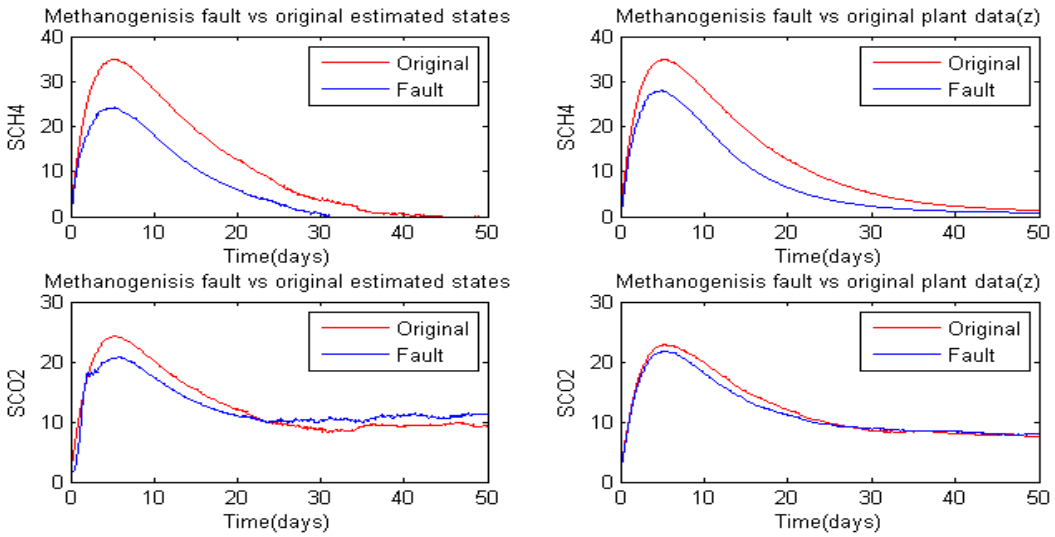

Figure 1:Inhibition of methanogens was the fault introduced. Various states estimated during the non-faulty (original) case and faulty case are shown. Deviation of the estimated states under non-faulty and faulty conditions provide clues for identification of the root cause for the fault.

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