Combined Activated Sludge and Biofilm Technology in a municipal wastewater treatment plant

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Abstract
Settecamini wastewater treatment plant (WWTP) in Rome, Italy, based on Activated sludge (AS) technology had to expand its facility's capabilities, allowing to increase its capacity from 2,500m3/d to 4,500 m3/d while reaching more stringent nutrients removal requirements.
Through an extensive evaluation of optional processes, the integrated fixed-film activated sludge (IFAS) process was determined to be the most cost-effective approach for plant upgrade. One of the two existing treatment trains was upgraded into a five-stage IFAS process. The second train remained as an AS and the two trains are operating in parallel.
This paper discusses the optimization efforts to reduce operational costs and efficiently achieve effluent quality requirements by upgrade to an IFAS system. Data collected on-site comparing the performance of the IFAS and AS treatment trains is presented.

Keywords
Biofilm; Integrated fixed-film activated sludge; nitrogen removal; wastewater treatment

INTRODUCTION

During the last decade, increasingly stringent effluent requirements concerning nutrients concentrations, have been imposed by the authorities around the world on wastewater treatment utilities. In order to meet these standards, the utilities are required to modify their treatment processes and to expand or upgrade existing plants.
Settecamini is a municipal wastewater treatment plant (WWTP) treating wastewater from the Settecamini quarter IV in Rome, Italy. The WWTP, operated by ACEA division ATO2, was based on the Activated Sludge (AS) technology treating 2,500 m^3/d. The existing WWTP included preliminary screening, two parallel AS reactor trains and two secondary clarifiers, effluent disinfection by hypochlorite, sludge holding tank and sludge dewatering through a belt filter press.
Between the years 2012-2013 the plant exceeded effluent discharge standards in Ammonia and Total Nitrogen average levels.
Due to population growth the WWTP was required to double its treatment capacity up to 4,500 m3/d due to population growth from 8,000 PE to 18,000 PE, and to improve its effluent quality in order to meet increasingly stringent nutrient limits of the EU directive for effluent discharging to sensitive area, local Italian regulations and specific regulation in the regional area of Lazio. The main challenge of this project was to maximize the capacity of the existing facility with minimal civil works under limited available area conditions as the plant is located in the city and there was almost no available area for construction of new biological reactors/trains.
The utility first conducted an extensive analysis of upgrade alternatives. The integrated fixed-film activated sludge (IFAS) process was determined to be the most cost-effective approach. It was then decided to upgrade one of two existing treatment trains into a five-stage IFAS process. Figure 1 presents an aerial view of the WWTP with the major process units identified.

The project will be conducted in two phases. Phase A included the upgrade of the first train to IFAS, upgrading the preliminary treatment and pipework modification to enable separation of the two trains (one bioreactor will flow to one secondary clarifier and RAS stream will flow from the corresponding RAS/WAS pumping station to the IFAS reactor).
Phase B will include the upgrade of the second train to IFAS and the refurbishing of the existing secondary clarifier with Stamford baffle technology.
This paper presents data collected on-site showing the plant performance before and after upgrade (phase A) to an IFAS plant during the years 2012-2016.

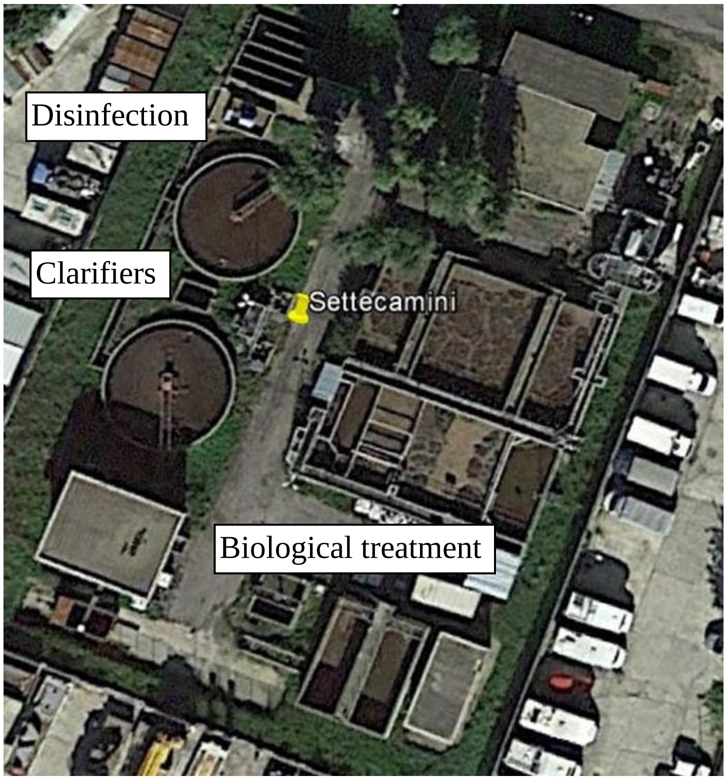

Figure 1. Settecamini WWTP after phase A upgrade

METHODS

The design criteria for Settecamini WWTP was to upgrade one train from 1,250 to 2,500 m^3/d using the existing reactor with an operative volume of 744 m^3. Figure 2 describes the process flow diagram of the original process.

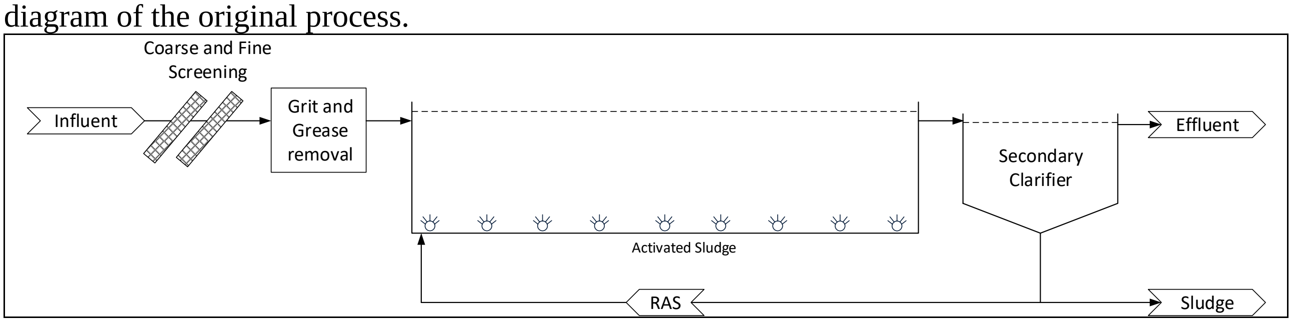

Figure 2. Settecamini WWTP original process configuration

The influent characteristics and the new effluent standards for the WWTP according to the European directive are summarized in Table 1. The wastewater temperature ranges between 12 to 25°C.

Table 1. Influent characteristics and required effluent requirements after secondary treatment

Parameter	Influent (mg/l)	Effluent (mg/l)
COD	550	125
BOD5	220	25
TSS	330	35
Total Nitrogen	71	15
Ammonia as N	51	2
Total P as P	8.1	10

The key effluent parameters are the ammonia and total nitrogen (TN) limits which were not achieved with the AS technology. The ammonia level limit was 2 mg/l as N, while from data collected during 2013, it was found that most of the time the AS effluent ammonia levels were above the required level (Figure 3).

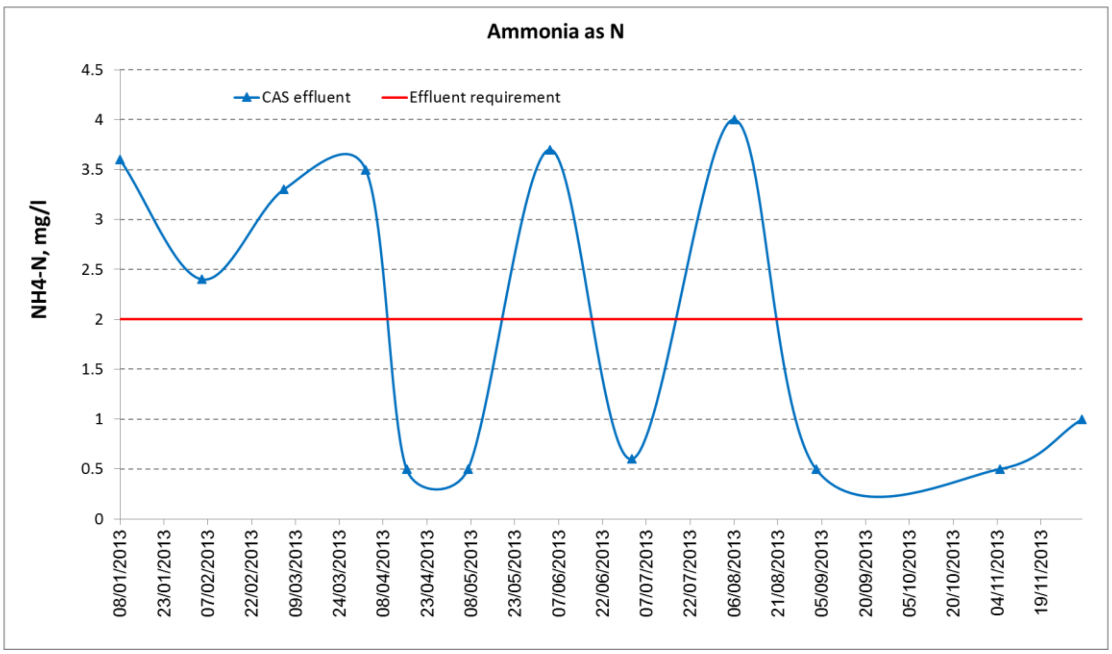

Figure 3. Effluent Ammonia concentrations in the AS train during 2013 (before upgrade)

IFAS is usually applied to upgrade existing plants to enhance nitrogen removal and total bio-degradation capacity, or in the design of new plants to enable extensive BOD and nitrogen removal. The process combines AS and biofilm systems into a single reactor. Biomass carriers are utilized in all or part of the aerated stages. This creates a synergy between two distinct biological processes: while the MLSS degrades most of the organic load (BOD), and the biofilm creates a strong nitrifying population for oxidation of the nitrogenous load. In addition, Moving bed biofilm reactors are favored as an upgrade or replacement technology for low temperature nitrification.

Comparison between the IFAS and the AS technologies is presented in Table 2.

The main disadvantage of the AS alternative is the site constrains since the expansion of the existing site requires constructing of additional AS trains.

Table 2. IFAS and AS systems comparison

Parameter	IFAS	Activated Sludge
Foot print	IFAS operates in relatively low (Sludge Retention Time) SRT for nitrification, resulting in lower reactor volume.	AS operates at higher SRT values, at the same wastewater temperature, compared to IFAS
Process stability	In fixed-film systems, diffusion of materials into the biofilm dictates a decrease in concentration through the biofilm. As a result, any toxic shock or extreme high organic loads will affect only the outer layer of the biofilm while the inner layer will remain unharmed and will ensure quick recovery of the biological activity.	In suspended-growth systems, such as AS, toxic shocks will usually result in loss of biological activity for days/weeks until the system re-stabilizes. In addition, flocculation characteristics of AS are easily compromised resulting in poor sedimentation and elevated TSS in effluent.
Future expansion	Future expansion and upgrades of the system can be easily achieved by the addition of biomass carriers.	Additional biological treatment train is required.

The IFAS train in Settecamini WWTP consists of the following stages, as presented in Figure 4: (1) anoxic zone for denitrification; (2+3) two aerobic zones with biomass carriers for nitrification; (4) anoxic zone for final denitrification and (5) post aeration zone for final BOD removal.

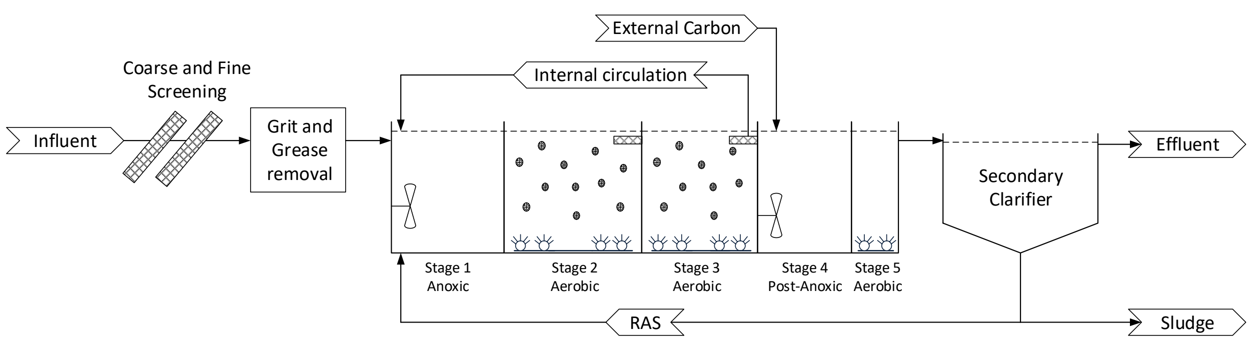

Figure 4. 5-stage IFAS upgraded configuration for one treatment train in Settecamini WWTP

The IFAS train was upgraded within one month. The construction work included reactor division with internal walls, installation of wedge wire screens in each outlet of the aerobic stages to prevent carriers' passage from one stage to another and diffusers arrangement (Figure 5). In order to reduce operational costs it was decided to use, for the aeration systems, fine-bubble diffuses having greater oxygen transfer efficiency compared to coarse-bubble.

Figure 5. Installation of fine bubble diffusers and retention screens

The IFAS train upgrade was completed and commissioned in October 2015, after introducing Aqwise biomass carriers into the IFAS reactor (Figure 6).

Figure 6. Introduction of Aqwise biomass carriers (left) and carriers mixing in the aerobic stage (right)

RESULTS AND DISCUSSION

After a quick plant start-up of less than 4 weeks, the IFAS train treated approx. 2,420 m^3/d (reaching the limit capacity of the existing secondary clarifiers before upgrade in Phase B) and achieved all effluent quality requirements.

Figure 7 presents the effluent BOD performance for both the IFAS upgraded train and AS train. The average BOD level in the influent was 274 mg/l, and varied between 50 to 813 mg/l.

As can be seen in figure 7, slightly better results are achieved in the IFAS train.

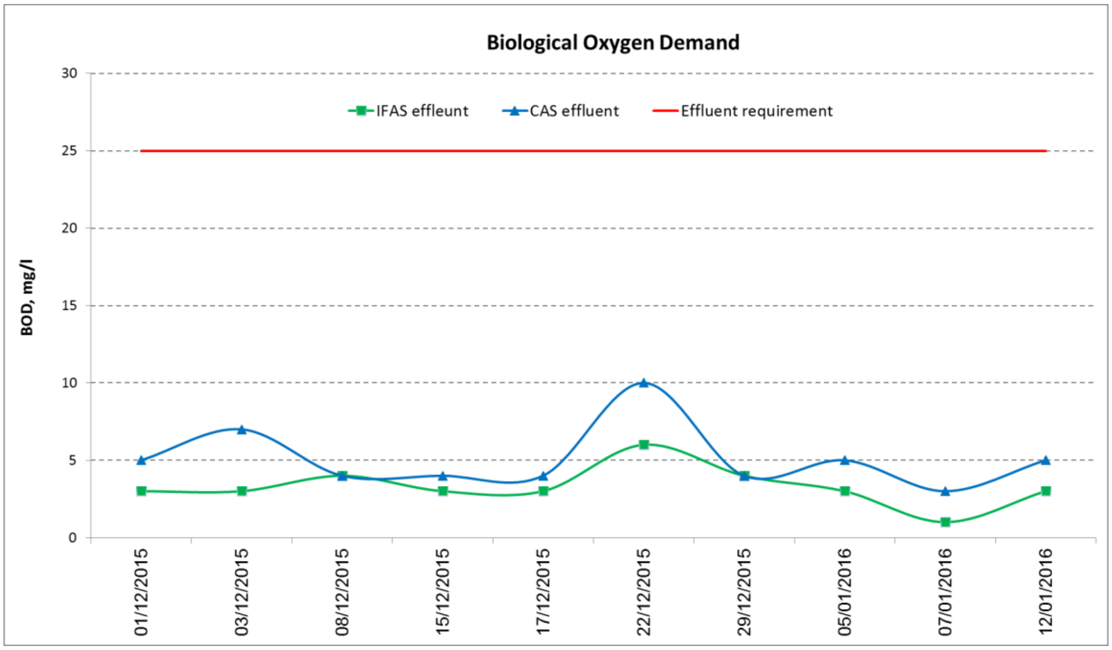

Figure 7. Effluent BOD concentrations in the IFAS train and in the AS train, 2015-2016

One of the main objectives of the WWTP upgrade was reduction in ammonia and TN effluent levels. Figure 8 presents the Ammonia effluent concentrations during 2012-2013 while two trains of AS were operating as well as the IFAS and AS trains operating in parallel, during 2015-2016. Between 2012-2013 several significant deviations in Ammonia levels were observed (up to 300% from the required standard level), while after the IFAS was operated, effluent concentrations were 7% below the discharge required standard.

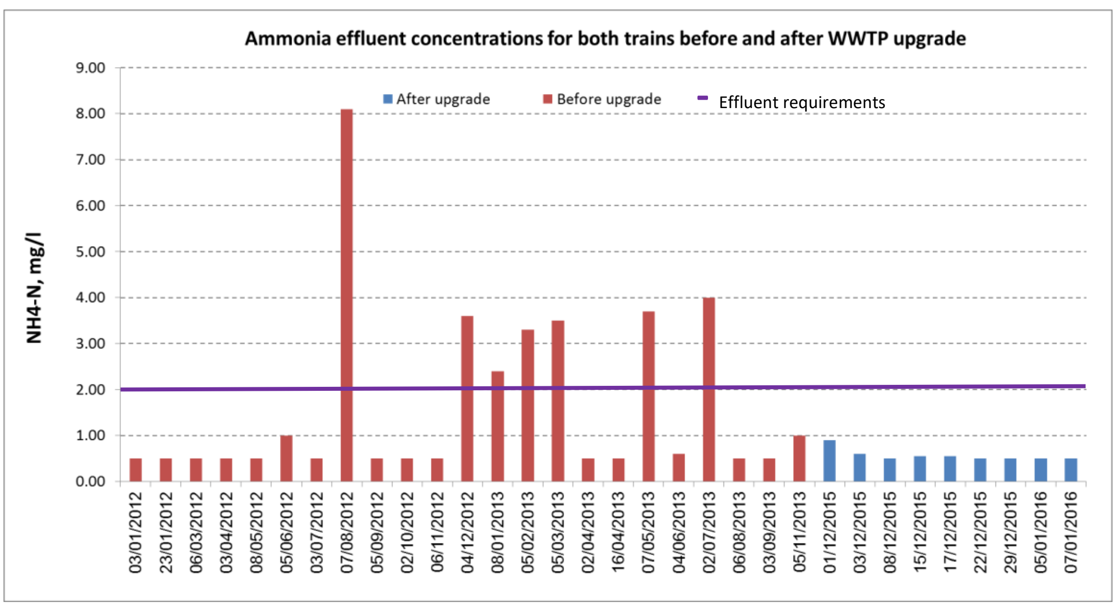

Figure 8. Ammonia effluent concentration before and after biological reactors upgrade

Figure 9 presents the effluent TN performance for both IFAS upgraded train and AS train. The average TN level in the influent was 75 mg/l, and varied between 35 to 119 mg/l. The improvement in effluent TN at the IFAS train was significant. The average effluent quality was 11 and 27 mg/l in

the IFAS train and AS train, respectively. The IFAS achieved 86% removal compared to 64% by the AS. Only the IFAS train met the effluent TN requirements of 15 mg/l.
If necessary, the TN removal rate in the IFAS can be improved in the future, by increasing the internal circulation flow.

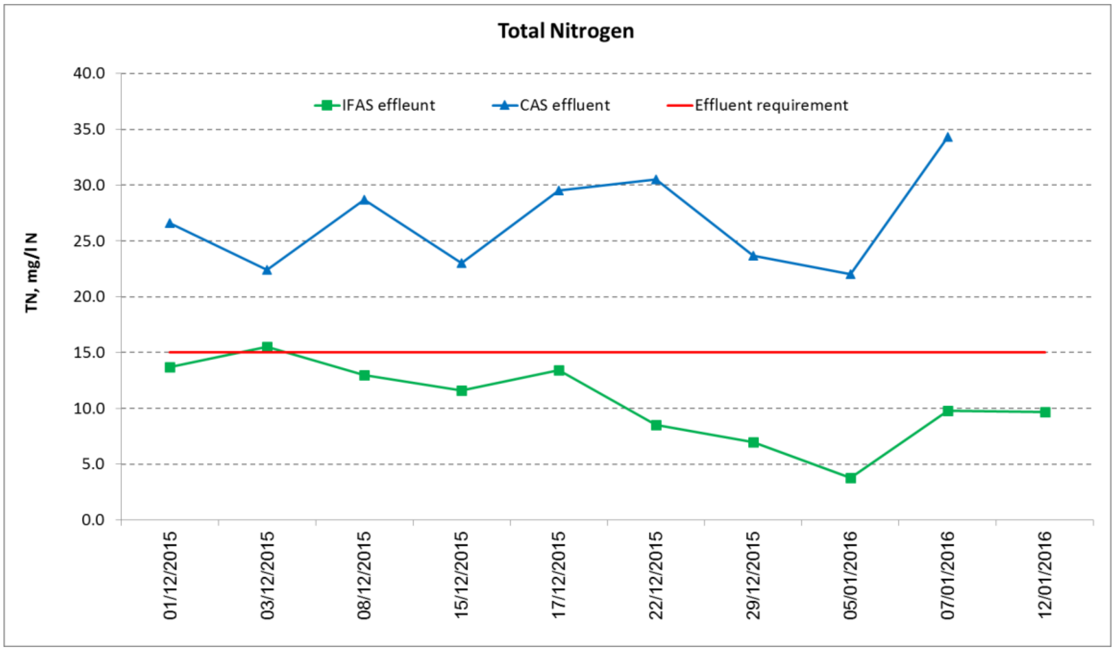

Figure 9. Effluent Total Nitrogen concentrations in the IFAS train and in the AS train, 2015-2016

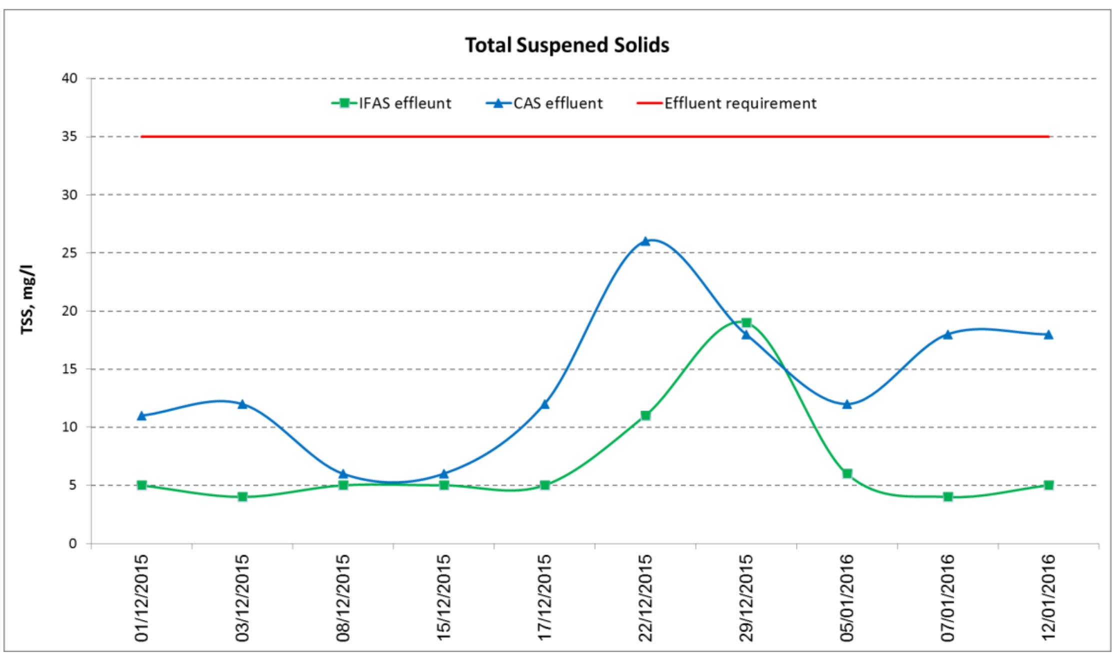

Figure 10. Effluent Total Suspended Solids concentrations in the IFAS train and AS train 2015-2016

Figure 10 presents the effluent TSS concentrations in the IFAS and AS trains.
Both trains achieved the effluent TSS requirement of 35 mg/l. However, the effluent TSS in the IFAS was lower compared to the AS. Furthermore, the IFAS was operated with relatively lower MLSS concentrations after system optimization. These results are explained by the IFAS technology, in which most of the active biomass is attached to the plastic carriers, which allow lower solid loading rates on the secondary clarifiers when operated with lower MLSS concentrations. This results in better performance of the secondary clarifier.

The IFAS upgrade of the municipal WWTP allowed new effluent requirements to be successfully achieved in the same existing biological reactor volume. The IFAS has a high and stable removal efficiency of organic loads and nitrogen compounds. In addition, the operation team indicated that the IFAS train is more stable and easy to operate.