**ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL**

# COMPARISON OF LONG TERM AND CYCLE DATA CALIBRATION FOR MODELLING OF SEQUENCING BATCH REACTOR

**M.Sc. THESIS**

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**Environmental Biotechnology Programme**

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**İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ**

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**YÜKSEK LİSANS TEZİ**

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Yasemin ÖZLİMAN FARIMAZ, a M.Sc. student of İTU Graduate School student ID 501191809, successfully defended the thesis entitled “COMPARISON OF LONG TERM AND CYCLE DATA CALIBRATION FOR MODELLING OF SEQUENCING BATCH REACTOR”, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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***To my dear family,***

## FOREWORD

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January 2023

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**TABLE OF CONTENTS**

**Page**

## ABBREVIATIONS

**ADM** **:** Anaerobic Digestion Model
**AMETO** **:** Acidclastic Methanogens
**AS** **:** Activated Sludge
**ASM** **:** Activated Sludge Modelling
**CAS** **:** Conventional Activated Sludge
**CASTO** **:** Carbon Storing Organisms
**COD** **:** Chemical Oxygen Demand
**DO** **:** Dissolved Oxygen
**GAO** **:** Glycogen Accumulating Organisms
**HMETO** **:** Hydrogenotrophic Methanogens
**IAWO** **:** International Association of Water Quality
**IFAS** **:** Integrated Fixed-Film Activated Sludge
**KOI** **:** Kimyasal Oksijen İhtiyacı
**MBBR** **:** Moving Bed Biofilm Reactor
**MLVSS** **:** Mixed Liquer Volatile Suspended Solid
**NITO** : Aerobic Nitrifying Organisms Kinetics
**OHO** : Ordinary Heterotrophic Organisms
**OUR** : Oxygen Uptake Rate
**PAO** **:** Phosphorus Accumulating Organisms
**PU** : Process Unit
**SBR** **:** Sequential Batch Reactors
**SBNR** **:** Simultaneous Biological Nutrient Removal
**sCOD** **:** Soluble Chemical Oxygen Demand
**SRT** **:** Solid Retention Time
**TKN** **:** Total Kjeldahl Nitrogen
**TN** : Total Nitrogen
**TSS** : Total Suspended Solid
**VFA** **:** Volatile Fatty Acid
**VSS** **:** Volatile Suspended Solid

**SYMBOLS**

| | |
|---|---|
| **bNITO** | **:** Decay rate of NITOs |
| **bOHO** | **:** Decay rate of OHOs |
| **frCU,CCOD** | **:** Fraction of colloidal unbiodegradable organics (CU) in colloidal COD |
| **frSCCOD,TCOD** | **:** Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD |
| **frSCOD,TCOD** | **:** Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD |
| **frSNH$_x$,TKN** | **:** Fraction of $NH_x$ in total Kjeldahl nitrogen (TKN) |
| **frSPO$_4$,TP** | **:** Fraction of $PO_4$ in total phosphorus (TP) |
| **frSU,SCCOD** | **:** Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) |
| **frVFA,SCCOD** | **:** Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) |
| **frVSS,TSS** | **:** Fraction of VSS/TSS |
| **frXE,XOHO** | **:** Fraction of endogenous products (XE) of OHOs |
| **frXOHO,TCOD** | **:** Fraction of heterotrophs (OHO) in total COD |
| **frXU,TCOD** | **:** Fraction of particulate unbiodegradable organics (XU) in total COD |
| **KHYD,AS** | **:** Half-saturation of particulates in hydrolysis (AS) |
| **KSB,AS** | **:** Half-saturation of readily biodegradable substrate for OHOs (AS) |
| **YOHO,VFA,ox** | **:** Yield of OHOs on VFA under aerobic conditions |
| **µNITO** | **:** Maximum specific growth rate of NITOs |
| **µOHO** | **:** Maximum specific growth rate of OHOs |

**LIST OF TABLES**

**Page**

**LIST OF FIGURES**

**Page**

## COMPARISON OF LONG TERM AND CYCLE DATA CALIBRATION FOR MODELLING OF SEQUENCING BATCH REACTOR

## SUMMARY

Biological treatment technologies are quite commen in recent years. Studies for the development of these technologies continues to accelerate. Conventional systems are still highly preferred. The first reason why it is preferred is that it provides high performance in wastewater treatment. It is also an important feature that there are modifications that can provide at the same time nitrogen and phosphorus removal. Treatment is provided by the mass of microorganisms called biomass.

Reactors used in treatment processes are also divided into categories. One of these categories is sequential batch reactors. In these reactors, aeration and treatment are provided in the same reactor. The small volume is advantageous. The processes that take place in this type of reactors are regulated for a period of time. The reaction times are measured with digital timers and the reactions take place respectively. While this type of reaction is take place, zonesare formed inside the reactor. After the aerobic conditions to be formed during the aeration period, anoxic condition occurs with the after of the aeration. Thus, one of the conditions required for both nitrification and denitrification is met. Both the reactor preferences and the biological treatment method that take place are diverse. With the modification of these systems, a number of specific treatment methods emerge.

The simulation of these technologies, which emerged as ideal approaches for ideal solutions, is also very important. Simulations are important in terms of obtaining a knowledge of biochemical activities, such as hydrolysis, growth and decay rate of the microorganisms found in the biomass, called activated sludge, in wastewater treatment plant designs or for improvement of existing plants. By obtaining results which are close to real composition, system kinetics are determined according to this information. The design parameters are also determined with the most realistic form. In the light of this information, treatment efficiency and costs are can be optimized. Afterwards, it takes a short time to to design.

The main purpose of this thesis is to, have a large number of criteria to be considered before the biological treatment systems are actually designed. The results of the experimental study used from the literature were simulated with a wastewater treatment system design program. In this study, the applicability of SUMO, Dynamita, another simulation program available in the market, was tested using these analyses. The reason for choosing this subject is that a real domestic wastewater, whose treatment has been experimentally studied, has not been simulated before in this estimation program. The results will contribute to the literature to be compared with other studies. In the current studies in the literature, there is no evaluation of the results of experimental studies with real domestic wastewater, SUMO, Dynamita software. The advantage of conducting this study is that it has proven the feasibility of the design and the reliability of the SUMO, Dynamita program according to the experimental data obtained from wastewater.

The success of the sequential batch reactors in the biological treatment systems was observed again.

The data used in this study were obtained from experimental analyzes by (Karlikanovaite, 2019). For the experimental studies, samples were taken from the Istanbul Baltalimanı Wastewater Treatment Plant. In the same study, it was reported that glucose was added as an "extra carbon source" due to the low COD/TKN ratio. Among the information about the study, there is also the information that the CAS-SBR is fed with the same wastewater continuously for 100 days in sequential batch reactor in an aerobic environment.

According to study, effluent soluble COD (chemical oxygen demand), ammonia and total nitrate and nitrite values of the reactors were taken and were operated at 2 different solid retention times. Data sets with retention times of 13 days and 20 days were preferred. In addition, it was stated that the efficiency of the system was again measured with soluble COD and ammonia data during a cycle (8 hours) with the samples taken from the sequential batch reactor of conventional activated sludge processes fed with wastewater 3 times a day for 100 days.

In this study, dynamic modeling method was used. Influent and effluent wastewater measurement data are dynamically modeled with a holistic modeling approach. The comparison of experimental data was made in two different ways in terms of 100-day long-term and 8-hour short-term cycles. Data sets obtained from the inside of the sequential batch reactor and the effluent.

Various dynamic and stoichiometric parameters are used in dynamic modeling. Thus, a comparison was made with the real, long-term data results and the model was evaluated. The difference of the study is the analysis of four different situations. In the first case analysis, the coefficients and fractions of the previous study were used. In the second case analysis fractions obtained from the experimental data from literature. Also the coefficients were applied from the literature. In the third case analysis, both the fractions and the coefficients as accepted in the SUMO, Dynamita program, without any changes. In the fourth case analysis, simulations were carried out with the fractions taken from the literature and the coefficients accepted in the SUMO, Dynamita program. The results were compared with the experimental data from the literature. It has been determined that the experimental data and simulation results are quite close. In this case, it has been seen that design can be made with SUMO, Dynamita software using conventional activated sludge systems in domestic wastewater treatment.

Within the scope of this thesis, information about the purpose and importance of the study is given in the first chapter. In the second part, the place of biological treatment in the literature is explained. The third part is the material and method part. In this chapter, the fractions and coefficients of the scenarios examined in the study are summarized for all cases. Frequently used variables, modified fractions and modified coefficients are discussed for each scenario. Finally, the fourth chapter is discussed as conclusion and discussion. In this section, the results of the dynamic modeling are interpreted by comparing them with the experimental data from the literature. For long-term studies (100 days), four different scenarios of sludge ages of 13 days and 20 days were analyzed. For the cycle measurement (8 hours), four different scenarios of sludge ages of 13 days and 20 days were analyzed in the same way. In total, 16 different results were obtained from four scenarios.

The SUMO1 model used has single-stage nitrification and denitrification stages. It is a simulation tool with a kinetic model approach. Some kinetic coefficients and stoichiometric coefficients were determined for modelling. The simulation results and the experimental results from the literature were not completely in agreement. In long-term evaluations, SCOD values were below the experimental data in Case 1 for 13 sludge ages. $NH_4$ results, on the contrary, were higher. The $NO_x$ results are in agreement with the experimental data obtained from the literature. In Case 2, the effluent SCOD values were lower in the simulator. $NH_4$ results were again higher than the literature. $NO_x$ results were also found to be in accordance with the literature data in harmony with the previous scenario. When the SCOD results for Case 3 are examined, the results of the dynamic modeling program SUMO are below from the literature data. $NH_4$ simulation data is higher than literature results. NOx measurement results are compatible with each other. In Case 4, which is the last scenario for 13 sludge ages, the SCOD is lower than the literature in terms of simulated results. $NH_4$ treatment performance is higher in terms of literature data. $NO_x$ measurements are compatible as in the other three scenarios. The SCOD and $NH_4$ values were below than the experimental data in Case 1 for 20 sludge ages. $NO_x$ results are in agreement between simulation and literature. SCOD simulation results and literature results for Case 2 are close to each other. The $NH_4$ values obtained with the simulation tool were higher than the literature. $NO_x$ results are in agreement. The SCOD results obtained by dynamic modeling in Case 3 are lower than the experimental study data in the literature. According to the literature results, the $NH_4$ results, which were close to zero, were high in the simulation tool. $NO_x$ results are still in agreement. As a result of the evaluations made for Case 4, the SCOD results are in line with those obtained from the simulation tool and the literature from which the experimental data were obtained. $NH_4$ results and $NO_x$ results are in the same agreement.

When the 8-hour cyclic data results were examined, the SCOD simulation was completed in the range from 20 mg/L to 40 mg/L according to Case 1 for the 13-day sludge age. $NH_4$ decreased to zero in the experimental study results in the literature. In the simulation, it was not possible to reset it. SCOD results and $NH_4$ results in Case 2 and Case 3 are harmonious. In Case 4, results were obtained with no major differences in terms of SCOD. It completed the 8-hour period in a repeating cycle. The $NH_4$ results showed differences too small to be significant. According to Case 1 applied for 20-day sludge age, the SCOD results obtained by simulation are higher than the experimental data obtained from the literature. It showed a difference between the SCOD data for Case 2 as well. $NH_4$ data behavior is similar to the previous case. There is also a difference between the Case 3 results in terms of SCOD. $NH_4$ data results are in compatible. For the last scenario, Case 4, the values that should be according to the dynamic modeling and the real experimental results obtained from the literature are close to each other. In terms of $NH_4$, trends have emerged as a perfect match.

When the study was evaluated, it was seen that the simulated SCOD results approached the real experimental results. This may be due to the fact that the carbon source required for the survival of both groups of microorganisms (autotrophs and heterotrophs) is provided. The simulated $NH_4$ results are higher than the experimental results. This may be due to the low amount of oxygen supplied to the nitrogen-removing nitrifying bacteria. Because the amount of oxygen provided during the aeration periods was kept constant while designing. On the other hand,

$NO_x$ removal cannot be associated with oxygen since it is provided by denitrification in anoxic conditions. Currently, $NO_x$ removal is very close to the real experimental data results from the literature study. Most of the time, results were obtained as close to zero. As a result of this study, which was obtained by using real domestic wastewater data from the literature, the usability of the dynamic modeling tool was tested. It has been prepared with the aim of being a study that can be a model for future studies.

# ARDIŞIK KESİKLİ REAKTÖRÜN MODELLENMESİ İÇİN UZUN DÖNEMLİ VE DÖNGÜSEL VERİ KALİBRASYONLARININ KARŞILAŞTIRILMASI

## ÖZET

Biyolojik arıtma teknolojileri son yıllarda oldukça yaygın olarak kullanılmaktadır. Bu teknolojilerin gelişmesi için yapılan çalışmalar hız kesmeden devam etmektedir. Konvensiyonel sistemler halen çok tercih edilmektedir. Atıksu arıtımında yüksek performans sağlaması tercih edilmesinin ilk sebebidir. Aynı azot ve fosfor giderimi de sağlayabilen modifikasyonların olması da önemli bir özelliktir. Biyokütle olarak adlandırılan mikroorganizma kütlesi sayesinde arıtım sağlanır.

Arıtma süreçlerinde kullanılan reaktörler de belli kategorilere ayrılırlar. Bu kategorilerden biri ardışık kesikli reaktörlerdir. Bu reaktörlerde havalandırma ve arıtma aynı reaktörde sağlanır. Kapladığı alanın az olması avantaj sağlar. Bu tip reaktörlerde gerçekleşecek işlemler süreli olarak ayarlanır. Dijital zaman ölçerlerle geçen süreler ölçülür ve sırası ile reaksiyonlar gerçekleşir. Bu tip reaksiyonlar oluşurken reaktör içerisinde tabakalar oluşur. Havalandırma süresinde oluşacak aerobik ortam sonrasında, havalandırmanın sonlandırılması ile anoksik ortam oluşur. Böylece hem nitrifikasyon hem de denitrifikasyon için gereken koşullardan bir tanesi sağlanmış olur. Hem reaktör tercihleri hem de gerçekleşecek biyolojik arıtma yöntemi çeşitlidir. Bu sistemlerin modifikasyonu ile özellikle bir takım arıtma yöntemleri ortaya çıkmaktadır.

İdeal çözümler için ideal yaklaşımlar olarak ortaya çıkan bu teknolojilerin simülasyonu da oldukça önemlidir. Simülasyonlar, atıksu arıtma tesisi tasarımlarında veya varolan tesislerin iyileştirilmesinde aktif çamur olarak adlandırılan biyolojik kütlenin içinde bulunan mikroorganizma çeşitlerinin hidrolize olma, büyüme ve ölüm hızı gibi biyokimyasal aktivitelere dair geniş bilgi edinilmesi açısından önemlidir. Gerçekçi bir kompoziyon elde edilerek, sistem kinetikleri bu bilgilere göre belirlenir. Tasarım parametreleri de gerçeğe en yakın şekli ile belirlenir. Bu bilgiler ışığında arıtma verimi ve maliyetler optimize edilir. Sonrasında tasarımı gerçekleştirmek kısa bir zaman almaktadır.

Bu tez çalışmasının yapılmasının ana amacı, biyolojik arıtma sistemlerinin gerçekte tasarlanmadan önce dikkat edilmesi gereken kriterler sayısının fazla olmasıdır. Literatürde bulunan çalışma başka bir çalışma için yapılmış deneysel çalışma sonuçları bir atıksu arıtma sistemi tasarım programı ile simüle edilmiştir. Bu çalışmada ise, bu analizler kullanılarak piyasada bulunan bir diğer simülasyon programı SUMO, Dynamita programının uygulanabilirliği test edilmiştir. Bu konunun seçilme nedeni ise arıtımı ile ilgili deneysel çalışma yapılmış gerçek bir evsel atıksuyun, daha önce bu tahmin programında simüle edilmemiş olmasıdır. Alınan sonuçlar diğer çalışmalar ile kıyaslanmak üzere literatüre katkıda bulunacaktır. Literatürde bulunan mevcut çalışmalarda gerçek evsel atıksu ile yapılmış deneysel çalışmaların sonuçlarının, SUMO, Dynamita yazılımı bir değerlendirmesinin mevcut olmamasıdır. Bu çalışmanın yapılmasının avantajı ise atıksudan elde edilen deneysel veri sonuçlarına göre tasarımın yapılabilirliğini ve SUMO, Dynamita programının güvenirliğini kanıtlamış olmasıdır. Çalışma yapılan ardışık kesikli reaktörlerin biyolojik arıtma sistemlerindeki başarısı tekrar görülmüştür.

Bu çalışma gerçek evsel atıksuyun aerobik ortamda, ardışık kesikli reaktörde arıtılması ile yapılan bir başka çalışmanın verileri kullanılarak yapılmıştır. 100 gün boyunca 2 farklı katı bekletme süresinde çalıştırılan reaktörlerin çıkış çözünebilir KOİ (kimyasal oksijen ihtiyacı), amonyak ve toplam nitrat ve nitrit değerleri alınmıştır. Bekletme sürelerinden 13 gün ve 20 gün olan veri setleri tercih edilmiştir. Ayrıca 100 gün boyunca günde 3 kez atıksu ile beslenen konvensiyonel aktif çamur proseslerinin ardışık kesikli reaktörünün içinden alınan numunelerle bir döngü boyunca (8 saat) sistemin verimi yine çözünebilir KOI ve amonyak verileri ölçüldüğü belirtilmiştir.

Holistik bir modelleme anlayışı ile giriş ve çıkış atıksu ölçüm verileri dinamik olarak modellenmiştir. Deneysel verilerin kıyaslanması 100 günlük uzun dönemli ve 8 saatlik kısa süreli döngüler açısından iki farklı şekilde yapılmıştır. Bu çalışmada dinamik modelleme yöntemi kullanılmıştır. Ardışık kesikli reaktörün içinden ve çıkışından elde edilen veri setleri kullanılmıştır. Dinamik modellemede çeşitli dinamik ve stokiyiyometrik parametreler kullanılmıştır. Böylece gerçek veri sonuçları ile kıyaslanma yapılmıştır.

Uzun dönemli veriler kullanılmıştır ve model değerlendirilmiştir. Çalışmanın farkı dört farklı durum analizi yapılmasıdır. Birinci durum analizinde daha önceki çalışmaya ait katsayılar ve fraksiyonlar kullanılmıştır. İkinci durum analizinde deneysel verilerden elde edilen ortalama fraksiyonlar kullanılmıştır. Katsayılar ise daha önce yapılan literatürden uygulanmıştır.

Üçüncü durum analizinde ise hem fraksiyonlar hem de katsayılar SUMO, Dynamita programında kabul edildiği şekli ile, değişiklik yapılmadan, simülasyonlar gerçekleştirilmiştir. Dördüncü durum analizinde ise literatürden alınan fraksiyonlar ile SUMO, Dynamita programında kabul edilmiş katsayılar ile simülasyonlar gerçekleştirilmiştir. Çıkan sonuçlar deneysel verilerle kıyaslanmıştır. Deneysel veriler ve simülasyon sonuçlarının oldukça yakın olduğu tespit edilmiştir. Bu durumda, evsel atıksu arıtımında konvensiyonel aktif çamur sistemleri kullanarak SUMO, Dynamita yazılımı ile tasarım yapılabileceği görülmüştür. Bu tez kapsamında, birinci bölümde çalışmanın amacı ve önemi hakkında bilgi verilmiştir. İkinci bölümde biyolojik arıtma, aktif çamur sistemleri, ardışık kesikli reaktörler, atıksu arıtımı çalışmaları için kulllanılan modeller ve dinamik model olarak SUMO, Dynamita programı özetlenmiştir. Üçüncü bölüm materyal ve metod kısmıdır. Bu bölümde, çalışmada incelenen senaryolara ait fraksiyonlar ve katsayılar ayrı bölümler halinde özetlenmiştir.

Sıkça kullanılan değişkenler, değişiklik yapılan fraksiyonlar ve değişiklik yapılan katsayılar her bir senaryo için ele alınmıştır. Son olarak dördüncü bölüm sonuç ve tartışma olarak ele alınmıştır. Bu bölümde, yapılan dinamik modelleme sonuçları, deneysel verilerle kıyaslanarak yorumlanmıştır. Uzun dönemli çalışmalar için (100 gün) 13 günlük ve 20 günlük çamur yaşlarına ait dörder farklı senaryo analiz edilmiştir. Döngü ölçümü için (8 saat) yine aynı şekilde 13 günlük ve 20 günlük çamur yaşlarına ait dörder farklı senaryo analiz edilmiştir. Toplamda dört senaryo üzerinden 16 farklı sonuç elde edilmiştir. Kullanılan SUMO1 modelinde tek aşamalı nitrifikasyon ve denitrifikasyon aşamaları bulunmaktadır. Kinetik bir model yaklaşımına sahip simülasyon aracıdır. Modelleme için bazı kinetik katsayılar ve stokiyometrik katsayılar belirlenmiştir. Simülasyon sonuçları ve literatürden alınan deneysel sonuçlar tamamen uyum içinde çıkmamıştır.

Uzun dönemli değerlendirmelerde SCOD değerleri 13 çamur yaşı için Senaryo 1'de deneysel verilerin altında çıkmıştır. $NH_4$ sonuçları ise tam tersi daha yüksek çıkmıştır. $NO_x$ sonuçları literatürden alınan deneysel veri sonuçları ile uyumludur. Senaryo 2'de çıkış suyu SCOD değerleri simülatörde daha düşük çıkmıştır. $NH_4$ sonuçları yine literatüre göre yüksek çıkmıştır. $NO_x$ sonuçları da bir önceki senaryoya göre uyum içinde literatür verilerine uygun bulunmuştur. Senaryo 3 için SCOD sonuçları incelendiğinde, dinamik modelleme programı SUMO sonuçları literatür verilerinin altındadır. $NH_4$ simülasyon verileri literatürün üstündedir. $NO_x$ ölçüm sonuçları birbiri ile uyumludur. 13 çamur yaşı için son senaryo olan Senaryo 4'te ise SCOD simüle edilen sonuçlar açısından literatürden daha düşüktür. $NH_4$ arıtım performansı literatür verileri açısından daha yüksektir. $NO_x$ ölçümleri diğer üç senaryoda olduğu gibi uyumludur. SCOD ve $NH_4$ değerleri 20 çamur yaşı için Senaryo 1'de, simülasyon sonuçları deneysel verilerin altında çıkmıştır. $NO_x$ sonuçları simülasyon ve literatür arasında uyumludur. Senaryo 2'ye ait SCOD simülasyon sonuçları ve literatür sonuçları birbirine yakındır. Simülasyon aracı ile elde edilen $NH_4$ değerleri ise literatürden daha yüksek çıkmıştır. $NO_x$ sonuçları uyum içerisindedir. Senaryo 3'te dinamik modelleme ile elde edilen SCOD sonuçları yapılan literatürde gerçekleştirilen deneysel çalışma verilerinden düşüktür. Literatür sonuçlarına göre sıfıra yakın olan $NH_4$ sonuçları, simülasyon aracında yüksek çıkmıştır. $NO_x$ sonuçları yine uyum içerisindedir. Senaryo 4 için yapılan değerlendirmeler sonucunda, SCOD sonuçları simülatörden alınanlar ve deneysel verilerin alındığı literatür ile uyumludur. $NH_4$ sonuçları ve $NO_x$ sonuçları da aynı uyum içerisindedir. Sekiz saatlik döngüsel veri sonuçları incelendiğinde, 13 günlük çamur yaşı için Senaryo 1'e göre SCOD simülasyon 20 mg/L ile 40 mg/L aralığında tamamlanmıştır. $NH_4$ literatüre giren deneysel çalışma sonuçlarında sıfıra kadar inmiştir. Simülasyonda ise sıfırlanması mümkün olmamıştır.

Senaryo 2'de ve Senaryo 3'te SCOD sonuçları ve $NH_4$ sonuçları uyumludur. Senaryo 4'te SCOD açısından büyük farklar bulunmayan sonuçlar elde edilmiştir. Kendini tekrar eden bir döngü halinde 8 saatlik süreyi tamamlamıştır. $NH_4$ sonuçları anlamlı olamayacak kadar küçük farklar sergilemiştir. 20 günlük çamur yaşı için uygulanan Senaryo 1'e göre simülasyon ile elde edilen SCOD sonuçları literatürden alınan deneysel veri sonuçlarının üzerindedir. Senaryo 2 için de SCOD verileri arasında önemli bir fark göstermiştir. $NH_4$ veri davranışları ise önceki senaryoya benzemektedir. Senaryo 3 sonuçları arasında da SCOD açısından fark bulunmaktadır. $NH_4$ veri sonuçları ise uyum içerisindedir. Son senaryo olan Senaryo 4 için dinamik modellemeye göre olması gereken değerler ile literatürden alınan gerçek deneysel sonuçlar birbirine yakındır. $NH_4$ açısından, mükemmel bir eşleşme olarak eğilimler ortaya çıkmıştır. Yapılan çalışmanın tamamı değerlendirildiğinde, gerçekleşen SCOD arıtımı sonuçlarına, simüle edilen sonuçların yaklaştığı görülmüştür. Bunun sebebi her iki mikroorganizma grubunun (ototrof ve heterotrof) da hayatta kalabilmesi için gereken karbon kaynağının sağlanmış olması olabilir.

Simüle edilen $NH_4$ sonuçlarının daha yüksek olmasının sebebi nitrojen giderimi yapan nitrifikasyon bakterilerine sağlanan oksijen miktarının az gelmesi olabilir. Çünkü tasarım yapılırken havalandırma sürelerinde sağlanan oksijen miktarı sabit tutulmuştur. $NO_x$ giderimi ise anoksik ortamda denitrifikasyon ile sağlandığından oksijen ile ilişkilendirilemez. Hali hazırda NOx giderimi literatür çalışmasından alınan gerçek deneysel veri sonuçlarına çok yakındır. Çoğu zaman sıfıra yakın sonuçlar elde edilmiştir. Literatürden alınan gerçek evsel atıksu verilerinin kullanılması ile elde edilen bu çalışma sonucunda, seçilen dinamik modelleme

aracının kullanılabilirliği test edilmiştir. Bu tez çalışması ile prosesin anlaşılması ve yeni tesis tasarımına yönelik önemli ipuçları elde edilmesi beklenmektedir.

## 1. INTRODUCTION

The environment in which people and other living things interact throughout their lives. Environmental pollution is categorized as air, soil and water pollution in a simple way. All ecosystems are affected by environmental pollution (İbadullayeva, 2019). Environmental pollution, which is a serious public and health problem for both the world and at the same time our country, is largely caused by industrial production and urban life. Regardless of the source, whether in urban or rural areas, when natural resources become polluted, they not only harm plant and animal health, but also adversely affect human health directly or through the food chain[i] (İbadullayeva, 2019). Especially in these days when the whole world is tending to biodynamic agriculture, that aims food quality with soil health, it is very important to work in an interdisciplinary way to prevent the pollution of natural resources. Therefore, among these pollutions, domestic wastewater is of great importance as if directly affects human health or contaminates soil and water resources. For all wastewater, treatment plants have a solution to this contamination problem to some extent in recent years, but other problems have arisen with this solution. Classical activated sludge (CAS) systems used in the biological treatment of domestic and industrial wastewater are widely preferred. The reasons for this are: There are different configurations where high quality effluent can be obtained. It can also be used for nitrogen and phosphorus removal. It costs are lower than chemical treatment (Kavak, 2016). The main purpose of these CAS is to ultimately convert organic substances, which is found in the wastewater as a pollutant, into water, $CO_2$ and biomass. Biomass is a concentrated sludge separated with water. Even if wastewater treatment is successful, sludge production is the problem which is mentioned above. This problem was not considered very important in the years when activated sludge processes were started to be developed. The focus was on wastewater treatment. Again, sludge production problem was neglected and new process alternatives were developed. The new process were focused on obtaining activated sludge with perfect settling properties. The reason for this was the search for a solution to the problem of coping with domestic wastewater loads which was caused by rapid population

growth and industrial developments (Allı, 2017). In sequential batch reactors (SBR), the aeration process and the treatment process take place in the same reactor. This is a fill-and-draw activated sludge system. Aeration is done simultaneously with mixing. Then settling is performed. Wastewater is withdrawn by horizontal centrifugal machine. Programmable cycles are used at certain time intervals. The MLSS remains in the reactor during all cycles. In conventional systems, there are 5 stages: filling, reaction, settling, discharging and idle. Since the system works intermittently, the flow must be balanced. Multiple reactors are used for this. Mixing and aeration equipment is the same as for continuous reactors. The wastewater, which is drawn by the horizontal centrifugal machine, is fed to the reactor continuously. Sludge disposal is carried out at regular intervals. SBR is generally used in the treatment of small flow wastewater. In some cases SBRs can be used for wastewater with a flow rate between 150,000 and 700,000 $m^3$/d (Thiel, 2002).

Currently, many modelling studies are carried out in order to determine the system kinetics in activated sludge systems. Treatment facilities are designed according to the results of these studies or existing facilities are revised according to these new approaches. In this context, in order to make the correct design or make the revisions correctly before the treatment facilities established, examining the entire facility on a holistic basis, taking into account not only system kinetics, but also variable wastewater characterization and mass balances that is vary according to design parameters, gives the most accurate results in the studies. With this holistic modeling approach since the characteristics of the influent and effluent wastewater can be determined dynamically, operation and control parameters of the facility can be monitored, and thus system optimization is carried out, the system can be utilized in the most efficient ways, and finally time and cost optimization takes place. Additionally, another advantage of performing modelling studies is that the performance of treatment plants under different dynamic conditions can be tested without risking the system (Gülhan, 2018). SUMO Model is a tool used for biokinetic degredation and transformation processes (Advanced Treatment Technologies), as well as for equlibrium chemistry-based methods (pH and settling) and physicochemical degredation and transformation processes. It was used in this study. With this simulation tools, generally Activated Sludge Models (ASM) Models (ASM1, ASM2d, ASM2d_TUD, ASM3_BioP, ASM3), Barker_Dold and

BUCTPHO can be based. These models are generally accepted activated sludge models, which have been studied for a long time and then supported by the data, and the coefficients and model structure related to the model have been determined. Various modelling methodologies (such as elemental balancing) related to wastewater treatment can be applied with the SUMO Simulator. Ease of schematic representation is available (Comeau, 2008). Site-specific modelling applications using this tool and phase seperation case studies were carried out (Wett, 2003). There are many publicions in the literature on biological system applications (N, P removal, anaerobic treatment) of model simulation studies using these models (Smith, 2008). [1]

In this study, the SUMO1 model was used. The model includes one-stage nitrification and one-stage nitrification processes. In addition, the model approach is also explained as kinetics. In other words, SUMO, the operating platform of the kinetic model, is the Dynamita dynamic modeling tool. The proposed process is designed for the kinetic model. The values of some constants such as kinetic parameters and stoichiometric coefficients used in the model structure were also determined. Various simulations were made in SUMO software using the data obtained from the experiments with real wastewater and the kinetic coefficients determined with the AQUASIM software in a (Karlikanovaite, 2019) study. Model simulation of SUMO software is based on growth rate, decay rate and single stage hydrolysis. The simulations were done in dynamic mode. As a result of the simulations, the effluent quality was compared with the experimental data. The obtained results were evaluated for four different case study scenarios.

### 1.1 Purpose of Thesis

This study has been prepared with the aim of dynamically modelling the data which is obtained from the CAS-SBR Process, which is a specific wastewater treatment configuration operated with microorganism. With the modelling study, the kinetic and stoichiometric parameters of the processes occurring in the biological system in these systems have been presented. Thus, the differences between reaction rates of

[1] Tifoid ateş, kolera, giardiyazis (ishal), dizanteri, bulaşıcı hepatit, şistozomiyazis, gine kurdu, filariazis Tripanozomiyazis, sarıhumma, deng hastalığı, onkoserkiyazis (nehir körlüğü), sıtma (Kukul, Y., Çalışkan, Ü.A.D. & Anaç, S., 2007)

the ASM1 modelling were determined. This study, in which long-term daily data is used, the model has been evaluated and it is aimed to predict the working conditions and yields that can be the basis for such processes.

# 2. LITERATURE REVIEW

## 2.1 Biological Treatment Systems

Water pollution is important threat to the whole world. With the effect of pollutants discharged in the water sources, including solid wastes, water pollution and soil pollution occur (Patel, 2021). Although the characterisrics of wastewater are specific, it generally contains organic, colloidal, and inorganic substances and other toxic pollutants. It is forbidden to discharge wastewater containing pollutants above the discharge standards. This means that wastewater must be treated before being discharge to another environment. Treatment methods are physical, chemical and biological or their combinations, which have been used more and more in practice in recent years. Biological treatment is preferred due to its high success, energy efficiency and cost-effectiveness (Yahui, 2022). To determining the biological treatment method, the characteristics of the wastewater is important. Biological treatment methods can be divided into aerobic and anaerobic. Among the aerobic applications;

Activated Sludge,

Biofilm,

Stabilization Pond,

Aerated Lagoons.

Among the anaerobic applications;

Anaerobic sludge reactors,

Anaerobic film reactors

Anaerobic filters (Olcay, 2014).

### 2.1.1 Conversation of organic matter in aerobic and anaerobic conditions

Oxygen is the electron acceptor in the oxidation state of organic matter under aerobic conditions. Hetrotrophs perform this conversion. Since the removal of organic matter is important in wastewater treatment, aerobic systems with good flocculation of biomass are preferred. Thus, the SS concentration will be lower. It is suitable to be used in the treatment of wastewater with an organic load of chemical oxygen demand

(COD) < 1000 mg/L. It works in the pH range of 6.5 – 8.5. The illustration of the aerobic conversion process is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy \quad (2.1)$$

Thanks to this mass balance, the required amount of oxygen and the amount of output carbon dioxide can be calculated (Rathore, 2018).

In anaerobic processes, the organic matter is stabilized in three steps. First, hydrolysis takes place. In the next step, acetogenesis takes place. Finally, methanogenesis takes place. The output products are $CH_4$, $CO_2$ and water. The efficiency of anaerobic processes is lower than that of aerobic processes. Its advantage is that the output products can be used as raw material for another process. This is bioenergy. It is more suitable for wastewater with a COD > 4000 mg/L load. The illustration of the aerobic conversion process is as follows:

$$C_6H_{12}O_6 \rightarrow 3CH_4 + 3CO_2 + Energy \quad (2.2)$$

### 2.1.2 Conversation of organic substances containing nitrogen

In recent years, it has been popular to do both carbon and nutrient removal at the same time. This is called simultaneous biological nutrient removal (SBNR). In these processes, removal is done by creating zones in the biomass or in separate reactors under different conditions. Thus, nirtification, denitrification and biological phosphorus removal processes occur simultaneously.

Nitrification process, ammonia is converted to nitrite and nitrate. Nitrification takes place in two steps in purification: Firstly, $NH_4^+$-N is transformed into $NO_2^-$N by means of nitrosomonas bacteria. It is then transformed into $NO_3^-$ by nitrobacter. These bacteria use carbon to convert inorganic matter. These are called autotrophs.

First step reaction:

$$2NH_4 + + 3O_2\ Nitrosomonas \rightarrow 2NO_2 - + 4H + + 2H_2O \quad (2.3)$$

Second step reaction:

$$2NO_2 - + O_2\ Nitrobacter \rightarrow 2NO_3^- \quad (2.4)$$

If both are written together;

$$NH_4 + + 2O_2 \rightarrow NO_3^- + 2H + H_2O \quad (2.5)$$

This type of bacteria has chemo-lithotrophic nature. They grow more slowly if the max specific growth rate is smaller and the SRT is longer. In this case, a high oxygen half saturation coefficient ($K_o$) value occurs for autotrophs who cannot tolerate less oxygen. If the dissolved oxygen concentration is lower than $K_o$; it causes the ammonia in the wastewater to not be removed (Rathore, 2018).

Denitrification process, nitrate ($NO^3$-N) is reduced to nitrogen gas ($N_2$). It takes place under anoxic conditions. Microorganisms are heterotrophic. Its reaction is as follows:

$$2NO_3 - + 2H + \rightarrow N_2 + 2.5O_2 + H_2O \quad (2.6)$$

In denitrification, oxygen and nitrate are electron acceptors. Denitrification requires a low-oxygen environment because there is an excess of oxygen inside the reactor (Rathore, 2018).

For various reasons, some techniques have been developed for nitrification and denitrification to occur together. Advantages:

• The amount of oxygen required for biological oxygen demand (BOD) removal and nitrification has decreased.

• No other carbon source is needed for denitrification.

• There is no need for settling between two processes.

• Settling efficiency has increased.

• The process has become more stable.

In this process, the carbon in the wastewater and the internal respiration of microorganisms are used for denitrification. Anoxic zone is needed for this process to take place in the same environment. For this reason, wastewater is recycled (Debik, 2017).

## 2.2 Activated Sludge Systems

Activated sludge systems can be used to treat wastewater of many different charazterizations. Basically, this process converts organiz pollutants into $CO_2$, $H_2O$ and biomass. The resulting biomass is removed from the system in the form of “sludge”. In classical activated sludge system, 0.5 mg dry weight biomass is formed per mg BOD. The sludge must be disposed of safely and economically, and the

treatment of this sludge costs 25-65% of the total operating costs (Gürtekin, 2006). In these systems, pollutants are used as nutrients and energy by microorganisms and are thus separated from the wastewater. According to the need; various configurations can be made for carbonaceous organic matter removal, nitrification and denitrification, and excess biological phosphorus removal. According to the process, it is possible to operate in aerobic, anaerobic and anoxic conditions. Biomass conservation is ensured by recycling the settled sludge. The amount that is not recycled is discarded as sludge. It is used for organic matter removal and nitification in aerobic processes. With nitrification, nitrifiers oxidize ammonium to nitrate. These processes are also named according to their location. Suspended growing processes are categorized as surface growing processes and hydride (surface and suspended) processes. Special modifications with multiple processes are also available (Çınar, 2010).

Activated sludge process are not convenient for wastewater with COD levels higher than 400 mg/L. CAS processes with a long hydraulic retention time are more economical and easy to operate comperad to other methods. However, it is a disadvantage that operational problems such a high energy requirement, excessive sludge production, coloring and foaming problems from time to time (Olcay, 2014). Designs for conventional activated sludge systems are based on carbon and other nutrients such as P, N. If there are non-biodegradable pollutants, the efficiency of this system will decrease (Toprak, 2006). In the process, the pollutants in the wastewater are consumed by the biomass. Therefore, carbonaceous material treatment is easily accomplished with these processes. However, N, P removal is more difficult in comparison. Activated sludge processes are operated in various configurations for the removal of these nutrients. A classical activated sludge process flowchart Figure 2.1 is included.

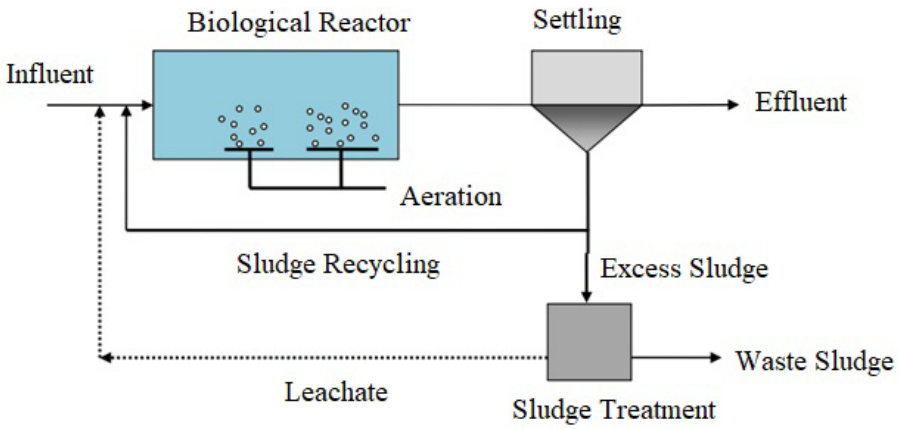


**Figure 2.1 :** Conventional activated sludge process flow chart (Kırım, 2015).

It is seen in the above figure that the biomass precipitated in the settling tank is returned to the biological reactor by recycling. Thus, the sludge age and F/M ratio of the created design unit, can be regulated at the required levels. Sludge waste is removed from the system by being pumped from the bottom of the settling tank. The active biomass in the process gains the energy required for growth and reproduction by oxidizing organic matter. The oxygen required for oxidation is provided by the aeration system. Growing microorganisms consume the substrate, which is the source of nutrients, by being suspended or suspended on the surface. Microorganisms consume organic matter and nitrate according to their species. Thus, organic matter and nitrate are converted into their stable forms. This type of bacteria is called heterotroph. Heterotrophic bacteria utilize dissolved organic carbon as a substrate in an aerobic environment. Oxygen acts as an electron acceptor (Orhon, 1994). In anoxic environment, heterotrophic bacteria that remove nitrogen, use $NO_3$ as electron acceptor. As a result, $NO_3$ is oxidized to $N_2$ gas. Another group of organisms are autotrophs. Autotrophic bacteria use $NH_4$ as a substrate in the presence of oxygen. Oxygen acts as an electron acceptor. Thus, oxidation to nitrate nitrogen is provided. Excess bacteria and inert substances are removed from the system as waste sludge. This is the basic working logic of activated sludge processes (Kırım, 2015).

### 2.2.1 Substrate removal

Excessive sludge production can be reduces during the treatment of wastewater with the CAS. This approach is explained by substrate removal and population dynamics correlation. Production of biomass from metabolized substrate is the ratio of the

biomass production rate to the substrate consumption rate, as well as the ratio of the specific growth rate to the specific substrate removal rate (Low, 1990).

### 2.2.2 Microbial growth in activated sludge

Activated sludge process is the most commen process for secondary treatment in the developed world. This concept was widely adopted when it was introduced in the late 19th century and subsequently converted into a full-scale process by Arden and Lockett in 1913 at the Davyhulme sewage treatment plant in Manchester, United Kingdom. Being advantageous in terms of cost has accelerated the replacement of other technologies (Scholz, 2016). It is a biological treatment which is use suspended-growth mechanisms. Activated sludge benefits from microbial culture because of biodegrade organic matter in the presence of oxygen. Than it forms a flock for solid sepereation via gravity. Aeration is the main factor for this system. It can be supplied mechanical or diffused aeration. Retention times in between 5 – 14 hours in classical units but it can be rise to 24 – 72 hours in low load systems. This system performance depends on parasites which calls as microorganism (Stott, 2003)**.**

### 2.2.3 Nutrient removal

The processes developed for nutrient removal in CAS are as follows:

Single Stage Nitrification

Separate Stage Nitrification

Single Stage Nitrification-Denitrification

Nitrogen and Phosphorus Removal.

The success of nutrient removal depends on the characterization of wastewater and also environmental conditions.

**Nitrogen and phosphorus removal;**

Nitrogen and phosphorus removal systems are exposed to variable environmental conditions and varying pollution loads. In order to ensure continuos removal efficiency, appropriate and sufficient measurements should be made, proper process equipment should be used and automation systems should be established. In the design, first of all it should be started from the nitrification process. In the second

step, the denitrification process should be designed. Finally, a design should be made for phosphorus removal. This is the order of operations. In domestic wastewater which is mixed with industrial wastewater, the amount of degredable organic matter, the types of these substances and their degredation rates are different. The accordance of nitrogen and phosphorus removal processes for such wastewater should be investigated in detail. The biological phosphorus removal efficiency is directly related to the volatile fatty acid (VFA) concentration in the wastewater. If VFA concentration is high, phosphorus removal can be done with anaerobic reactor before removing nitrogen from wastewater.

If sludge age is longer than 4-5 days, it causes the loss of VFA which is required for nutrient removal. Heterotrophic bacteria meet their nutrient needs during the reproduction process by taking in phosphorus in the wastewater. This provides a phosphorus removal of 10-30% from the wastewater.

However, phosphorus-storing microorganisms store more phosphorus than they need for their bodies and remove phosphorus with an efficiency of 85-95% from wastewater. These microorganisms store VFA in wastewater and remove phosphorus from their bodies in anaerobic environments where there is no nitrate and dissolved oxygen. If anoxic and/or aerobic conditions is provided afterwards, they use the stored products in new cell synthesis and consume more than the phosphorus they release. Nitrogen removal efficiency from domestic wastewater depends on the the COD/ Total Kjeldahl Nitrogen (TKN) ratio in the influent wastewater. If COD/TKN<10 pre-denitrification systems, COD/TKN>10 post-denitrification systems are more useful. In such cases, Bardenpho type activated sludge system with multiple anoxic reactors and denitrification processes at the influent and effluent can be used (Çınar, 2010).

### 2.2.4 Endogenous decay

In CAS modelling, two basic processes are considered in the removal of organic carbon. The first is the multiplication of microorganisms by anabolic reactions, the second is endogenous decay. The existence of the endogenous decay process was demonstrated by Porges et al. (1953). Accordingly, it has been proven that oxygen consumption takes place in an aerobic conditions, even if the absence of nutrients (Porges, 1953). Endogenous decay is expressed as cell death and mass reduction. In

other words, endogenous decay means that when there is no food in the environment, the microorganism breaks down the edbogenous biomass to provide energy. The reduction in the amount of volatile suspended solids (VSS) used to describe endogenous respiration is due to the limited data obtained by measuring the parameter. However, in order for the biomass to be formed for desing to be disposed of as excess sludge and thus to operate the system in a balanced way, it is necessary to know the endogenous respiration kinetics as well as the increase kinetics of the biomass. In activated sludge process, the amount of sludge produced decreases as the sludge age increases. This proves the existence of endogenous respiration. In this case, as a result of the endogenous respiration process, an extra oxygen requirement arises in the activated sludge system. In CAS modeling, the reduction of biomass depending on the endogenous respiration coefficient is given in the following fist-order reaction:

$$d_X/d_t = -kd_x \quad (2.7)$$

$k_d$, endogenous respiration coefficient [$day^{-1}$]

X, amount of biomass [mg VSS/L]

In CAS models, dissolved oxygen consists of substrate and biomass. Endogenous respiration is expressed by the reduction of VSS. An endogeneous respiration coefficient is given for the sludge formed and the sludge reduction is calculated. In multicomponent models, the biomass is defined as “heterotrophic biomass” and the decrease in this biomass is expressed as an endogenous respiration. Sludge components are identified and the endogenous respiration coefficient is defined for heterotrophic biomas. Biomass reduction due to the endogenous respiration coefficient is a first-order reaction:

$$d_{XH}/d_t = -b_{HX} \quad (2.8)$$

$b_H$, endogenous respiration coefficient [$day^{-1}$]

$X_H$, total heterotrophic biomass [mg cell COD/L] (Okutman, 2010).

**2.3 SBR Systems**

The SBR is a type of reactor that works as a fill-and-draw system and is used in wastewater treatment. In this system, wastewater is filled into a reactor. All processes take place in this reactor. Multiple reactors can be used to optimize the system. SBR

systems are used for the treatment of both urban and industrial wastewater. Perfect for intermittent or low flow wastewater. Its history dates back to the 1910s. However, interest in SBRs increased after 1950 and new technologies were developed. Especially with the development of aeration equipment, SBR performance has increased significantly. In 1983, the U.S. The EPA report stated that the SBR system is the conventional activated sludge system. Only the time-determined sequence of the SBR is its distinguishing feature (EPA, 1999).

SBR type reactors take a certain volume of wastewater into the sludge, remaining from the previous cycle, in a certain part of the total cycle time in activated sludge systems. When the cycle is complete, the treated water is discharged intermittently. Each time, a certain amount of wastewater is taken and a certain amount is discharged. In this way, there is no need for a pump to return sludge and nitrogenous organic materials to the activated sludge process. Wastewater can be treated at continuous flow without the need for more than one tank or pool. Also called fill-and-empty systems. If each cycle continues under the same conditions, the system becomes steady. The duration of all processes can be controlled. Step-feeding regime is possible. This enables different processes to be operated in the same area without the need for a different area. The cycle can be started with the desired operation, under the desired conditions. The desired conditions can be repeated in the cycle. Only after the anaerobic condition does not the anoxic condition come. There should be aerobic condition in between. Filling can also be done in one go or several times. The tank where the biological processes take place in the SBR is also the settling tank. Since there is no need for a pump in the return of sludge and nitrogenous organic matter, energy consumption is also less. But since everything is automatic, it requires an advanced control and automation system (İnsel, 2021).

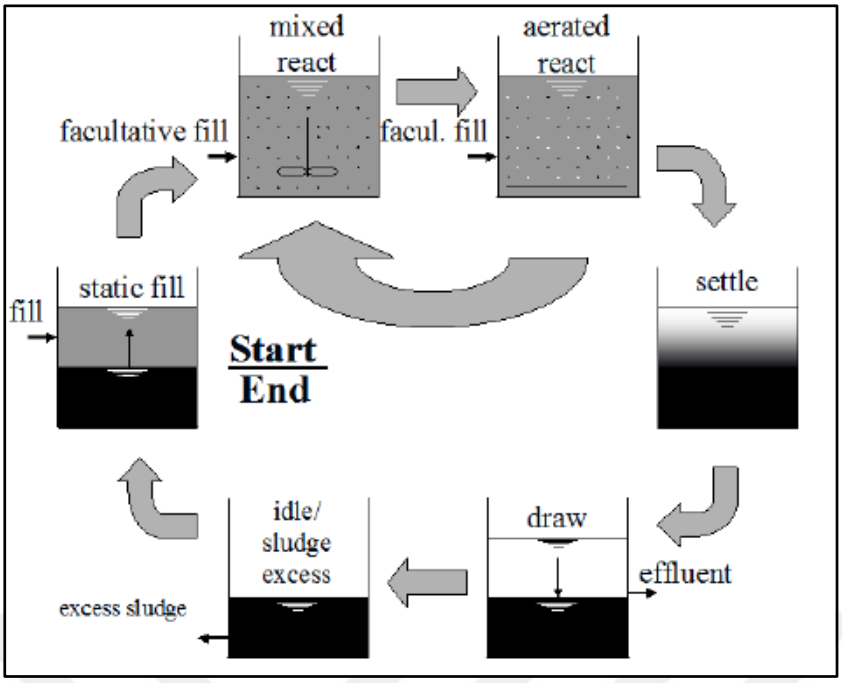


**Figure 2.2 :** SBR processes in one cycle (Juergen, 2003).

In addition to its SBR performance in recent years, it has been observed that it exhibits nitrogen removal performance by forming aerobic and anoxic zones. It is also used for this purpose in many facilities (Irvine, 1988). Time allocation on SBRs are used for nitrification and denitrification (Blackburne, 2008). During the filling and anoxic process, nitrate remaining from the previous cycle is removed by denitrification. After denitrification comes the aerobic process. Nitrification is done with oxygen. Afterwards, the anoxic process continues. Treatment is achieved with this cycle. After the reaction cycle is complete, the settling phase begins. Then the decant phase takes place. Thus, the treatment with the SBR system is completed.

### 2.4 Modelling Approach

Modeling can be used for many different purposes. Making current situation analysis and determining optimum conditions are the primary objectives. It also helps in the development of wastewater treatment plants. Modeling is also used to evaluate a prepared project. Modeling has also proven beneficial for operators working in the treatment plant. With simulations, the effects of changing inputs, operation strategies (waste load, flow rate change, return water, etc.) are evaluated (Hug, 2009).

### 2.4.1 Modelling of activated sludge

In activated sludge systems, it is important to determine the characteristics of wastewater, to determine the process kinetics, and to determine the quality of the effluent. The total amount of organic matter must be known for both BOD and COD determination. To be able to model, the COD fractions must be known. Modeling is a valuable method for designing for treatment systems. It allows to analyze the role and effects of parameters in the total. Thus, it helps to understand and optimize the entire process. In 1983, IAWO (International Association of Water Quality) established a group for model development studies for use in biological wastewater treatment systems. The primary aim was to examine existing models, then to create a common model for predicting the efficiency of carbon removal, nitrifying and denitrifying systems. In 1987, the decision was made on the Activated Sludge Model No.1 (Ulf Jeppsson, MSc, PhDDept of Industrial Electrical Engineering and Automation Lund Institute of Technology Lund, Sweden). All models used today are based on the ASM1. This model is designed for domestic or urban wastewater treatment. It should be modified for industrial wastewater. ASM1 works by considering three components: Biomass, substrate and oxygen (Olcay, 2014). IAWQ developed ASM2 after ASM1 and recently ASM3. These models are simple models that simulate the working processes of activated sludge systems. The reason for the widespread use of these models is their high adaptability to different conditions (Sabri, 2017).

### 2.4.2 Dynamic modelling

Modeling is necessary to describe and interpret biochemical reactions under certain conditions. It also provides forecasting for inaccessible processes. It helps to determine control actions. When we examine the dynamic models, they are suitable for the following situation:

Intracellular activities, components resulting from activity and metabolism are constantly changing. While this change is taking place, the model has to keep up with it. So the new process must be configured. For this, kinetic parameters are needed. In order to derive the correct equation, dynamic models are formed by combining the stoichiometry of the reaction, redox potentials and biochemical processes (Çığgın, 2011). Modeling studies for wastewater treatment plants are

popular all over the world. The dynamic modeling is derived from the steady-state model of Ekame and Marias. To the working group formed in 1987, Prof. Henze led the way. The ASM1 model, which was created for the biological purification of carbon and nitrogen, was prepared. The basis of this model is based on the model developed by the University of Cape Town (Ndeba-Nganongo, 2018). If check dynamic modeling; conditions similar to real conditions can be created. This ensures accurate results. However, variations in load and legal limits are the biggest challenges of operating the plant. At the same time, the characteristics of the inlet wastewater also affect the success of the facility. The fact that there are dynamic variables of wastewater has revealed the need for simulation (El-Din, 2002).

### 2.4.3 Multi-component activated sludge models

Multicomponent models contain both biomass data and substrate data. Thus, activated sludge systems are better understood. Traditional models fall short of multi-component models. With this type of models, the characteristics of wastewater can also be determined (Ciner, 2005)**.** In addition, in modeling of multi-component activated sludge systems, biomass reduction is associated with internal respiration, unlike the conventional system (Okutman, 2010).

#### 2.4.3.1 ASM 1 model

The model was developed in 1987. It is designed for activated sludge systems involving carbon removal, nitrification and denitrification processes. A total of eight processes were modeled, including three biomass growth, two degradation processes, organic N ammonization and two hydrolysis processes. There are nineteen model parameters. Accepted values are available. Before use, the inlet wastewater must be defined. When using the ASM1 model, pH is assumed to be near neutral. Arrerenius equations can be used to model temperature changes as well (Carlsson).

#### 2.4.3.2 ASM 2 model

The purpose of the development of the ASM2 model is to dynamically simulate the removal of COD, nitrogen and phosphorus. It is an improved version of the ASM1 model. It is not the only model made in this field, and it is not the latest model either. The ASM2 model is more complex than the ASM1. Due to its complexity, wastewater can be analyzed better. In particular, the results related to phosphorus

removal are interesting. In addition, the intracellular structure of the biomass is taken into account in the ASM2 model. That is, it is defined in more detail (Henze, 1995). The later developed ASM2d model is a higher version. It also includes two more processes. PAO (Phosphorous Accumulation Organisms) is considered to grow under aerobic conditions. The products stored by these organisms are used for denitrification. The formation of PAOs is different from ASM2 (Taşkınoğlu, 2008).

### 2.4.4 Determining model parameters

While modeling classical activated sludge systems, the parameters to be used must be based on previous test results and initial measurement results. Then, optimum values are determined according to these results.

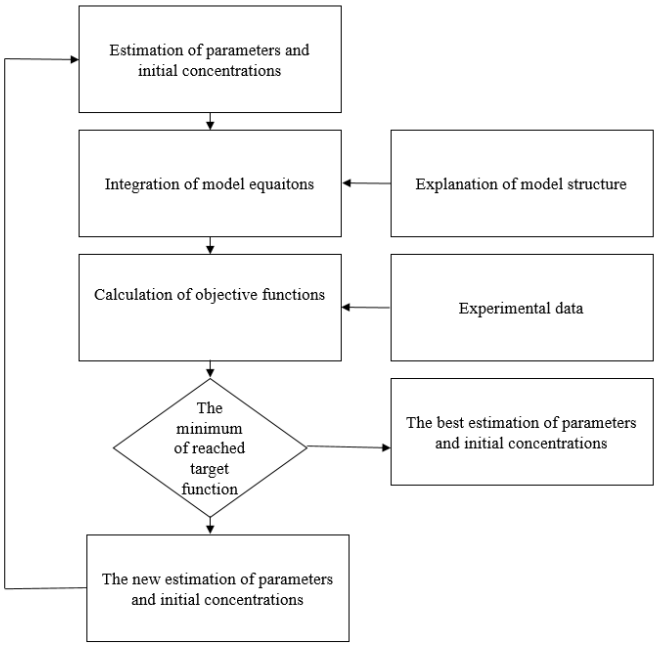


**Figure 2.3 :** Parameter estimation steps (Taşkınoğlu, 2008).

### 2.4.5 Effect of model parameters

Knowing the kinetic and stoichiometric parameters for ASM1 and ASM2 is important for wastewater characterization. The COD found in the wastewater at the inlet is as follows:

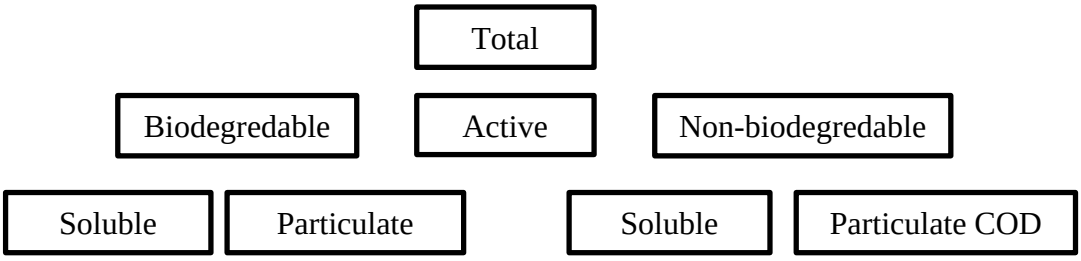


**Figure 2.4 :** COD fractions influent (Taşkınoğlu, 2008).

COD fractions depend on $Y_H$ (heterotrophic yield). While kinetic parameters are found; it is recommended to find parameters related to heterotrophic and autotrophic activities. Maximum specific growth rate is obtained by Monod Kinetics ($K_s$ and $K_{NH}$). It is also important to know the maximum hydrolysis rate ($K_h$) and semi-saturation constant ($K_x$) in ASM models. Again, internal respiration is an important parameter of the model. It is directly related to the amount of sludge to be produced. In the model, the precipitator information is related to each other in terms of determining the quality of the effluent (Taşkınoğlu, 2008).

### 2.5 Simulation Platform: SUMO, By Dynamita

SUMO Software was developed by France-based company Dynamita. It is a user-friendly software. With SUMO, traditional biokinetic models can be simulated dynamically or steady-state, mixed equilibrium-kinetic models and direct algebraic models. There are seven most known models (Dynamita, 2022). The open source code of the software also enables the calculations of the model to be understood. It also allows the user to code the process model and define parameters and parameter valus (Svennevik, 2019). In addition to these; SUMO Simulation considers the typical biological and physico-chemical reactions of activated sludge systems. It offers the opportunity to study different groups of organisms:

i) Heterotrophs (BOD removal and denitrification)

ii) Using methanol (BOD removal in anoxic conditions)

iii) Involved in the nitrification process

iv) Phosphate accumulating organisms (PAO)

v) Acidclastic (AMETO) and Hydrogenotrophic methanogens (HMETO).

The physico-chemical model takes into account:

i) Chemical phosphorus removal (Iron dosage, Surface Complexation Model)

ii) Settling (ACP, Struvite, Vivianite)

iii) Chemical balance for pH calculation

iv) Gas transfer (Svennevik, 2019).

SUMO Simulation is innovative and versatile. For wastewater treatment plants; it has the ability to model the removal of BOI, nitrogen, phosphorus. Digester, side streams, integrated fixed-film activated sludge (IFAS) and, moving bed biofilm reactor (MBBR), SBRs, trickling filters, primary and final settling, thickeners, centrifuges, are process units typically found in SUMO used in municipal and industrial treatment plants. While doing this, digester, IFAS, MBRR, trickling filters, primary and final settling, thickeners, centrifuges are available in SUMO as processes. These processes are frequently used in domestic and industrial wastewater treatment plants. The model interface has multiple models including ASM (ASM1, ASM2D, ASM2D_TUD, ASM3 and ASM3_BioP), Barker_Dols and BUCTPHO+. SUMO models can run on several different interfaces. The ADM1 model is the most suitable model for the design of anaerobic processes. But there is no in SUMO. For this reason, it can be used by converting ADM1 state variables to ASM1 model variables (Ndeba-Nganongo, 2018).

This modeling study and research was carried out using the environmental process simulator SUMO (Dynamita Nyons, France).

### 2.5.1 SUMO model structures

The model is dynamic - biokinetic in SUMO. State Variables are concentration in SBR and parameters are growth rate, endogeneous decay rate. Biochemical model based on biomass growth for SBR and COD/N removal.

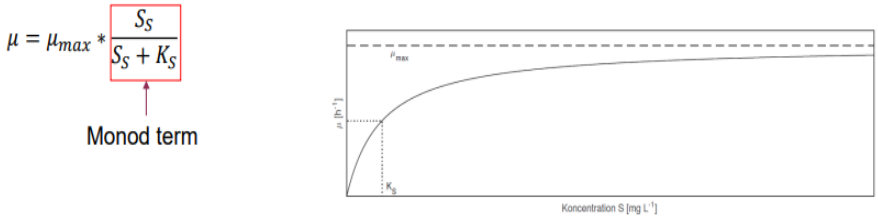


**Figure 2.5 :** Monod growth kinetics for biomass.

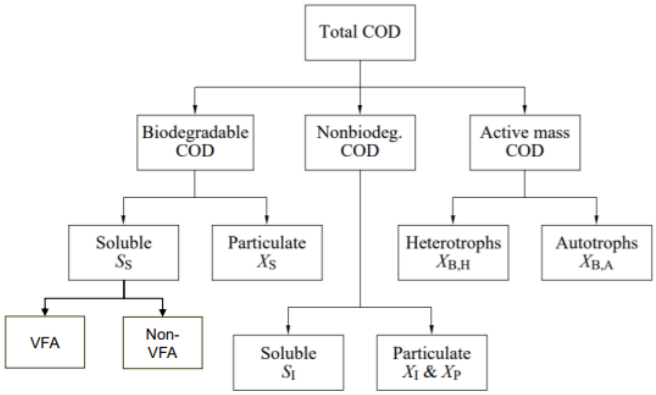


**Figure 2.6 :** Detailed distribution of measured pollutants into model COD fractions in SUMO, Dynamita (Wärff, 2019).

Table 2.1 shows default fractions in SUMO dynamic modelling tool. It is also stated in the SUMO Manual that these rates werw arranged according to literature studies. However, it is possible to change it according to the fractions to be used in the study.

**Table 2.1:** Default COD fractions in SUMO (Dynamita, 2022).

| Name | Default Fractions |
|---|---|
| Fraction of VSS/TSS | 84.86% |
| Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 40.47% |
| Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 20.23% |
| Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 11.76% |
| Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 11.76% |
| Fraction of particulate unbiodegradable organics (XU) in total COD | 14% |
| Fraction of heterotrophs (OHO) in total COD | 5% |
| Fraction of endogenous products (XE) of OHOs | 20% |
| Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 20% |

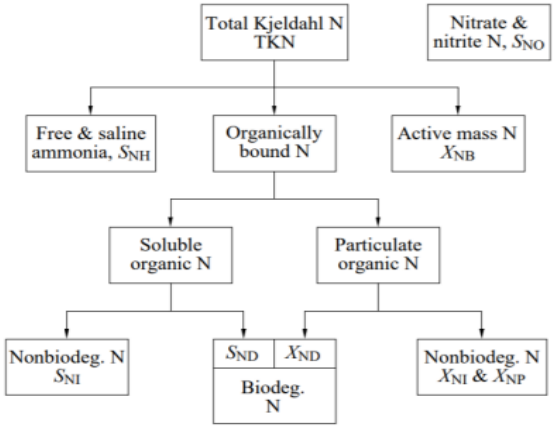


**Figure 2.7 :** Detailed distribution of measured pollutants into model fractions nitrogen in SUMO, Dynamita (Wärff, 2019).

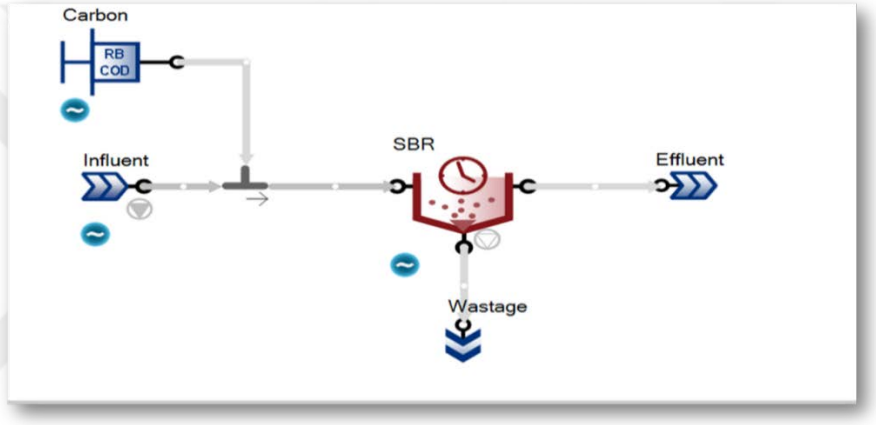


**Figure 2.8 :** Experimental setup flow chart.

| | General full plant models | | | Focus models | | |
|---|---|---|---|---|---|---|
| | **Mini_Sumo** | **Sumo1** | **Sumo2** | **Sumo2S** | **Sumo2C** | **Sumo4N** |
| **COD removal** | x | x | x | x | Two populations: OHO and AHO | x |
| **EPS production** | | | | | x | |
| **Denitrification** | 1-step | 1-step | 2-step | 2-step | 2-step | 4-step |
| **Hydrolysis** | x | x | x | x | x | x |
| **Fermentation** | x | x | x | x | x | x |
| **Anoxic methylotrophs** | | x | x | x | x | x |
| **Nitrification** | 1-step | 1-step | 2-step | 2-step | 2-step | 4-step |
| **EBPR (PAO-GAO model)** | | x | x | x | x | x |
| **Three-population anaerobic digestion** | x | x | x | x | x | x |
| **Temperature sensitivity** | x | x | x | x | x | x |
| **Precipitation** | | x | x | x | x | x |
| **Chemical P removal** | based on ASM2d approach | Kinetic approach | Kinetic approach | Kinetic approach | Kinetic approach | Kinetic approach |
| **Sulfur cycle** | | | | x | | |

**Figure 2.9 :** Main processes included in SUMO whoke plant models (Dynamita, 2022).

# 3. MATERIALS AND METHOD

## 3.1 Characteristics of Wastewater

In addition to the changing demographic trends around the world, stricter monitoring of the legal regulations according to the countries has brought along new searches in wastewater treatment. It is important to know the wastewater characteristics well, in order to determine the preferred technological method while fulfilling these requirements. In general, when determining the characteristics of wastewater, organic matter content, mineral and gas measurements, alkalinity, BOD, COD, nitrogen compounds, pH, phosphorus, and solids are examined. It is especially important to know the COD in terms of oxidizable organic matter content (Balanica, 2020). As it is known, a large part of domestic wastewater originates from human activities. Up to 90% of the consumed water occurs as wastewater. Domestic wastewater contains high amounts of organic matter, phosphorus and nitrogen compounds. Approximately 75% of domestic wastewater coming to treatment plants originates from residences. The rest comes from businesses, offices and public institutions (Wulan, 2022).

The data used in this study were obtained from experimental analyzes by (Karlikanovaite, 2019). For the experimental studies, samples were taken from the Istanbul Baltalimanı Wastewater Treatment Plant. It was stated in the study by (Karlikanovaite, 2019) that the samples taken were subjected to settling process and stored at 4°C. In the same study, it was reported that glucose was added as an "extra carbon source" due to the low COD/TKN ratio. This addition was made for full nitrification. The characteristics of the wastewater and glucose mixture used in the experimental studies are given below. Among the information about the study, there is also the information that the CAS-SBR is fed with the same wastewater continuously for 100 days. It is also informed that the pH value of the wastewater for CAS-SBR is measured as 7.71±0.2 and alkalinity as 370±99.

**Table 3.1 :** Real wastewater characteristics in CAS process (Karlikanovaite, 2019).

| | tCOD (mg/L) | sCOD (mg/L) | TKN (mg/L) | $NH_4$-N (mg/L) | MLSS (mg/L) | MLVSS (mg/L) |
|---|---|---|---|---|---|---|
| CAS-SBRs | 294±78 | 154±50 | 59±21 | 32±11 | 196±74 | 110±34 |

### 3.2. Experimental Principles of CAS-SBR System

Experiments were carried out with cylindrical SBR. Inoculation sludge was taken from the aeration tank of the biological wastewater treatment plant and SBRs were inoculated with that. The CAS was operated with a total volume of 3.4 L ($VT_{SBR}$) and an initial volume of 2 L. Duration of the stages are shown in Figure 3.1.

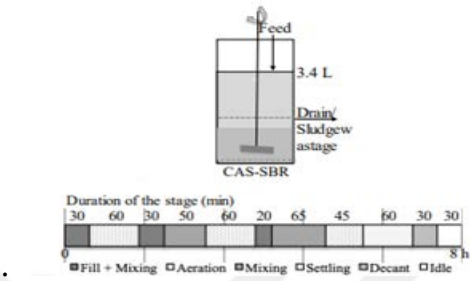


**Figure 3.1 :** Schematic presentation of CAS system and operational durations of stages in each sequence of SBR (Karlikanovaite, 2019).

Two active conventional activated sludge systems are named as CAS-SBR. It was stated that one CAS-SBR sludge age was 13 days and the other was 20 days. Sludge ages were checked for all CAS-SBR with discharged sludge. SBR cycles are adjusted with Digital Timers. Aeration equipment is located at the bottom of the each reactor. In addition, there are mixers in all reactors to ensure homogeneous distribution. The whole experimental setup was carried out in an environment at a constant temperature of 20ºC. HRT was kept constant for all systems at 19.4 hours. Each CAS-SBR was operated three times a day. These will also be referred to as 8h/day cycles. Each cycle consists of 5 minutes of feeding time, 2 hours and 45 minutes of aeration and 3 hours and 15 minutes of mixing. Finally, there is a settling/discharge and idle phase for 2 hours. In order to increase the treatment performance of nitrogenous substances, step-feeding regime was used to form anoxic/aerobic zones in all CAS-SBRs (Cokgor, 2005). In order to have less nitrogenous substance in the treated effluent water, more time was allocated for the anoxic times within the reaction time. Aeration was done for 60 minutes, another 60 minutes and 45 minutes. Operation times are given in Table 3.2.

**Table 3.2 :** Operation strategy (Karlikanovaite, 2019).

| Operation | Duration |
|---|---|
| Fill + | 30 min |
| Aeration | 60 min |
| Fill + | 30 min |
| Mixing | 50 min |
| Aeration | 60 min |
| Fill + | 20 min |
| Mixing | 65 min |
| Aeration | 45 min |
| Settling | 60 min |
| Decant | 30 min |
| Idle | 30 min |

CAS-SBRs were operated for sludge ages of 13 days, 17 days and 20 days. Data for 17 days were not used in this study. In order to obtain these selected SRTs, sludge was removed from the system once at the end of the cycle. Its calculation is (3.1);

$$QW_i = VT_{SBR} / SRT_i \quad (3.1)$$

CAS-SBRs were operated in parallel for 100 days. All CAS-SBR systems were operated with real domestic wastewater samples taken from the grit chamber outlet of the Istanbul Baltalimani Wastewater Treatment Plant. Wastewater samples were taken weekly. During the mean winter condition of the incoming wastewater sample, the TCOD level was measured as 294±78 mg/L. This value represents a low COD wastewater (COD < 400 mg/L). Because of that an external carbon source was added

to have a COD/TKN ratio of 10. Glucose was chosen as the carbon source (Mara, 2003). Specific characteristics of the wastewater are given in detail in Section 3.1.

### 3.3 SUMO, Dynamita Modelling

The basic model considers the typical biological and physico-chemical reactions of activated sludge and aerobic treatment. Different groups of organisms are involved in these processes (i) heterotrophs (removal of organic matter and denitrification); (ii) methanol-consuming organisms (COD removal under anoxic conditions); (iii) nitrifiers (nitrification). This model considers nitrogen removal and COD removal (Hauduc, 2019). A conventional activated sludge model (Sumo1) by Dynamita, considers biological reactions of activated sludge. This was a base model. Related parameters are changed for various scenarios. This model was modified with components which were required for cyclic working instructions. Steady state and dynamic simulation options are available in SUMO tool. It covers ASM1, ASM2d, ASM3, Barker-Dold, ADM1 and many more (Dynamita, 2022).

In this study, the SUMO1 model was used. After the plant configuration was completed in the SUMO dynamic modeling tool described earlier, the operating configurations were tested. The model includes one-stage nitrification and one-stage nitrification processes. In addition, the model approach is also explained as kinetics. In other words, SUMO, the operating platform of the kinetic model, is the Dynamita dynamic modeling tool. The proposed process is designed for the kinetic model. The values of some constants such as kinetic parameters and stoichiometric coefficients used in the model structure were also determined. Stoichiometric coeffcients and modified kinetic coefficients data summarized in Table 3.3. Various simulations were made in SUMO software using the data obtained from the experiments with real wastewater and the kinetic coefficients determined with the AQUASIM software in a (Karlikanovaite, 2019) study. Model simulation of SUMO software is based on the growth rate, decay rate and single-stage hydrolysis. The simulations were done in dynamic mode. As a result of the simulations, the effluent quality was compared with the experimental data. The obtained results were evaluated for four different case study scenarios.

### 3.4 Case Studies

For this study, 4 different case analyzes were conducted. Each case analysis was performed for both SRT 13 and SRT 20. The first case analysis was named as Case 1. In this case analysis, both coefficients and fractions were used the same as those used in the ASM1 modelling in the results of the Karlikanovaite (2019). Case 1 modified coefficients which are different from SUMO as $\mu_{NITO}$: 0,25 $d^{-1}$, $\mu_{OHO}$: 6 $d^{-1}$, $b_{OHO}$: 0,35 $d^{-1}$ and $b_{NITO}$: 0,04 $d^{-1}$. Fractions were SCCOD 30%, SCOD 14% frVFA 30% frSU 20% and frVSS/TSS 75%.

The second case analysis was named as Case 2. For this case study, the coefficients were left the same, but the fractions of the Özyıldız (2017) were used. Case 2 modified coefficients which are different from SUMO as $\mu_{NITO}$: 0,25 $d^{-1}$, $\mu_{OHO}$: 6 $d^{-1}$, $b_{OHO}$: 0,35 $d^{-1}$ and $b_{NITO}$: 0,04 $d^{-1}$. Fractions were SCCOD 37%, SCOD 22,2% frVFA 24%, frSU 13,3% and frVSS/TSS 75%.

The third case study was named as Case 3. In this case study, the coefficients and fractions in the modeling program SUMO, Dynamita are used as they are. No changes were made before the simulation. Case 3 modified coefficients which are different from SUMO as $\mu_{NITO}$: 0,9 $d^{-1}$, $\mu_{OHO}$: 4 $d^{-1}$, $b_{OHO}$: 0,17 $d^{-1}$ and $b_{NITO}$: 0,62 $d^{-1}$. Fractions were SCCOD 37%, SCOD 22,2% frVFA 24%, frSU 13,3% and frVSS/TSS 84,86%.

The fourth case study was named as Case 4. In this case study, the coefficients were used as they were in the modeling program. Fractions were taken from Özyıldız (2017). thesis study Case 1 modified coefficients which are different from SUMO as $\mu_{NITO}$: 0,9 $d^{-1}$, $\mu_{OHO}$: 4 $d^{-1}$, $b_{OHO}$: 0,17 $d^{-1}$ and $b_{NITO}$: 0,62 $d^{-1}$. Fractions were SCCOD 37%, SCOD 22,2% frVFA 24%, frSU 13,3% and frVSS/TSS 75%.

All four case studies were applied for both sludge ages. The simulation results were compared with the results of the experimental data and the usability of the SUMO, Dynamita dynamic model was tested.

#### a) Parameters affecting in CAS

In order to evaluate the kinetic behavior according to sludge production in activated sludge processes, first of all, the mass balances of CAS should be well understood.

Like sludge retention time (SRT), heterotrophic yield ($Y_{NH}$) and observed yield ($Y_{OBS}$) etc. important parameters must be known. These parameters enable to analyze the sludge produced in the CAS system (Allı, 2017). In conventional activated sludge processes, the removal of COD and nitrogenous substances that are expected to be removed by creating and aerobic/anoxic zones, which must be at the legal limit in the effluent, is the focus of this study. Two different SRT (13 days and 20 days) results were obtained in the simulations created for the treatment efficiency. Also, the yield of autotrophic microorganism under aerobic conditions was observed. Within the scope of modeling studies, SUMO software was used for process simulation and estimation of kinetic coefficients. Estimated effluent parameters were determined as COD, $NH_4$ and $NO_x$. In addition, SCOD and $NH_4$ data were evaluated for the samples taken from the reactor for an 8-hours cycle. $NO_x$ assessment was not performed due to the lack of experimental data results.

### 3.5 Determination of Model Parameters

The coefficients were changed on the determined situations and the response of the model were investigated. By using the data of Istanbul Baltalimanı Wastewater Treatment Plant, time-dependent performance was monitored by dynamic modeling. In order to determine the process performance, SCOD, $NH_4$ and $NO_x$ parameters of the plant effluent water were selected for modeling. 100 days of data were used to determine the plant performance. The reason for choosing SCOD, $NH_4$ and $NO_x$ is the COD removal in a single tank and the measurement of nitrogenous substances removed by aerobic/anoxic processes. In Table 3.2, the parameters examined during the simulations are listed. A number of parameters have been modified for each case the results were discussed.

**Table 3.3 :** Coefficients for case studies.

| Symbol | Name | Unit |
|---|---|---|
| $\mu_{NITO}$ | Maximum specific growth rate of NITOs | d-1 |
| $\mu_{OHO}$ | Maximum specific growth rate of OHOs | d-1 |
| $b_{OHO}$ | Decay rate of OHOs | d-1 |

**Table 3.3 (continued) :** Coefficients for case studies.

| Symbol | Name | Unit |
|---|---|---|
| $b_{NITO}$ | Decay rate of NITOs | d-1 |
| KHYD,AS | Half-saturation of particulates in hydrolysis (AS) | g COD.g COD-1 g |
| YOHO,VFA,ox | Yield of OHOs on VFA under aerobic conditions | XOHO.g SVFA- 1 |
| KSB,AS | Half-saturation of readily biodegradable substrate for OHOs (AS) | mg COD/L |

In Table 3.2, the equivalents of the kinetic and stoichiometric coefficients used in the previous ASM1 modeling in the dynamic modeling program SUMO are listed.

**Table 3.4 :** Comparison of coefficients for case studies.

| **Literature** (Karlikanovaite, 2019) | **Symbol** | **Unit** | **Value** | **SUMO** | **Symbol** | **Value** | **Unit** |
|---|---|---|---|---|---|---|---|
| Yield coefficient of $X_H$ | $Y_H$ | gr COD/ gr COD | 0.67 | Yield of OHOs on VFA under aerobic conditions | YOHO, VFA,ox | 0.67 | gr XOHO / gr SB |
| Yield coefficient of $X_A$ | $Y_A$ | gr COD/ gr COD | 0.24 | Yield of NITOs | | 0.24 | gr XNITO / gr SNHX |
| Maximum growth rate of heterotrophs | $\mu_H$ | 1 / d | 6 | Maximum specific growth rate of OHOs | $\mu_{OHO}$ | 4 | 1 / d |
| Maximum growth rate of autotrophs | $\mu_A$ | 1 / d | 0.25 | Maximum specific growth rate of NITOs | $\mu_{NITO}$ | 0.9 | 1 / d |

**Table 3.4 (continued) :** Comparison of coefficients for case studies.

| **Literature** (Karlikanovaite, 2019) | **Symbol** | **Unit** | **Value** | **SUMO** | **Symbol** | **Value** | **Unit** |
|---|---|---|---|---|---|---|---|
| Endogeneous decay rate of $X_H$ | $b_H$ | 1 / d | 0.35 | Decay rate of OHOs | $b_{OHO}$ | 0.62 | 1/d |
| | | | | | $b_{NITO}$ | | |
| Endogeneous decay rate of $X_A$ | $b_A$ | 1 / d | 0.04 | Decay rate of NITOs | | 0.17 | 1/d |
| Maximum hydrolysis rate for $X_S$ | $k_{hx}$ | 1 / d | 0.03 | Rate of hydrolysis | $K_{Hx}$ | 0.083 | 1 / d |
| Maximum hydrolysis rate for $S_H$ | $k_h$ | 1 / d | 0.5 | | | | |

**Table 3.4 (continued) :** Comparison of coefficients for case studies.

| **Literature** (Karlikanovaite, 2019) | **Symbol** | **Unit** | **Value** | **SUMO** | **Symbol** | **Value** | **Unit** |
|---|---|---|---|---|---|---|---|
| Half saturation constant for growth | $K_s$ | mg COD/ L | 20 | Half saturation of readily biodegredable substrate for OHO | KSB,AS | 5 | mg COD/ |
| Hydrolysis half saturation constant for $S_H$ | $K_x$ | gr COD/ gr COD | 0.03 | | KHYD,AS | | |
| Hydrolysis half saturation constant for $X_S$ | $K_{xx}$ | gr COD/ gr COD | 0.01 | Half saturation of particulate in hydrolysis (AS) | | 0.05 | gr COD / gr COD |
| Active biomass fraction | $(X_A+X_H)/X_T$ | % | 75 | Fraction of VSS/TSS | | 84.86 | % |

### 3.5.1 Case studies for SRT 13 days

**a) Case 1 - SRT 13 days**

The coefficents are shown in Table 3.3 and fractions are shown in Table 3.4 For this case coefficients and fractions were selected from literature. This selection is important for comparing results. Also the influent fraction values can be examined at the Table 3.5 Table 3.6 is important to see which parameters are generally used in wastewater treatment plant design and what are the values for this design.

**Table 3.5 :** Modified coefficients for Case 1 - CAS13.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0.25 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 6 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0.35 | d-1 |
| KSB,AS | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0.04 | d-1 |
| KHYD,AS | Kinetic | Half-saturation of particulates in hydrolysis (AS) | 0.03 | g COD.g COD-1 |
| YOHO,VFA,ox | Stoichio. | Yield of OHOs on VFA under aerobic conditions | 0.67 | g XOHO.g SVFA-1 |

**Table 3.6 :** Influent fractions for Case 1– CAS13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 30 | % |
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 14 | % |
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 30 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 20 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) in total COD | 10 | % |
| frXOHO,TCOD | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| frXE,XOHO | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 16 | % |
| frSNH$_x$,TKN | Fraction of NHx in total Kjeldahl nitrogen (TKN) | 69.2 | % |
| frSPO$_4$,TP | Fraction of $PO_4$ in total phosphorus (TP) | 50 | % |

**Table 3.7 :** Frequently used varibales for case 1– CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370.00 | 5931.14 | mg COD/L |
| Total suspended solids (TSS) | 203.31 | 5986.20 | mg TSS/L |
| Volatile suspended solids (VSS) | 152.48 | 4248.60 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 159.06 | 2110.06 | mg $O_2$/L |

**Table 3.7 (continued) :** Frequently used varibales for case 1– CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Dissolved oxygen ($O_2$) | 0.00 | 7.65 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 26.99 | mg $O_2$/L/h |
| Total nitrogen | 56.00 | 366.25 | mg N/L |
| Total ammonia ($NH_x$) | 38.75 | 43.00 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0.00 | 0.03 | mg N/L |
| Total phosphorus | 4.00 | 102.15 | mg P/L |
| Orthophosphate ($PO_4$) | 2.00 | 0.00 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0.00 | mg $O_2$/L |

**b) Case 2 - SRT 13 days**

The coefficents are shown in Table 3.6 and fractions are shown in Table 3.7 For this case coefficients were selected from doctoral study (Karlikanovaite, 2019). Fractions also selected from another study (Özyıldız, 2017). Also the simulated values at the effluent and inside the reactor are in Table 3.8 can also be examined. When examined, it will be seen that there is a difference between Table 3.6 and Table 3.9 from the data taken from the SBR.

**Table 3.8 :** Modified coefficients for Case 2– CAS13.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,25 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 6 | d-1 |
| $K_{SB,AS}$ | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |

**Table 3.8 (continued) :** Modified coefficients for Case 2– CAS13.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,35 | d-1 |
| KSB,AS | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,04 | d-1 |
| KHYD,AS | Kinetic | Half-saturation of particulates in hydrolysis (AS) | 0,03 | g XOHO.g |
| YOHO,VFA,ox | Stoichiometric yields | Yield of OHOs on VFA under aerobic conditions | 0,67 | SVFA-1 |

**Table 3.9 :** Influent fractions for Case 2– CAS13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 37 | % |
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 22,2 | % |
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 24 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 13,3 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) in total COD | 10 | % |

**Table 3.9 (continued) :** Influent fractions for Case 2– CAS13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frXOHO,TCOD | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| frXE,XOHO | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 5 | % |
| frSNH$_x$,TKN | Fraction of NHx in total Kjeldahl nitrogen (TKN) | 69,2 | % |
| frSPO$_4$,TP | Fraction of PO$_4$ in total phosphorus (TP) | 50 | % |

**Table 3.10 :** Frequently used variables for Case 2– CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 5903,62 | mg COD/L |
| Total suspended solids (TSS) | 184,12 | 5850,58 | mg TSS/L |
| Volatile suspended solids (VSS) | 138,09 | 4227,11 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 177,42 | 2182,47 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,65 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 27,10 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 369,04 | mg N/L |
| Total ammonia (NH$_x$) | 38,75 | 43,00 | mg N/L |
| Nitrate and nitrite (NO$_x$) | 0,00 | 0,02 | mg N/L |
| Total phosphorus | 4,00 | 102,34 | mg P/L |
| Orthophosphate (PO$_4$) | 2,00 | 0,00 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 1,33 | mg $O_2$/L |

**c) Case 3 - SRT 13 days**

The coefficents are shown in Table 3.10 and fractions are shown in Table 3.11 For this case coefficients and fractions were selected as default from SUMO, Dynamita

Program. Also the simulated values at the effluent and inside the reactor are in Table 3.12 can also be examined.

**Table 3.11 :** Modified coefficients for Case 3 - CAS13.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,9 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 4 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,62 | d-1 |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,17 | d-1 |

**Table 3.12 :** Influent fractions for Case 3– CAS13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 84.86 | % |

**Table 3.13 :** Frequently used variables for Case 2– CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 5270,63 | mg COD/L |
| Total suspended solids (TSS) | 161,25 | 4732,86 | mg TSS/L |
| Volatile suspended solids (VSS) | 136,85 | 3797,85 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 161,35 | 1345,21 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,60 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 34,21 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 265,18 | mg N/L |
| Total ammonia ($NH_x$) | 39,07 | 0,08 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0,00 | 3,73 | mg N/L |
| Total phosphorus | 4,00 | 96,51 | mg P/L |
| Orthophosphate ($PO_4$) | 2,32 | 0,20 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0,00 | mg $O_2$/L |

**d) Case 4 - SRT 13 days**

The coefficents are shown in Table 3.13 and fractions are shown in Table 3.14 For this case coefficients were selected as default from SUMO, Dynamita Program. Fractions were selected from the study (Özyıldız, 2017). Also the simulated values at the effluent and inside the reactor are in Table 3.15 can also be examined.

**Table 3.14 :** Modified coeffcients for Case 4 - CAS13.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,9 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 4 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,62 | d-1 |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,17 | d-1 |

**Table 3.15 :** Influent fractions for Case 4– CAS13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 37 | % |
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 22,2 | % |
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 24 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 13,3 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) in total COD | 10 | % |
| frXOHO,TCOD | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| frXE,XOHO | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 5 | % |
| $frSNH_x$,TKN | Fraction of $NH_x$ in total Kjeldahl nitrogen (TKN) | 69,2 | % |
| $frSPO_4$,TP | Fraction of $PO_4$ in total phosphorus (TP) | 50 | % |

**Table 3.16 :** Frequently used variables for Case 4 - CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 4747,23 | mg COD/L |
| Total suspended solids (TSS) | 184,12 | 4920,76 | mg TSS/L |

**Table 3.16 (continued):** Frequently used variables for Case 4 - CAS13.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Volatile suspended solids (VSS) | 138,09 | 3385,54 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 177,42 | 1457,77 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,56 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 36,68 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 268,79 | mg N/L |
| Total ammonia ($NH_x$) | 38,75 | 0,08 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0,00 | 3,78 | mg N/L |
| Total phosphorus | 4,00 | 97,75 | mg P/L |
| Orthophosphate ($PO_4$) | 2,00 | 0,16 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0,00 | mg $O_2$/L |

### 3.5.2 Case studies for SRT 20 days

#### a) Case 1 - SRT 20 days

The coefficents are shown in Table 3.16 and fractions are shown in Table 3.17 For this case coefficients and fractions were selected from literature (Karlikanovaite, 2019). This selection is important for comparing results. Also the simulated values at the effluent and inside the reactor are in Table 3.18 can also be examined.

**Table 3.17 :** Modified coefficients for Case 1– CAS20.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 6 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0.35 | d-1 |

**Table 3.17 (continued):** Modified coefficients for Case 1– CAS20.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| KSB,AS | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0.25 | d-1 |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0.04 | d-1 |
| KHYD,AS | Kinetic | Half-saturation of particulates in hydrolysis (AS) | 0.03 | g COD.g COD-1 |
| YOHO,VFA,ox | Stoichiometric | Yield of OHOs on VFA under aerobic conditions | 0.67 | g XOHO.g SVFA-1 |

**Table 3.18 :** Fractions for Case 1– CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 30 | % |
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 14 | % |

**Table 3.18 (continued):** Fractions for Case 1– CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 30 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 20 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) | | |
| frXOHO,TCOD | in total COD | 10 | % |
| frXE,XOHO | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in | | |
| $frSNH_x$,TKN | colloidal COD | 16 | % |
| $frSPO_4$,TP | Fraction of $NH_x$ in total Kjeldahl nitrogen (TKN) | 69.2 | % |
| | Fraction of $PO_4$ in total phosphorus (TP) | 50 | % |

**Table 3.19 :** Frequently used variables for Case 2– CAS20.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370.00 | 7820.24 | mg COD/L |
| Total suspended solids (TSS) | 203.31 | 8133.70 | mg TSS/L |
| Volatile suspended solids (VSS) | 152.48 | 5601.37 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 159.06 | 2547.21 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0.00 | 7.42 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 52.82 | mg $O_2$/L/h |
| Total nitrogen | 56.00 | 457.91 | mg N/L |
| Total ammonia ($NH_x$) | 38.75 | 22.74 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0.00 | 2.52 | mg N/L |
| Total phosphorus | 4.00 | 152.33 | mg P/L |
| Orthophosphate ($PO_4$) | 2.00 | 0.03 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0.00 | mg $O_2$/L |

**b) Case 2 - SRT 20 days**

The coefficents are shown in Table 3.19 and fractions are shown in Table 3.20 For this case coefficients were selected from doctoral study (Karlikanovaite, 2019). Fractions also selected from another study (Özyıldız, 2017). Also the simulated values at the effluent and inside the reactor are in Table 3.21 can also be examined.

**Table 3.20 :** Modified coeffcients for Case 2– CAS20.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,25 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 6 | d-1 |
| KSB,AS | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,35 | d-1 |
| KSB,AS | Kinetic | Half-saturation of readily biodegradable substrate for OHOs (AS) | 20 | mg COD/L |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,04 | d-1 |
| KHYD,AS | Kinetic | Half-saturation of particulates in hydrolysis (AS) | 0,03 | g COD.g COD-1 |
| YOHO,VFA,ox | Stoichio. | Yield of OHOs on VFA under aerobic conditions | 0,67 | g XOHO.g SVFA-1 |

**Table 3.21 :** Influent fractions for Case 2 – CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 37 | % |

**Table 3.21 (continued) :** Influent fractions for Case 2 – CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 22,2 | % |
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 24 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 13,3 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) in total COD | 10 | % |
| frXOHO,TCOD | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| frXE,XOHO | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 5 | % |
| $frSNH_x$,TKN | Fraction of $NH_x$ in total Kjeldahl nitrogen (TKN) | 69,2 | % |
| $frSPO_4$,TP | Fraction of $PO_4$ in total phosphorus (TP) | 50 | % |

**Table 3.22 :** Frequently used variables for Case 2 – CAS20.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 7760,28 | mg COD/L |
| Total suspended solids (TSS) | 184,12 | 7936,05 | mg TSS/L |
| Volatile suspended solids (VSS) | 138,09 | 5548,12 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 177,42 | 2663,15 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,51 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 43,48 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 476,51 | mg N/L |

**Table 3.22 (continued):** Frequently used variables for Case 2- (

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total ammonia ($NH_x$) | 38,75 | 34,48 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0,00 | 1,22 | mg N/L |
| Total phosphorus | 4,00 | 154,65 | mg P/L |
| Orthophosphate ($PO_4$) | 2,00 | 0,00 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0,00 | mg $O_2$/L |

**c) Case 3 - SRT 20 Days**

The coefficents are shown in Table 3.22 and fractions are shown in Table 3.23. For this case coefficients and fractions were selected as default from SUMO, Dynamita Program. Also the simulated values at the effluent and inside the reactor are in Table 3.24 can also be examined.

**Table 3.23 :** Modified coeffcients for Case 3 – CAS20.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,9 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 4 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,62 | d-1 |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,17 | d-1 |

**Table 3.24 :** Influent fractions for Case 3 – CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 84,86 | % |

**Table 3.25 :** Frequently used variables for Case 3 – CAS20.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 7190,66 | mg COD/L |
| Total suspended solids (TSS) | 161,25 | 6601,20 | mg TSS/L |

**Table 3.25 (continued):** Frequently used variables for Case 3 –

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Volatile suspended solids (VSS) | 136,85 | 5204,39 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 161,35 | 1648,73 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,55 | mg $O_2$/L |
| Oxygen uptake rate (OUR) | | 38,78 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 344,73 | mg N/L |
| Total ammonia ($NH_x$) | 39,07 | 0,07 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0,00 | 3,85 | mg N/L |
| Total phosphorus | 4,00 | 147,44 | mg P/L |
| Orthophosphate ($PO_4$) | 2,32 | 0,19 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0,00 | mg $O_2$/L |

**d) Case 4 - SRT 20 Days**

The coefficents are shown in Table 3.25 and fractions are shown in Table 3.26. For this case coefficients were selected as default from SUMO, Dynamita Program. Fractions were selected from the study (Özyıldız, 2017). Also the simulated values at the effluent and inside the reactor are in Table 3.27 can also be examined.

**Table 3.26 :** Modified coeffcients for Case 4 – CAS20.

| Symbol | Coeff. | Name | Value | Unit |
|---|---|---|---|---|
| $\mu_{NITO}$ | Kinetic | Maximum specific growth rate of NITOs | 0,9 | d-1 |
| $\mu_{OHO}$ | Kinetic | Maximum specific growth rate of OHOs | 4 | d-1 |
| $b_{OHO}$ | Kinetic | Decay rate of OHOs | 0,62 | d-1 |
| $b_{NITO}$ | Kinetic | Decay rate of NITOs | 0,17 | d-1 |

**Table 3.27 :** Influent fractions for Case 4 – CAS20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| frVSS,TSS | Fraction of VSS/TSS | 75 | % |
| frSCCOD,TCOD | Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD | 37 | % |
| frSCOD,TCOD | Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD | 22,2 | % |
| frVFA,SCCOD | Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 24 | % |
| frSU,SCCOD | Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids) | 13,3 | % |
| frXU,TCOD | Fraction of particulate unbiodegradable organics (XU) in total COD | 10 | % |
| frXOHO,TCOD | Fraction of heterotrophs (OHO) in total COD | 1 | % |
| frXE,XOHO | Fraction of endogenous products (XE) of OHOs | 2 | % |
| frCU,CCOD | Fraction of colloidal unbiodegradable organics (CU) in colloidal COD | 5 | % |
| $frSNH_x$,TKN | Fraction of NHx in total Kjeldahl nitrogen (TKN) | 69,2 | % |
| $frSPO_4$,TP | Fraction of $PO_4$ in total phosphorus (TP) | 50 | % |

**Table 3.28 :** Frequently used variables for Case 4 – CAS20.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Total chemical oxygen demand | 370,00 | 6349,71 | mg COD/L |
| Total suspended solids (TSS) | 184,12 | 6838,53 | mg TSS/L |
| Volatile suspended solids (VSS) | 138,09 | 4546,23 | mg VSS/L |
| Total biochemical oxygen demand (5 days) | 177,42 | 1794,98 | mg $O_2$/L |
| Dissolved oxygen ($O_2$) | 0,00 | 7,52 | mg $O_2$/L |

**Table 3.28 (continued):** Frequently used variables for Case 4 – CAS20.

| Symbol | Influent | SBR | Unit |
|---|---|---|---|
| Oxygen uptake rate (OUR) | | 41,41 | mg $O_2$/L/h |
| Total nitrogen | 56,00 | 347,11 | mg N/L |
| Total ammonia ($NH_x$) | 38,75 | 0,07 | mg N/L |
| Nitrate and nitrite ($NO_x$) | 0,00 | 3,95 | mg N/L |
| Total phosphorus | 4,00 | 148,86 | mg P/L |
| Orthophosphate ($PO_4$) | 2,00 | 0,15 | mg P/L |
| Oxygen gas ($O_2$) off-gas concentration | | 0,00 | mg $O_2$/L |

## 4. RESULTS AND DISCUSSION

### 4.1 Contribution of The Study to The Literature

The results of the treatment of a conventional activated sludge system which fed with real wastewater in a sequential batch reactor were evaluated with SUMO, Dynamita software. Dynamic modeling was performed with case studies created with various stoichiometric and kinetic coefficients. Dynamic modeling studies were carried out respectively for 13 days and 20 days sludge ages. The simulations were made with two different methods as a long-term and as a cycle. Long-term studies include 100 days of data. Cyclic studies represent a full 8 hours.

### 4.2 Long Term (100 Days) Dynamic Simulation Results for SRT 13

According to the results obtained from the experimental setup, which was operated for 100 days, it was tried to predict what the effluent values would be under other cases conditions with the dynamic modeling program. The comparison of the treated wastewater with the simulation results was made according to the results of the real experiments. As seen in Table 4.1, the physical data of the CAS-SBR experimental setup were introduced to the SUMO simulation program. System configurations were performed using SUMO, Dynamita simulation program in steady-state conditions at SRT13 sludge age.

**Table 4.1 :** Simulation conditions in terms of SBR in SRT 13.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| Atank,train | Surface per train | 34 | $cm^2$ |
| htank,max | Depth when tank is full | 110 | cm |
| hdecant | Decant to this level | 58.83 | cm |
| L.V_0 | Initial reactor volume | 2 | L |
| tcycle | Cycle length | 8 | h |
| treact | React phase length | 6 | h |
| tdecant | Decant phase length | 0.5 | h |
| tidle | Idle phase length | 0.4 | h |
| SRTtarget | Target SRT | 13 | d |
| XTSS,decant,target | Effluent solids concentration | 5 | mg/L |
| XTSS,sludge,target | Sludge concentration | 8000 | mg/L |
| SlopeQ | Overflow control slope | 0.5 | |

In Figure 4.1 below, there is a graph comparing the simulated SCOD results for Case 1 with the experimental results from the literature. The comparison of the $NH_4$ results and the experimental data set is given in Figure 4.2. and Figure 4.3 shows the evaluation graph of $NO_x$ results.

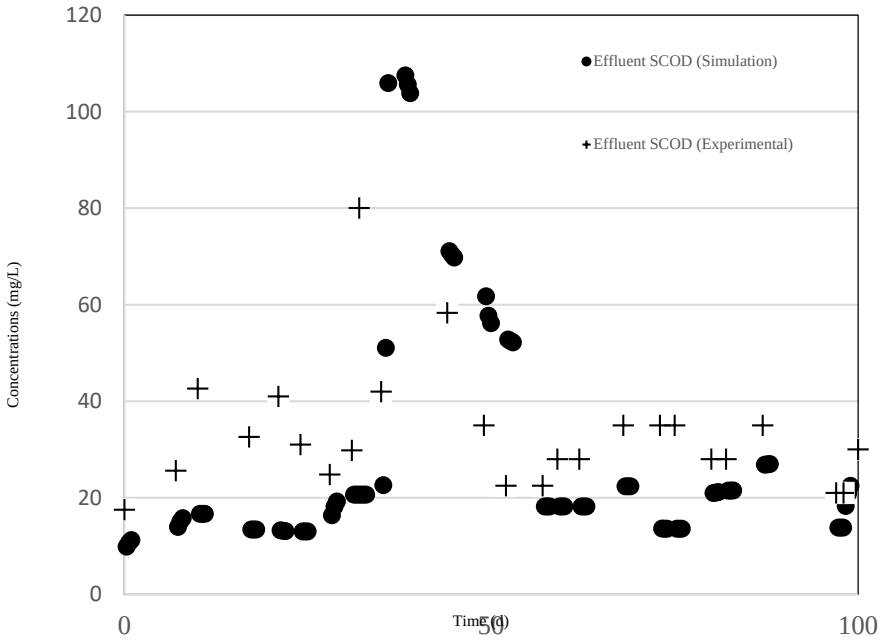


**Figure 4.1 :** Case 1 the SCOD (simulation ● and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

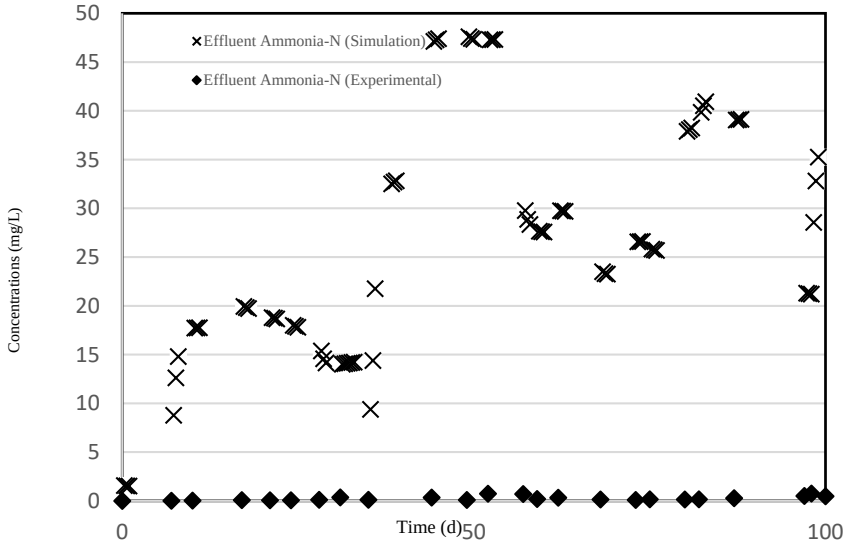


**Figure 4.2 :** Case 1 ammonia (simulation x and experimental ◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

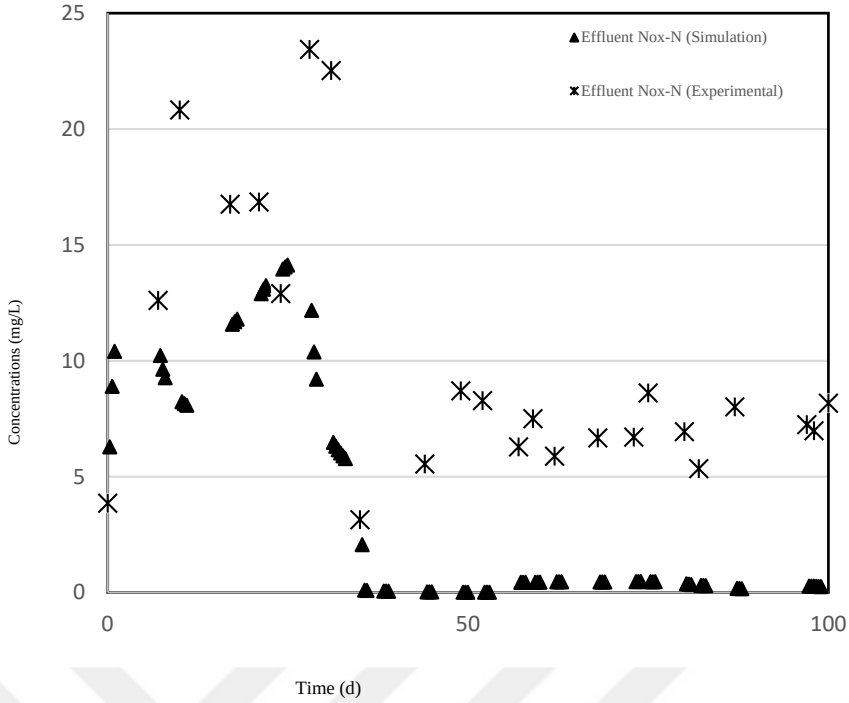


**Figure 4.3 :** Case 1 nitrate and nitrite (simulation ▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

The dynamic modeling results of SCOD effluent wastewater data were lower than the real experimental data results. The modeling tool appears to have higher treatment efficiency. 35-50 between days, the treatment yield decreased both relative to the real results and relative to the modeling tool. It is estimated that the values are high due to the adaptation of microorganisms to the carbon source added from the outside in order to bring the COD/TKN ratio to around 10 and increase the efficiency of biological treatment. For $NH_4$, the experimental data results are much lower than those predicted by the modeling tool. The efficiency of the modeling tool remained low compared to the actual wastewater treatment efficiency. In the modeling results, the actual data is close to zero, while the real results approach 40 mg/L. The $NO_x$ removal efficiencies are in agreement with the real experimental data in terms of modeling tool data. But there is a difference in terms of yield rate. In contrast to the SUMO program, which estimates around 9 mg/L after day 35, real data show near zero $NO_x$ in the effluent.

In Figure 4.4 the simulated SCOD results for Case 2 are compared with the experimental results from the literature. The comparison of $NH_4$ results and experimental data from the literature is given in Figure 4.5. Figure 4.6 shows the $NO_x$ results.

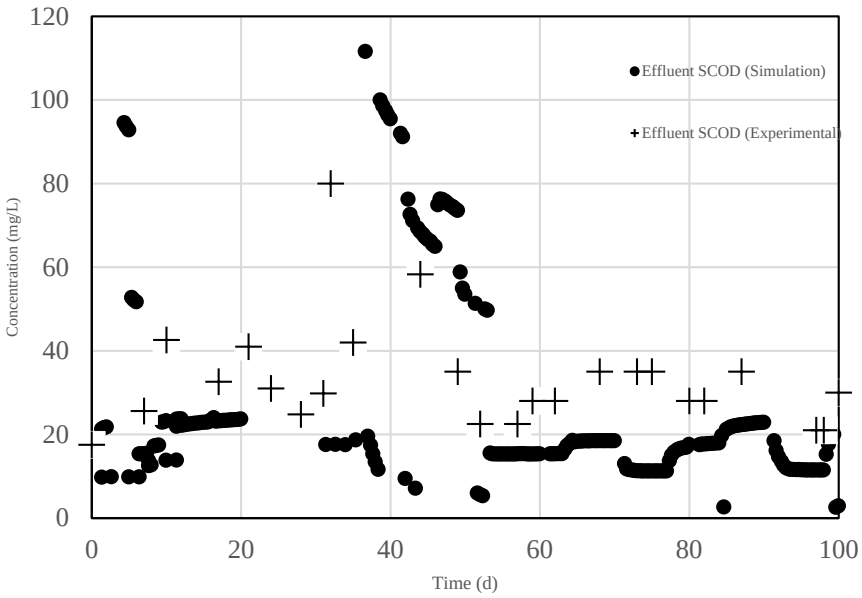


**Figure 4.4 :** Case 2 the SCOD (simulation ● and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

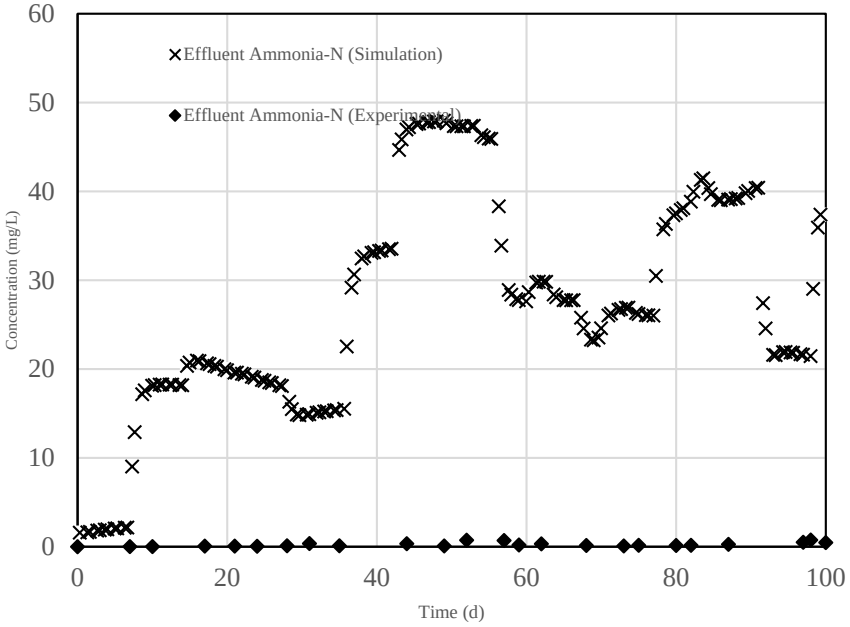


**Figure 4.5 :** Case 2 ammonia (simulation x and experimental ◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

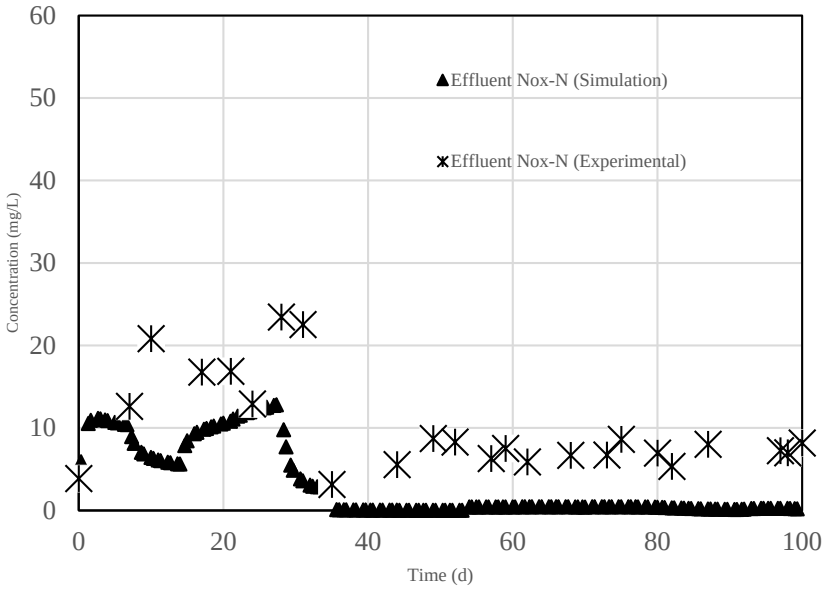


**Figure 4.6 :** Case 2 nitrate and nitrite (simulation ▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

The treatment efficiency of the simulation tool was better than the experimental results for SCOD. Again, the rise in the 35th day and 50th day range continues in this scenario as in other scenarios. When the SCOD amount in the effluent is determined to be around 100 mg/L, the real experimental data result indicates 80 mg/L. While the $NH_4$ experimental output values are quite low, the simulation data is not in a certain balance according to the days and the treatment efficiency can be called more unsuccessful than the experimental work. It is observed that the $NO_x$ experimental data are in good agreement with the simulation results.

In Figure 4.7 there are SCOD results for Case 3. The comparison of $NH_4$ results and experimental data from the literature is given in Figure 4.8 and also Figure 4.9 shows the $NO_x$ results.

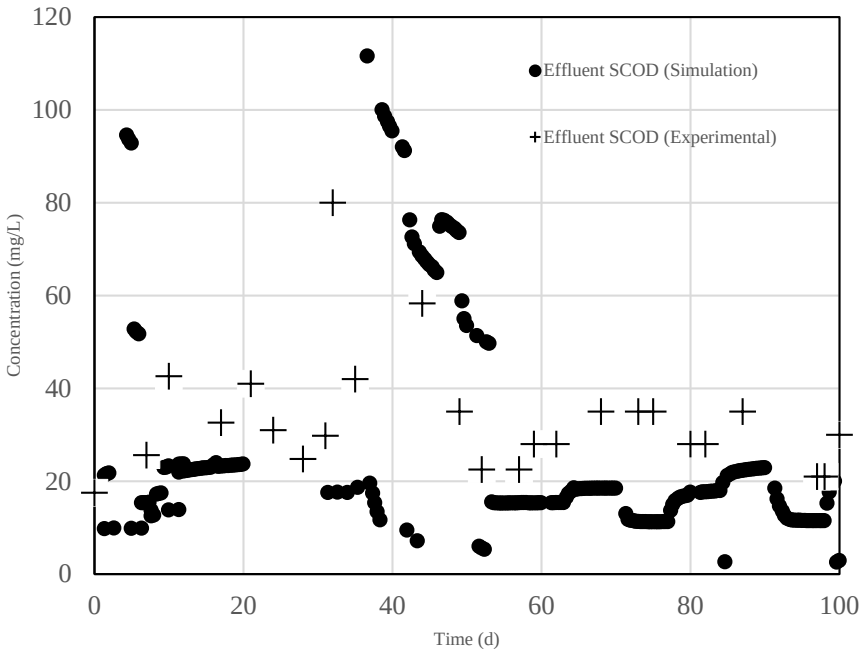


**Figure 4.7 :** Case 3 the SCOD (simulation● and experimental +) concentrations long-term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

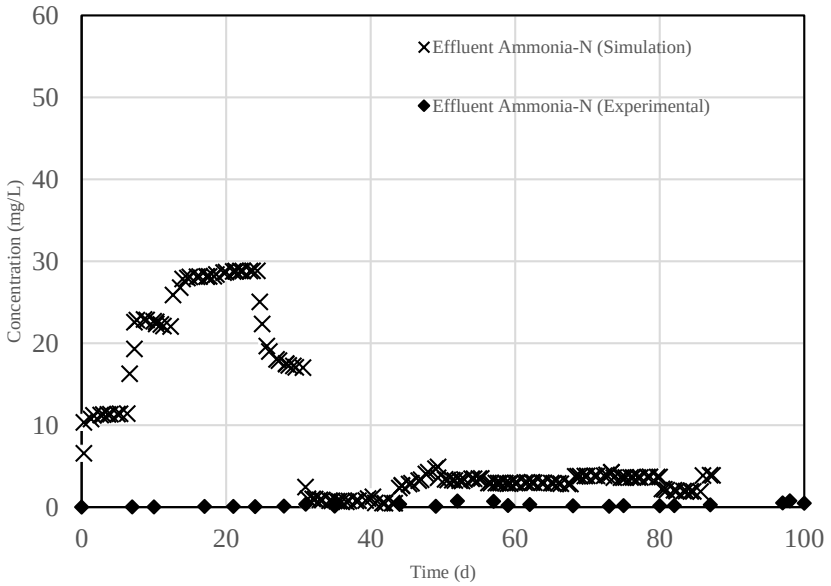


**Figure 4.8 :** Case 3 ammonia (simulation x and experimental ◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

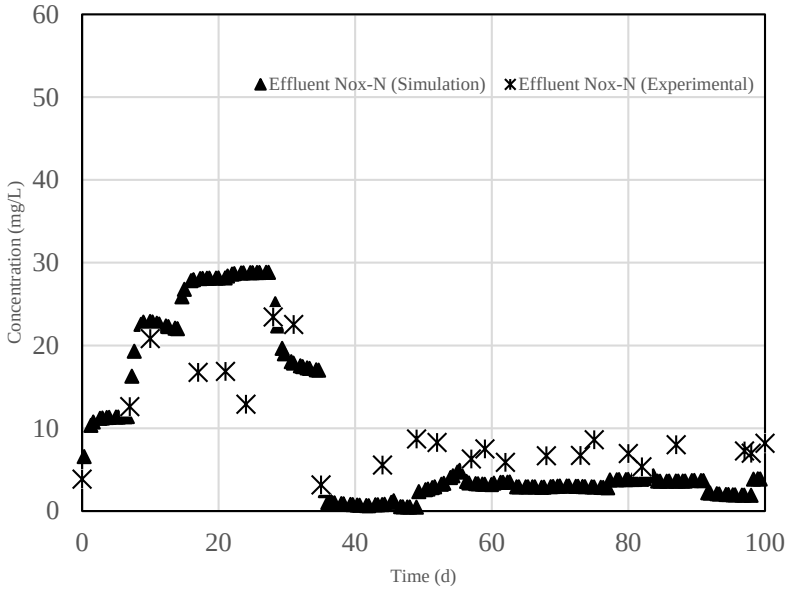


**Figure 4.9 :** Case 3 the nitrate and nitrite (simulation▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

In the evaluations made for the SCOD output data, it is observed that the simulation results are high, that is, the efficiency decreases, due to the adaptation problem, as in the other results, both at the start of the experiments and between the 35th and 50th days. The $NH_4$ data was initially higher than the experimental data in the simulation. With a sudden decrease from the 30th day, it reached the same level with the experimental data results and this situation continued until the end of the 100 days. Evaluations for $NO_x$ are similar to Case 1 and Case 2. According to both the experimental data and the data obtained as a result of the simulation, it can be seen from the graph that the $NO_x$ removal efficiency in the first days of the experiments was low. It is estimated that this is due to the shortage of organic matter.

Figure 4.10 shows SCOD results for Case 4. $NH_4$ results and experimental data is given in Figure 4.11 and also there are $NO_x$ results in Figure 4.12.

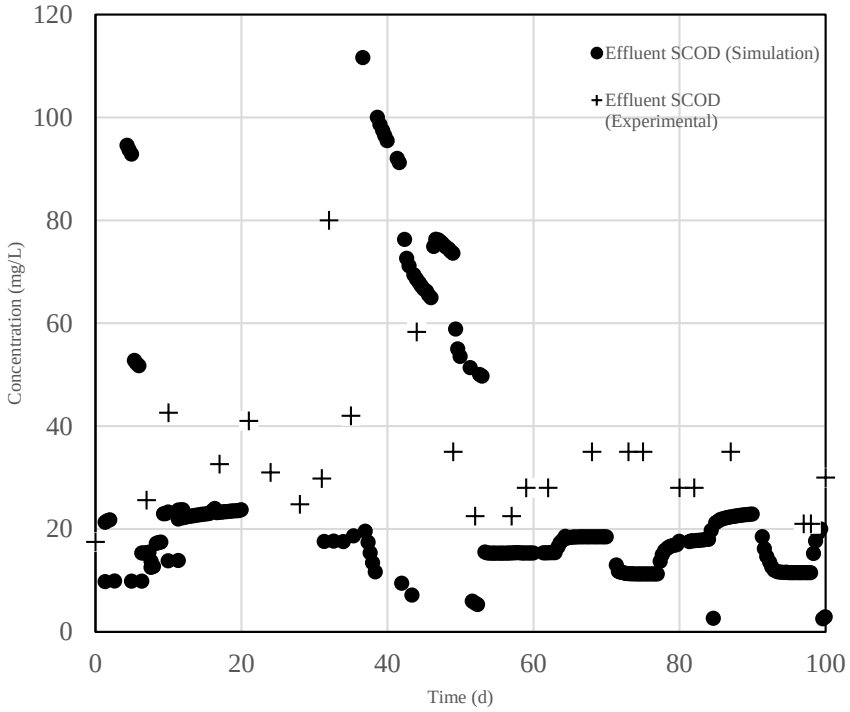


**Figure 4.10 :** Case 4 the SCOD (simulation ● and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

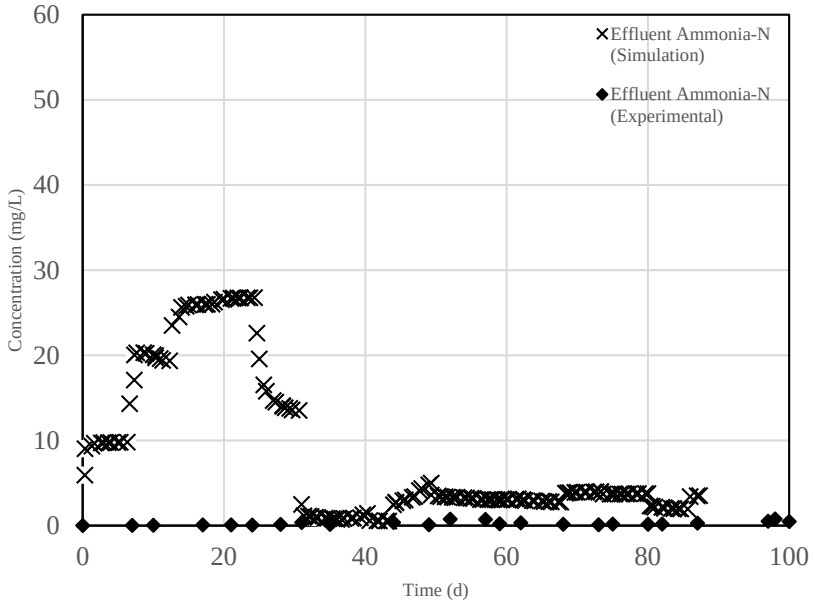


**Figure 4.11 :** Case 4 ammonia (simulation x and experimental ◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

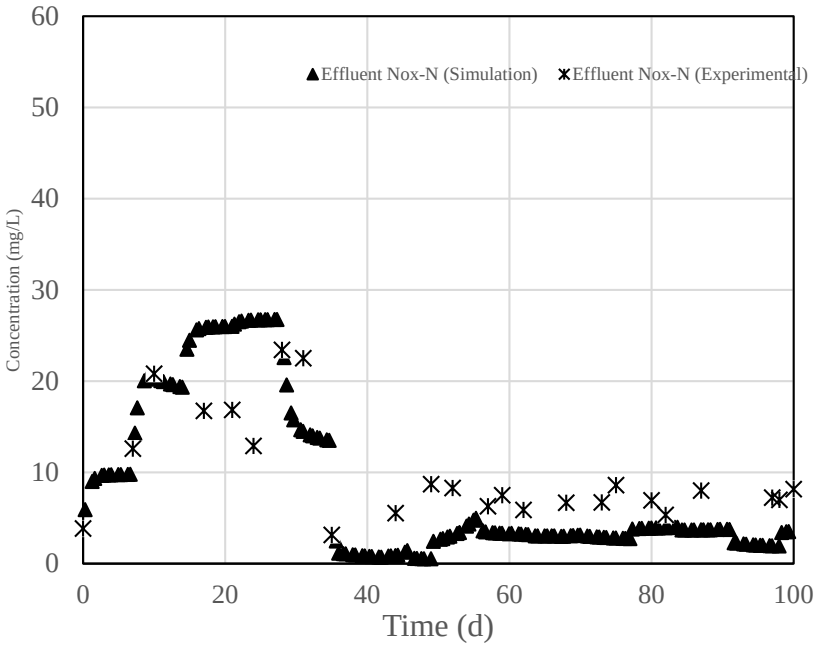


**Figure 4.12 :** Case 4 nitrate and nitrite (simulation▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

When the SCOD results is examined in the first 10 days of the 100 days in which the experimental study is performed, the efficiency of SCOD in simulated effluent is low. A decrease in the treatment efficiency is observed as a result of the addition of carbon source between the 35th and 55th days and the partial changes in the sample characteristics due to snowy weather. However, this decrease is at higher levels in the simulation program. This indicates that the sensitivity of the program is high. In the following days, the simulation data is below the experimental results. According to the experimental data results for the ammonia removal efficiency from the effluent, it is quite high from the beginning to the 100th day. The amount of ammonia in wastewater is close to zero. However, when the simulation results were examined, it was observed that the maximum amount of ammonia in the effluent for the first 30 days was 30 mg/L. $NO_x$ removal is almost the same both in simulation and according to experimental data results. The presence of higher levels of $NO_x$ in wastewater up to the first 40 days and a decrease between 0 – 10 mg/L in the following days is compatible with both real data and simulation.

### 4.3 Long Term (100 Days) Dynamic Simulation Results for SRT 20

System configurations were performed using SUMO, Dynamita simulation program in steady-state conditions at SRT 20. All physical conditions are same for SRT 13 and SRT 20. There are only one difference between two of them in terms of SRT and that is the number of days.

**Table 4.2 :** Simulation conditions in terms of SBR in SRT 20.

| Symbol | Name | Value | Unit |
|---|---|---|---|
| Atank,train | Surface per train | 34 | $cm^2$ |
| htank,max | Depth when tank is full | 110 | cm |
| hdecant | Decant to this level | 58.82 | cm |
| L.V_0 | Initial reactor volume | 2 | L |
| tcycle | Cycle length | 8 | h |
| treact | React phase length | 6 | h |
| tdecant | Decant phase length | 0.5 | h |
| tidle | Idle phase length | 0.4 | h |
| SRTtarget | Target SRT | 20 | d |
| XTSS,decant,target | Effluent solids concentration | 5 | mg/L |
| XTSS,sludge,target | Sludge concentration | 8000 | mg/L |
| SlopeQ | Overflow control slope | 0.5 | |

Figure 4.13 shows SCOD results for Case 1 at SRT 20 days. Comparison of $NH_4$ results from simulation tool and experimental data is given in Figure 4.14 and also there are $NO_x$ results in Figure 4.15.

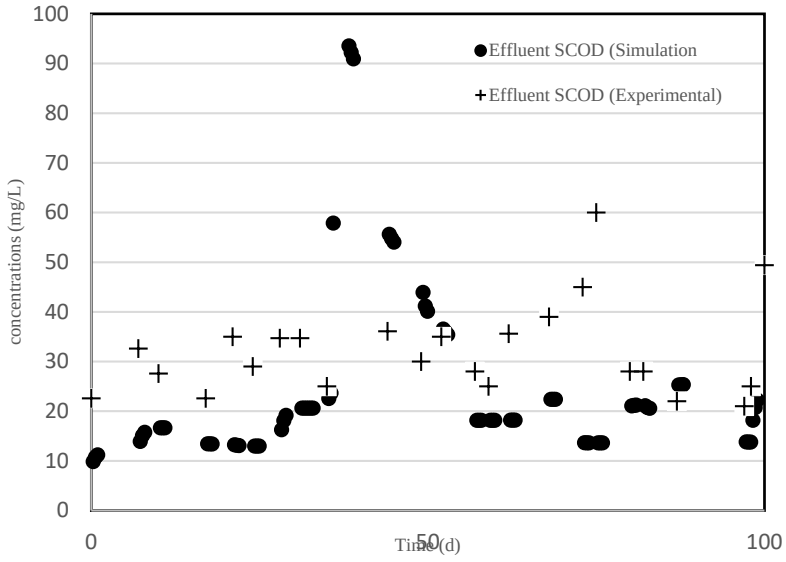


**Figure 4.13 :** Case 1 the SCOD (simulation ● and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

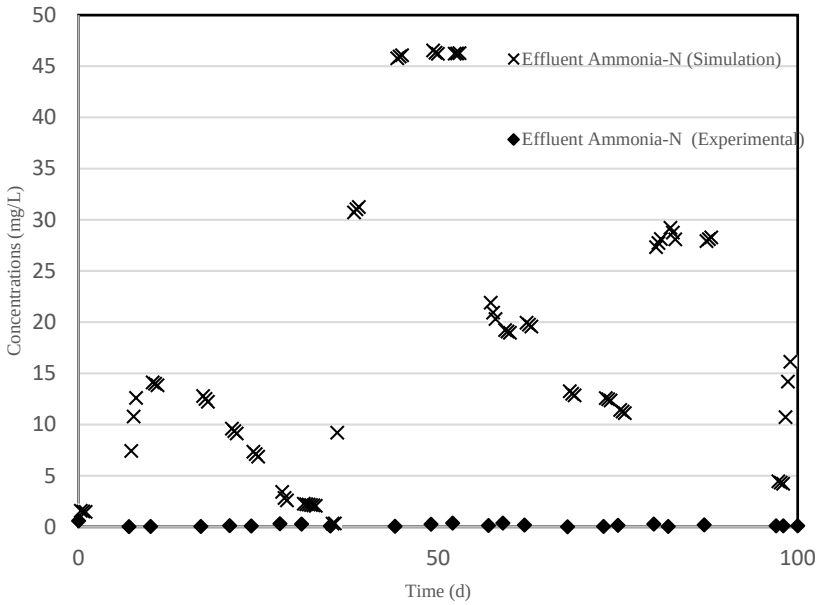


**Figure 4.14 :** Case 1 ammonia (simulation x and experimental◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days**.**

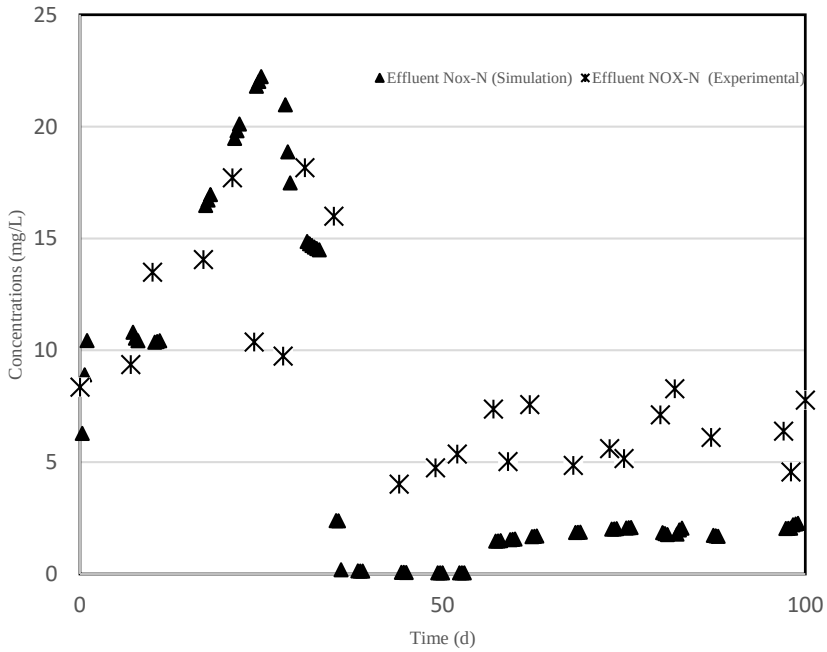


**Figure 4.15 :** Case 1 nitrate and nitrite (simulation ▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

When the results for the Case 1 scenario are examined, as seen in Figure 4.13, while the simulation results are below the experimental results in the first 35 days, it is seen that the effluent value increases between the 35th day and the 50th day due to

glucose supplement as a carbon source and snowy weather. When the effluent ammonium data in Figure 4.14 is examined, it is seen that the success of the experimental data is better than the simulation. The reason for the high effluent values according to the simulation is that the amount of oxygen supplied to the nitrifying bacteria is likely to be low. When Figure 4.15 is examined, it is seen that the simulation results and the experimental data results are quite balanced. However, after the 50th day, it was observed that the simulation results were lower than the experimental data, that is, the treatment of wastewater was better.

In Figure 4.16 there are SCOD results for Case 2 and also there are $NH_4$ results from simulation tool and experimental data is given in Figure 4.17. Comparison of $NO_x$ results in Figure 4.18.

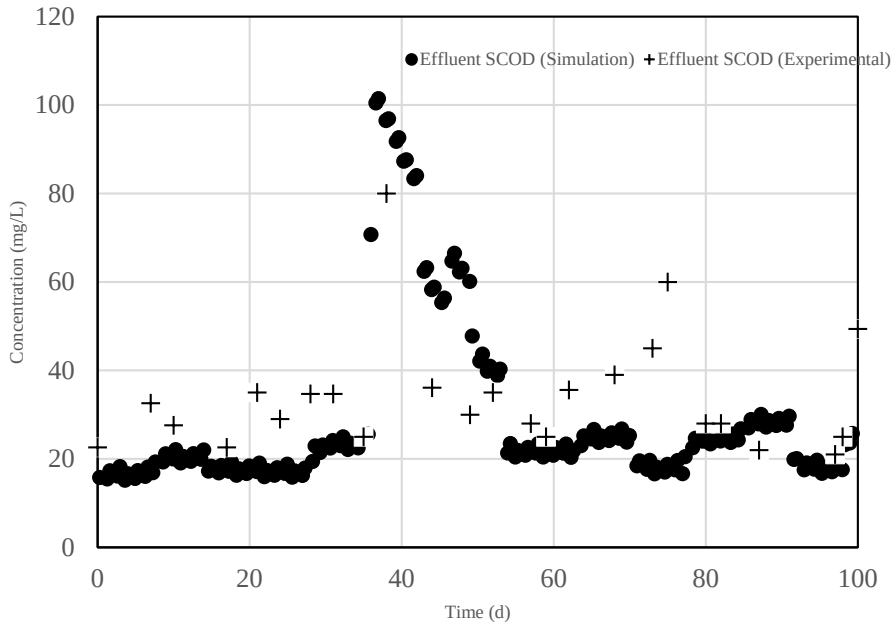


**Figure 4.16 :** Case 2 the SCOD (simulation ● and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

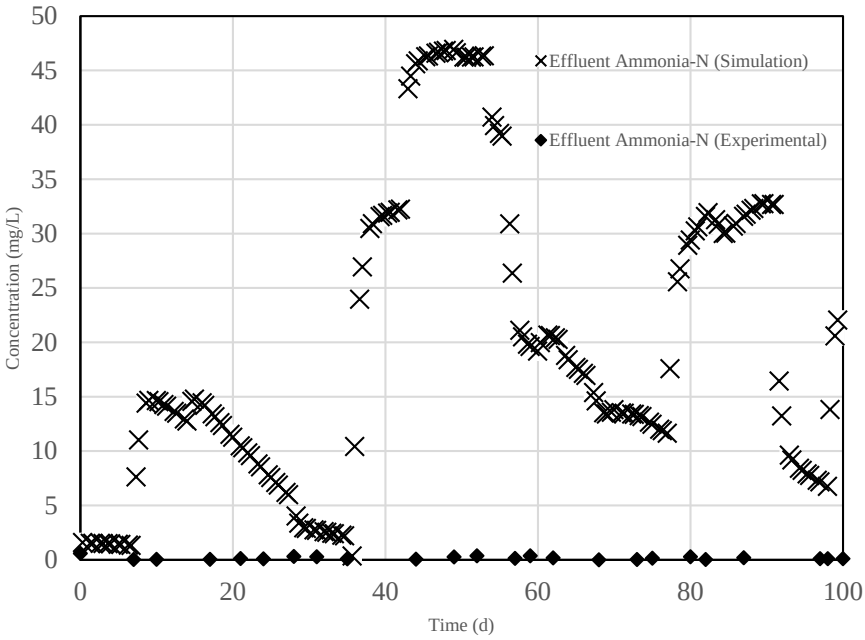


**Figure 4.17 :** Case 2 ammonia (simulation x and experimental◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

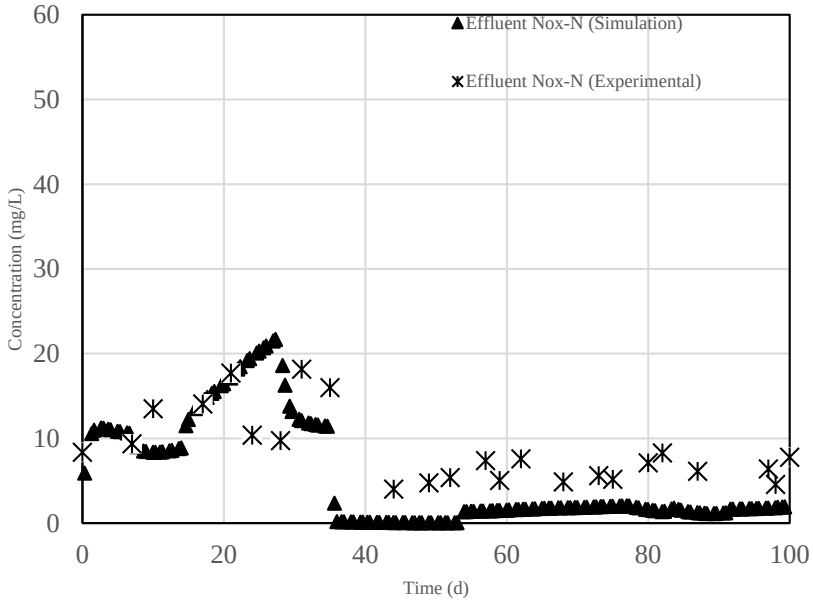


**Figure 4.18 :** Case 2 nitrate and nitrite (simulation ▲and experimental✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

The evaluation for Case 2 is as follows: SCOD results are similar to Case1 as can seen Figure 4.16. The simulation effluent data were very close to experimental effluent data. As a result of the examination made in terms of ammonia, it was

observed that the treatment efficiency of the simulation was lower than the experimental data. Considering the changes in fractions and coefficients, if we accept that the amount of oxygen has not been changed, this may be proof that oxygen is not enough. This can seen in Figure 4.17. The results examined in terms of $NO_x$ can be observed in Figure 4.18. The experimental data of the effluent and the simulation results are parallel to each other. If examined in terms of small differences, the treatment simulation is more successful than the real data. This means that the nitrification process is more successful.

In Figure 4.19 the simulated SCOD results for Case 3 are compared with the experimental results from the literature. The comparison of $NH_4$ results and experimental data from the literature is given in Figure 4.20. Figure 4.21 shows the $NO_x$ results.

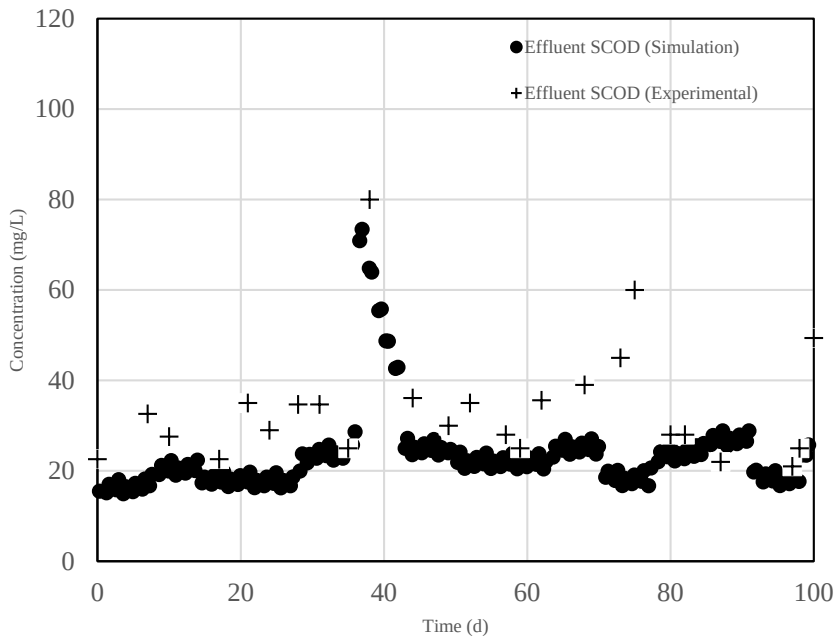


**Figure 4.19 :** Case 3 the SCOD (simulation ●and experimental) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

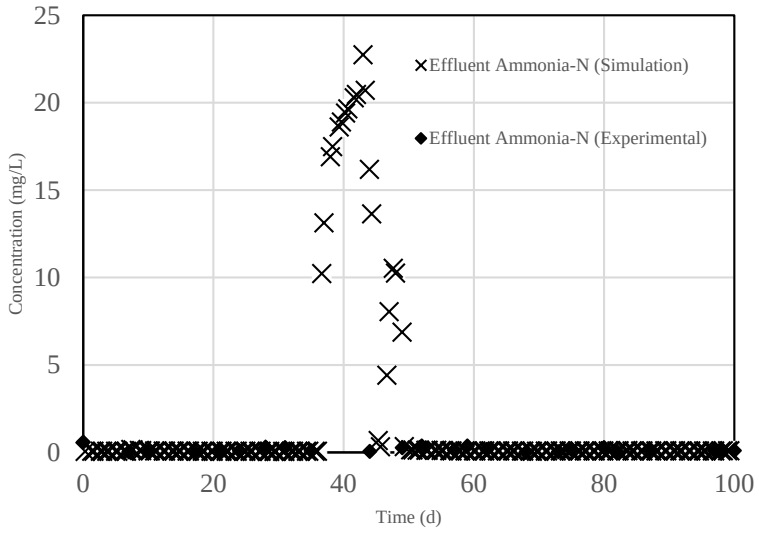


**Figure 4.20 :** Case 3 ammonia (simulation x and experimental ◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

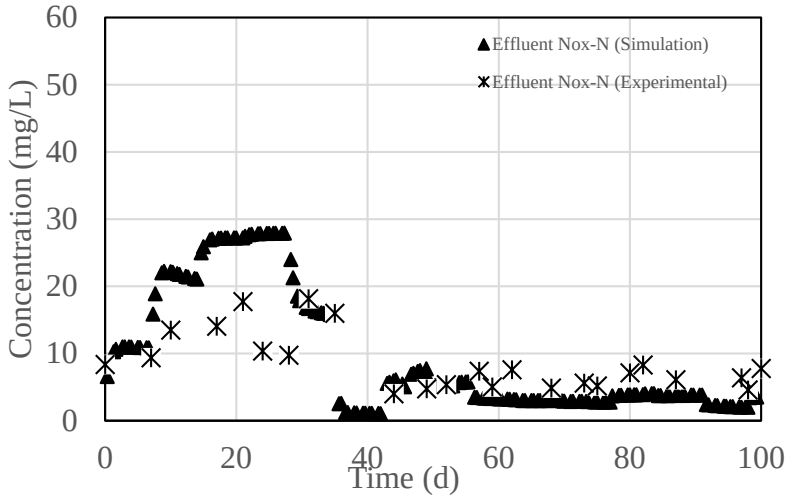


**Figure 4.21 :** Case 3 nitrate and nitrite (simulation ▲and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

The evaluation of the experimental data and simulation results for the Case 3 scenario is as follows; The SCOD results obtained with dynamic modeling between 35-45 days are lower than the actual experimental data results. This means that the refinement performance expected by the modeling tool is higher. $NH_4$ results are very close to zero in experimental study results. However, according to the dynamic modeling results made with the SUMO program, the values that were close to zero in the first 35 days increased to 23 mg/L levels between 35 and 55 days. From the 55th to the 100th day, excellent removal efficiency was achieved with results close to zero with dynamic modelling. The $NO_x$ removal efficiency is consistent with the

experimental data and simulation results. As in all other scenarios, the values that increased up to 30 mg/L in the first 35 days decreased below 10 mg/L in the following days.

Figure 4.22 shows SCOD results for Case 4. The comparison of $NH_4$ results is given in Figure 4.23 and also there are $NO_x$ results in Figure 4.24.

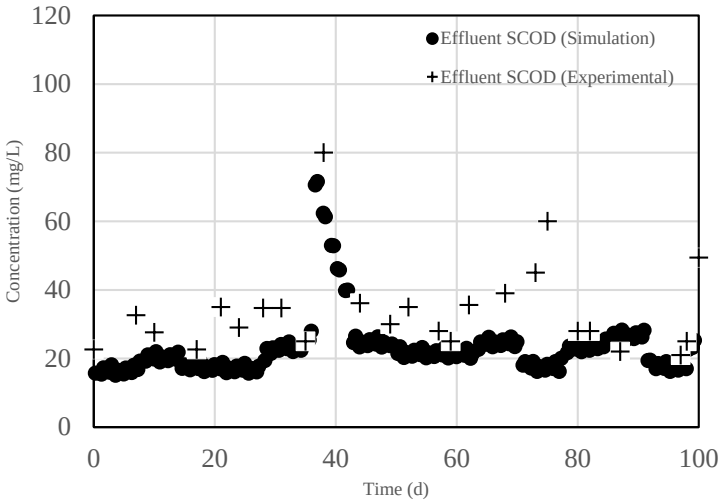


**Figure 4.22 :** Case 4 the SCOD (simulation ●and experimental +) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

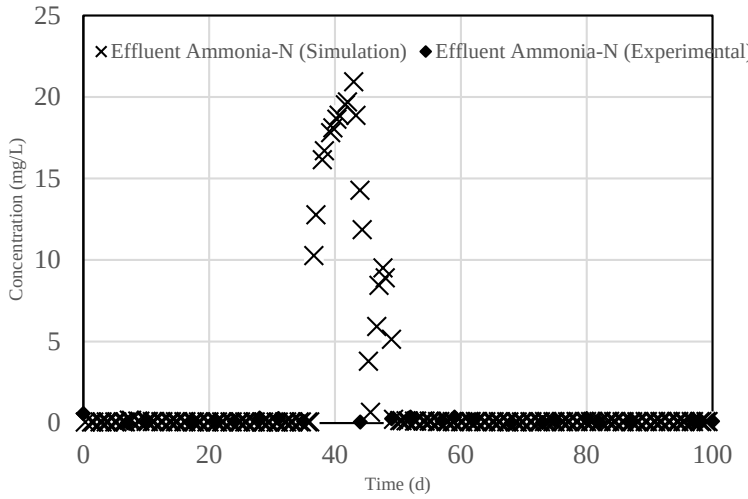


**Figure 4.23 :** Case 4 ammonia (simulation x and experimental◆) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

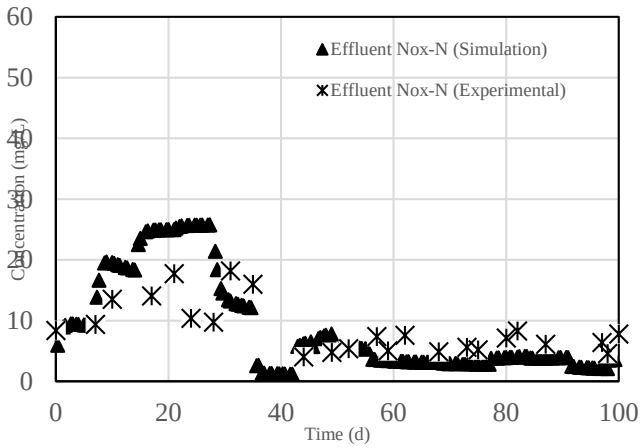


**Figure 4.24 :** Case 4 nitrate and nitrite (simulation ▲ and experimental ✳) concentrations long term experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

The interpretation of the results for Case 4, which is the last scenario of long-term forecasts, is as follows; Experimental data results and simulation results for SCOD were very close. The behavior of high effluent SCOD between 35 and 40 days was consistent with the experimental results and dynamic modeling results. This situation is observed differently from other scenarios. Experimental results for effluent analysis were around 80 mg/L, while dynamic modeling results were close to 75 mg/L. As in all other scenarios for $NH_4$, the dynamic modeling result and the real experimental data result agree, except that the simulation result between 35 and 55 days is as high as 22 mg/L. $NO_x$ data is quite coherent as in all other long-term scenarios. Experimental data were higher than the results of the modeling tool. However, this difference varies between 19 mg/L and 25 mg/L.

### 4.4 For 8 Hours Cycle Dynamic Simulation Results for SRT 13

Cyclic analysis was carried out in order to obtain information about the reaction results in the sequential batch reactor operated with 8 hour cycles in the experimental setup operated for 100 days. Experimental measurements of SCOD and $NH_4$ amounts in an 8-hour cycle and simulation results were compared separately for 13 SRTs in 4 scenarios. It was seen that the results of the SUMO modeling tool and the experimental results were compatible in terms of SCOD, but exhibited different behavior in terms of $NH_4$.

In Figure 4.25 shows SCOD results for Case 1 at SRT 13 days for one cycle. The comparison of $NH_4$ results is given in Figure 4.26 for 8 hours.

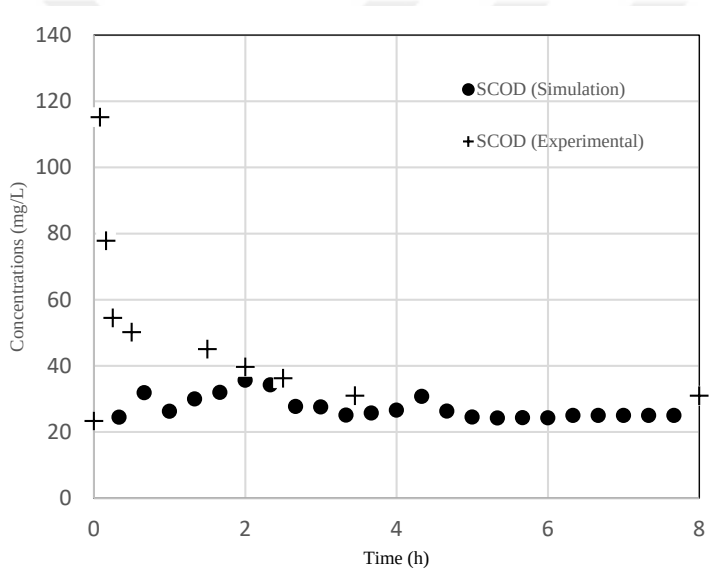


**Figure 4.25 :** Case 1 the SCOD (simulation ● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

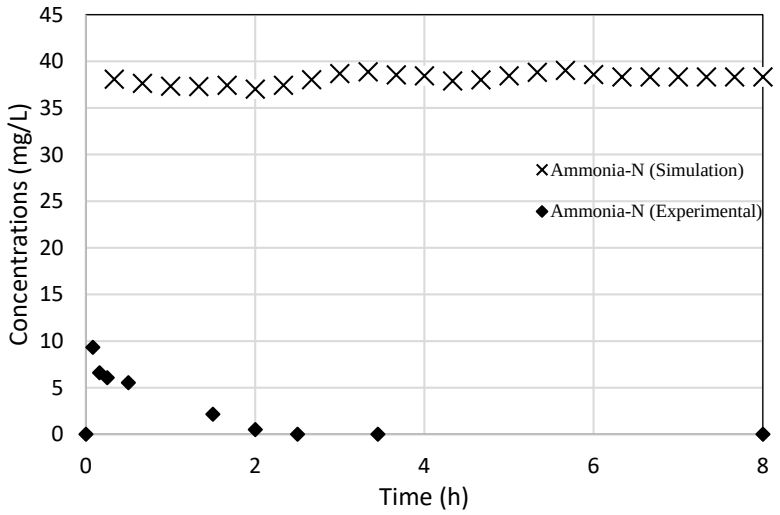


**Figure 4.26 :** Case 1 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

When the sample results whis were taken from the SBR for scenario 1 in an 8-hour cycle are compared with the results of the SUMO dynamic simulation tool, it is observed that the amount of SCOD decreases from 120 mg/L to around 40 mg/L in the first 2 hours in experimental data. In SUMO simulation, it can be seen in Figure 4.25 that the cycle is completed with values ranging from 20 mg/L to 40 mg/L. While the amount of $NH_4$ decreased from 10 mg/L to zero in the first 2 hours in real experimental data, it can be seen in Figure 4.26 that it covers around 35 mg/L for 8 hours in SUMO dynamic modeling.

Figure 4.27 shows SCOD results for Case 2 and also there is comparison of $NH_4$ results in Figure 4.28 for 8 hours.

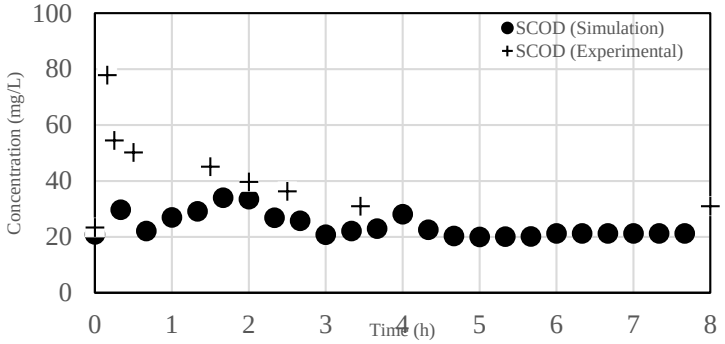


**Figure 4.27 :** Case 2 the SCOD (simulation● and experimental +) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

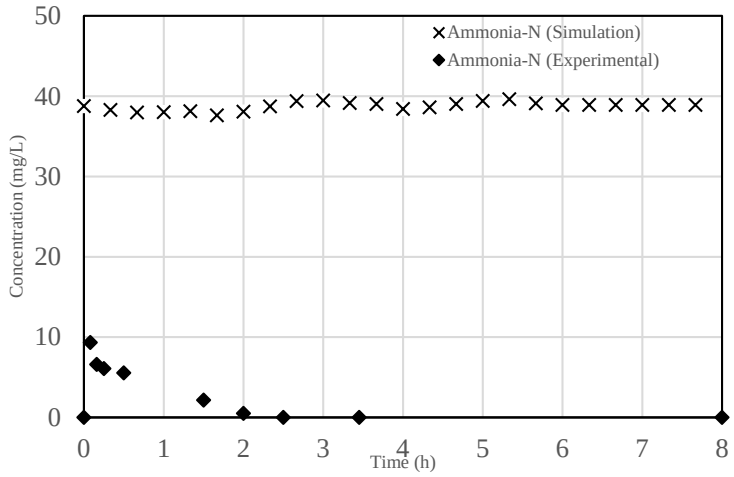


**Figure 4.28 :** Case 2 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

When the experimental data and dynamic modeling results are compared, it is seen in Figure 4.27 that the dynamic modeling results are in balance for 8 hours. The real experimental data results are broke in half starting around 80 mg/L the start of the 2nd hour. As it can be understood from Figure 4.28, where the $NH_4$ results can be examined, very similar results were obtained with scenario 1.

In Figure 4.29 there is a graph comparing the simulated SCOD results for Case 3 with the experimental results from the literature. The comparison of the $NH_4$ results is given in Figure 4.30.

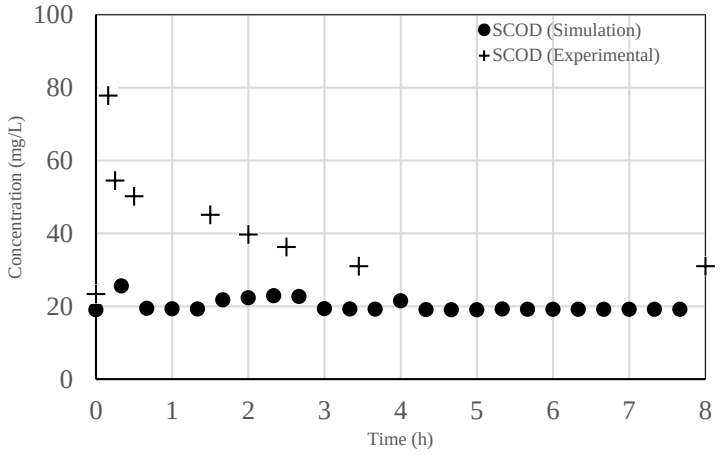


**Figure 4.29 :** Case 3 the SCOD (simulation ● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

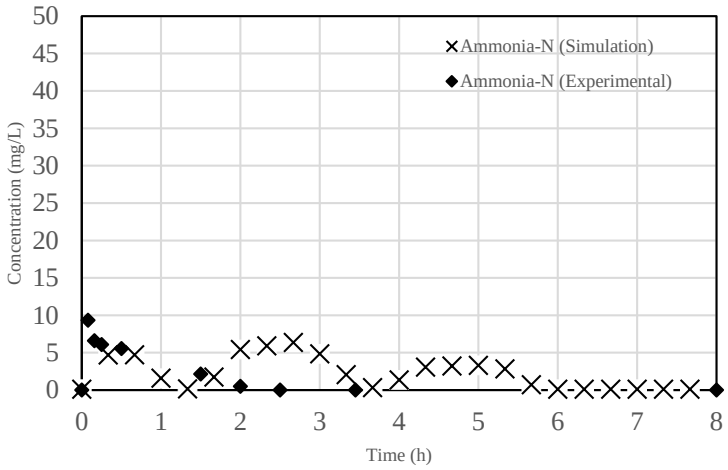


**Figure 4.30 :** Case 3 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

Monitoring the SCOD measurements can be seen in Figure 4.29, where the simulation remained constant at approximately 20 mg/L throughout the 8 hour cycle. However, experimental data started from 77 mg/L and decreased to 30 mg/L at the end of 8 hours. Unlike the other two scenarios, simulation results and experimental results are very consistent for $NH_4$. It can be seen from Figure 4.30 that it experienced the same rate of change at almost the same time.

In Figure 4.31 the simulated SCOD results for Case 4 are compared with the experimental results from the literature. The comparison of $NH_4$ results is given in Figure 4.32.

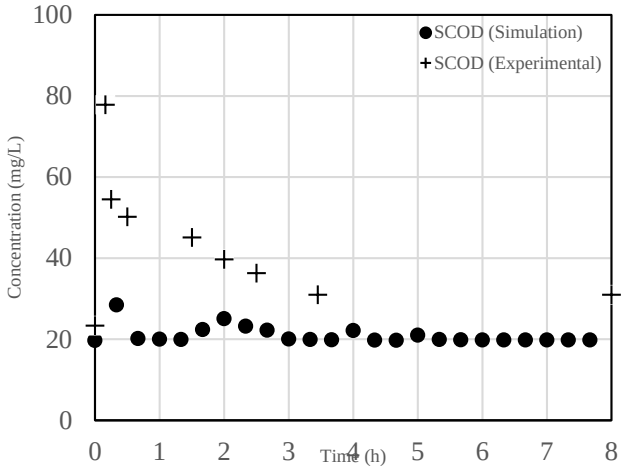


**Figure 4.31 :** Case 4 the SCOD (simulation ● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

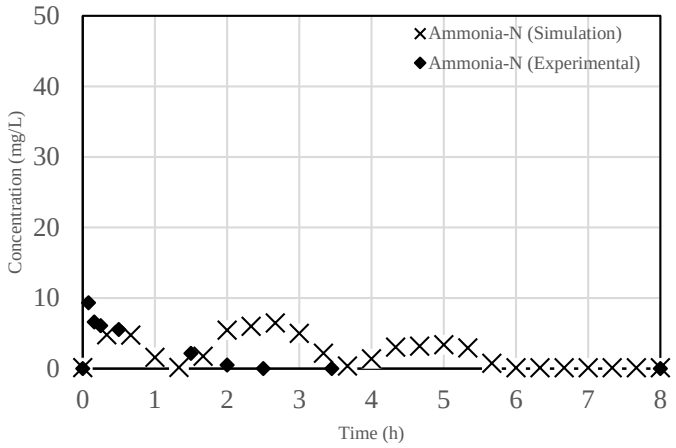


**Figure 4.32 :** Case 4 ammonia (simulation x and experimental ◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 13 days.

Evaluations in terms of SCOD are very similar to Case 3. Again, according to the experimental data, the amount of SCOD, which started at a high rate, decreased after 8 hours, while the result of dynamic modeling routinely repeated itself at the same interval. It can be examined from Figure 4.31. As can be seen in Figure 4.32, $NH_4$ measurements contain little difference, both experimentally and simulated results. At the end of 8 hours, there is almost zero $NH_4$ in both cases. This has demonstrated the success of dynamic modeling by achieving real results.

### 4.5 For 8 Hours Cycle Dynamic Simulation Results for SRT 20

In the experimental setup, analyzes were made in order to obtain information about the reactions occurring in the SBR which was operated with 8 hour/day cycles. The measurement results and dynamic measurement results of SCOD and $NH_4$ amounts over 8 cycle times were compared for SRT 20 in four scenarios. While SCOD is quite high in simulation results for the first three scenarios, it is low in analysis results. As of the fourth scenario, harmony has been achieved. $NH_4$ is quite high in terms of simulation results in the first two scenarios. The data results used in the third and fourth scenarios were in agreement with the dynamic measurement results.

In Figure 4.33 there are SCOD results for Case 1. $NH_4$ results is given in Figure 4.34.

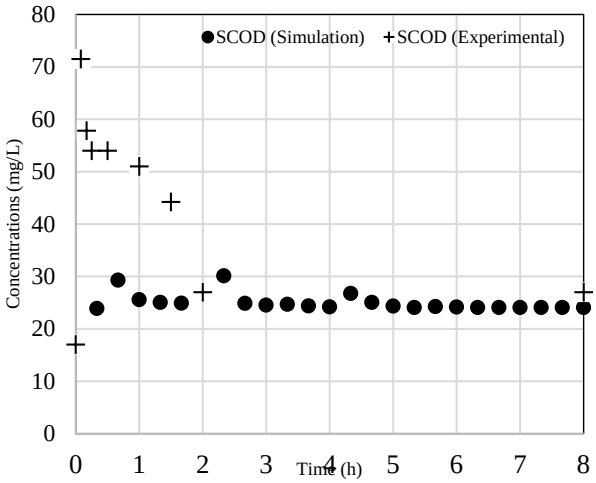


**Figure 4.33 :** Case 1 the SCOD (simulation ● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

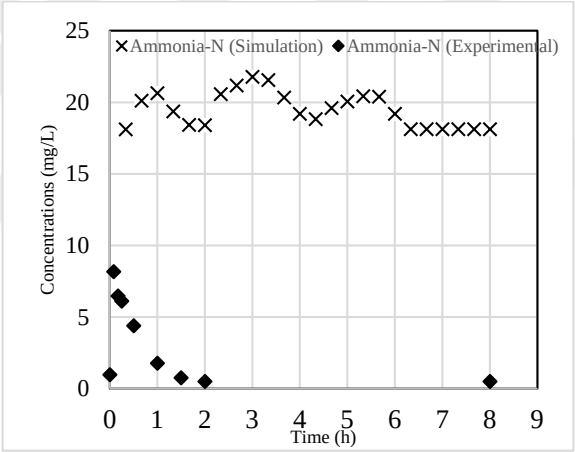


**Figure 4.34 :** Case 1 ammonia (simulation x and experimental ◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

When the experimental data and simulation results are compared, the experimental data show that it decreases from 75 mg/L to 50 mg/L within the first hour, as seen in Figure 4.33. However, the results from SUMO, a dynamic modeling tool, increased from 22 mg/L to around 31 mg/L. For the next seven hours, both the experimental data and the simulation results are between 20 mg/L and 30 mg/L. The amount of $NH_4$ varies between 18 mg/L and 22 mg/L for 8 hours, according to the results obtained in the simulation tool. In the experimental data, these measurements went from 8 mg/L to zero in the first 2 hours.

In Figure 4.35 the simulated SCOD results for Case 2 are compared with the experimental results from the literature. The comparison of $NH_4$ results and experimental data from the literature is given in Figure 4.36.

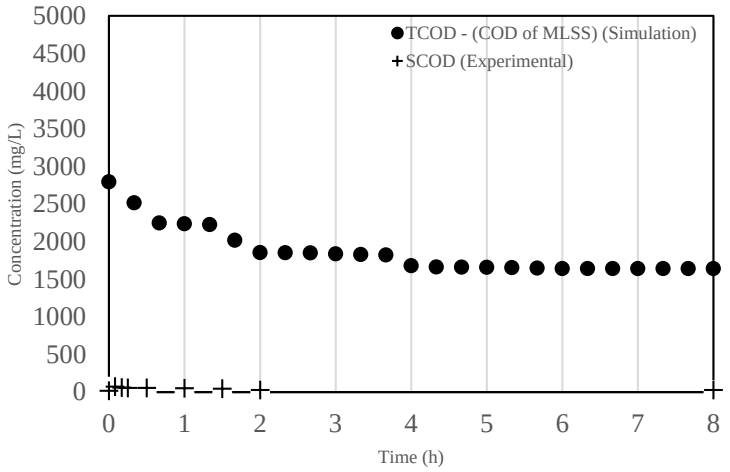


**Figure 4.35 :** Case 2 the SCOD (simulation● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

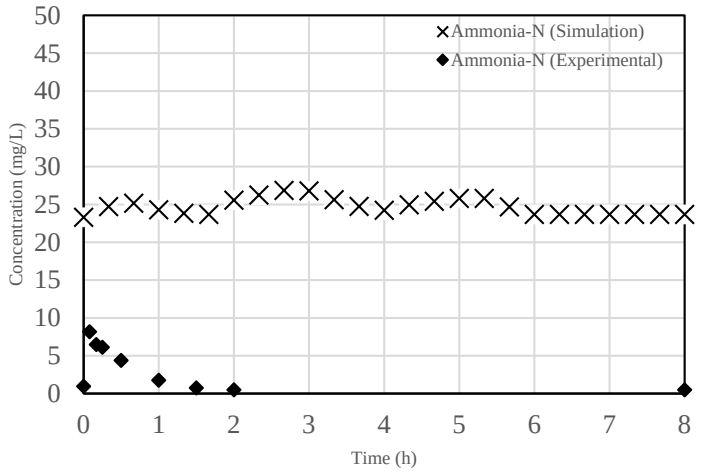


**Figure 4.36 :** Case 2 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

As it can be seen from Figure 4.36, for this scenario, the SCOD amounts showed a difference between the real data and the simulated dynamic model. The evaluation made in terms of $NH_4$, on the other hand, was similar to the previous scenario, both in terms of values and behavior.

Figure 4.37 shows SCOD results for Case 3. Comparison of $NH_4$ results from simulation tool and experimental data is given in Figure 4.38.

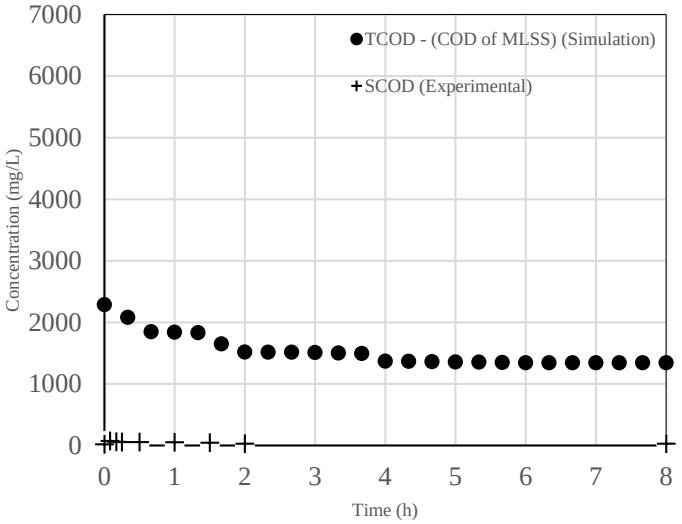


**Figure 4.37 :** Case 3 the SCOD (simulation● and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

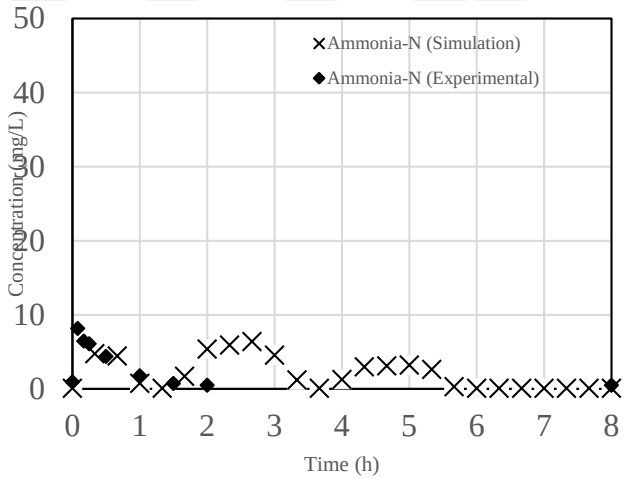


**Figure 4.38 :** Case 3 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

It is possible to examine Case 3 from Figure 4.37 in the analysis results made according to the samples taken from the SBR. Simulation results and experimental results look quite different. In Figure 4.38, which will be examined in terms of ammonia, it is seen that the results are similar both in simulations made with the modeling tool SUMO and in real experimental data results.

Figure 4.39 shows SCOD results for Case 4. $NH_4$ results and experimental data is given in Figure 4.40.

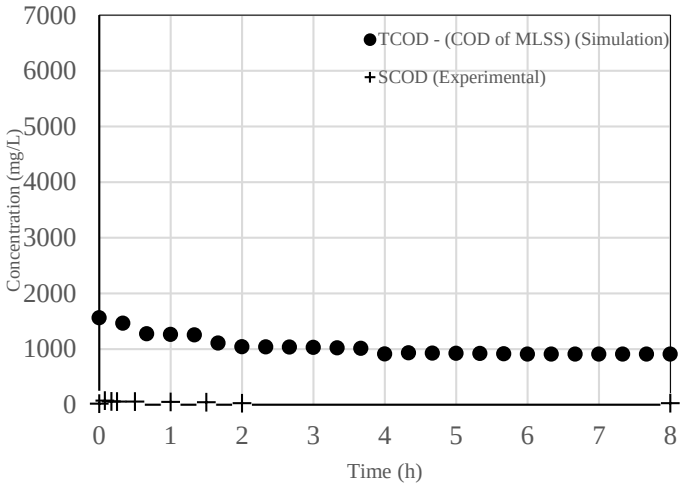


**Figure 4.39 :** Case 4 the SCOD (simulation ●and experimental +), concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

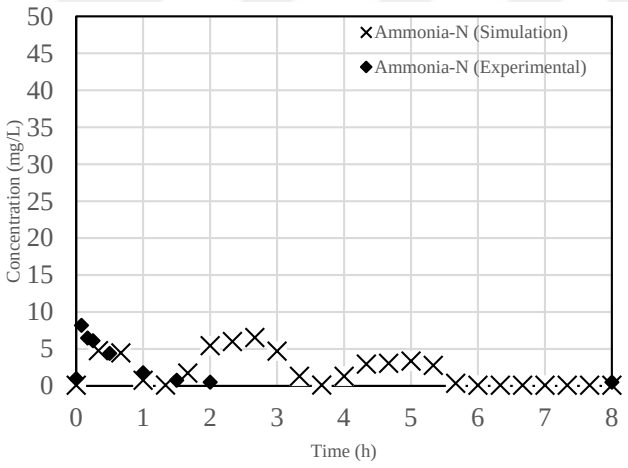


**Figure 4.40 :** Case 4 ammonia (simulation x and experimental◆) concentrations short term (8 hours) experimental data and SUMO simulation benchmark results in the effluent stream of CAS-SBR at SRT 20 days.

As seen in Figure 4.39, the values that should be according to the dynamic modeling and the real experimental results were closer to each other in the last case. In terms of $NH_4$, the same behavioral tendencies emerged during the 8-hour cycle, as seen in Figure 4.40, with a perfect match.

### 4.6 Recommendations

As a result of all simulations, the reliability of the SUMO, Dynamita dynamic model has been tested. The simulation tool is not in full agreement with all experimental data. The reason for this may be that the experimental analysis data is not enough to improve the learning ability of the simulation tool.

Long-term efficacy assessments are as follows: Dynamic modeling results of SCOD wastewater data for SRT 13 – Case 1 are lower than real experimental data results. For $NH_4$, the experimental data outcomes are much lower than those predicted by the modeling tool. $NO_x$ removal efficiencies are consistent with real experimental data in terms of modeling tool data. However, there is a difference in terms of yield rate. The efficiency of the Simulator for SRT 13 – Case 2 is better than the experimental results for SCOD. Although the $NH_4$ experimental effluent values are quite low, the simulation data is not in a certain balance according to the days and the treatment efficiency can be said to be less successful than the experimental study. It was observed that the $NO_x$ experimental data were in good agreement with the simulation results. The evaluations for SCOD effluent data for SRT 13 - Case 3 are the same as for other cases. The $NH_4$ data is initially higher than the experimental data in simulation. From the 30th day, it reached the same level with the experimental data results with a sudden decrease and this situation continued until the end of the 100 days. According to the $NO_x$ experimental data and the data obtained as a result of the simulation, the $NO_x$ removal efficiency is low in the first days of the experiments. The efficiency of SRT 13 – Case 4 SCOD in simulated wastewater is low. Effluent values are lower in experimental data. In other words, a more efficient treatment was achieved. According to the experimental data, the ammonia removal efficiency from the effluent is quite high from the beginning to the 100th day. $NO_x$ removal is almost the same according to both simulation and experimental data results. SRT 20 – Case 1 while the simulation results are below the experimental results in the first 35 days, they are between the 35th and 50th days. When the effluent ammonium data is examined, it is seen that the success of the experimental data is better than the simulation. According to the simulation, the reason for the high waste values is that the amount of oxygen given to the nitrifying bacteria is likely to be low. It is seen that the $NO_x$ results and the experimental data results are quite balanced. SRT 20 – Case 2 SCOD results are similar to Case 1. The simulation wastewater data are very

close to the experimental wastewater data. As a result of the examination made in terms of ammonia, it was seen that the treatment efficiency of the simulation was lower than the experimental data. This may be evidence of insufficient oxygen. According to the results examined in terms of $NO_x$, the experimental data of the effluent and the simulation results are parallel to each other. SRT 20 – Case 3 SCOD results obtained with dynamic modeling are lower than real experimental data results. This means that the sensibilty is the modelling tool is higher. In the experimental study results, the $NH_4$ results are very close to zero. However, according to the dynamic modeling results made with the SUMO program, values close to zero in the first 35 days increased to 23 mg/L levels between 35 and 55 days. Excellent removal efficiency was achieved with near-zero results by dynamic modeling from day 55 to day 100. The $NO_x$ removal efficiency is consistent with the experimental data and simulation results. SRT 20 – Case 4 For Case 4, the last scenario of long-term predictions, the SCOD experimental data results and simulation results are very close. As for all other scenarios for $NH_4$, the dynamic modeling result and the real experimental data result are compatible. $NO_x$ data is fairly consistent, as in all other long-term scenarios.

Circular data assessments are as follows: SRT 13 – Case 1 It is seen that the amount of SCOD decreases in the first 2 hours in experimental data. In the SUMO simulation, it is seen that the cycle is completed with values ranging from 20 mg/L to 40 mg/L. While the amount of $NH_4$ decreases from 10 mg/L to zero in the first 2 hours in real experimental data, it appears to cover about 35 mg/L for 8 hours in SUMO dynamic modeling. Comparing the SRT 13 – Case 2 experimental data and dynamic modeling results were in equilibrium for 8 hours. Real experimental data results were broken in half starting at about 80 mg/L at the start of the 2nd hour. Where the $NH_4$ results can be examined, very similar results were obtained with scenario 1. Monitoring of SCOD measurements can be seen where the simulation remained constant at about 20 mg/L over the 8 hour cycle. However, experimental data started from 77 mg/L and decreased to 30 mg/L after 8 hours. Unlike the other two scenarios, the simulation results and experimental results are quite consistent for $NH_4$. It can be seen that it experienced the same rate of change at almost the same time. In terms of SCOD, the assessments are very similar to Case 3. Again, according to the experimental data, the amount of SCOD, which started at a high

rate, decreased after 8 hours, while the result of dynamic modeling was routinely repeating itself in the same interval. $NH_4$ measurements show little variation in both experimental and simulated results. At the end of 8 hours there is almost zero $NH_4$ in both cases. This demonstrated the success of dynamic modeling, achieving real results. Analyzes were made in order to obtain information about the reactions occurring in the SBR operating at 8 hours/day in the experimental setup. Measurement results and dynamic measurement results of SCOD and $NH_4$ amounts over 8 hours cycle times were compared in four scenarios for SRT 20. For the first three scenarios, while the SCOD is quite high in the simulation results, it is low in the analysis results. As of the fourth scenario, adaptation has been achieved. In the first two scenarios, $NH_4$ is quite high in terms of simulation results. The data results used in the third and fourth scenarios were in agreement with the dynamic measurement results. When the experimental data and simulation results are compared, the experimental data show that it decreases from 75 mg/L to 50 mg/L within the first hour. However, results for SUMO, a dynamic modeling tool, increased from 22 mg/L to about 31 mg/L. For the next seven hours, both experimental data and simulation results are between 20 mg/L and 30 mg/L. According to the results obtained in the simulation tool, the amount of $NH_4$ varies between 18 mg/L and 22 mg/L for 8 hours. In experimental data, these measurements decreased from 8 mg/L to zero in the first 2 hours. For this scenario, unlike the other first scenario, the SCOD amounts showed difference between the real data and the simulated dynamic model. The assessment for $NH_4$, on the other hand, was similar to the previous scenario in terms of both numbers and behaviour. It is possible to examine Case 3 in the results of the analysis made according to the samples taken from the SBR. Simulation results and experimental results look quite different. Which will be examined in terms of ammonia, it is seen that the results are similar both in the simulations made with the SUMO modeling tool and in the real experimental data results. The values that should be according to the dynamic modeling are closer to each other than the real experimental results in the last case. In terms of $NH_4$, the same behavioral trends as a perfect match emerged during the 8 hour cycle.

**REFERENCES**


Allı, B. İ. (2017). Behavior of activated sludge systems with an active heterotrophic biomass inflow – a novel perspective for sludge minimization. *Journal of Chemical Technology and Biotechnology*, https://doi.org/10.1002/jctb.5368.

Al-Omari, A. H. (2019). Colloids, flocculation and carbon capture – a comprehensive plant-wide model. *Water Science & Technology*, 15-25 https://doi.org/10.2166/wst.2018.454.

Balanica, C. M. (2020). Statistical Analysis of the Physicochemical Characteristics of Urban Wastewater Treatment Plants from Romania. *Revista de Chimie*, 100-107.

Blackburne, R. Y. (2008). Partial nitrification to nitrite using low dissolved oxygen concentration as the main selection factor. *Biodegradation*, 303-312.

Carlsson, B. (n.d.). The Activated Sludge Model No 1 ASM1. *Uppsala, Sweden. Retrieved from Uppsala University.*

Çığgın, A. S. (2011). Growth and storage kinetics of activated sludge systems operated with various carbon sources for different sludge ages (Doctoral dissertation). *İstanbul Technical University, Institute of Science and Technology*, İstanbul.

Çınar, Ö. (2010). Aktif çamur prosesi I. bölüm. http://www.avesis.yildiz.edu.tr. Retrieved from www.yildiz.edu.tr: www.yildiz.edu.tr

Ciner, F. S. (2005). Multicomponent activated sludge model for reactors in series with recycling. *International Journal of Environment and Pollution*, 397-409.

Cokgor, E. O. (2005). Effect of primary sludge fermentation products on mass balance for biological treatment. *Water Science & Technology*, 105-114.

Comeau, Y. T. (2008). Schematic representation of activated sludge models. *Proc. 81st Annual Water Envronment Federation Technical Exhibition and Conference*, (pp. 18-22). Chicago, İllinois, October 20.

Damar, Y. (2009). Tekstil Endüstrisi Atıksularının Ardışık Kesikli Biyoreaktör ile Arıtılması ve Modellenmesi. *Sakarya: Sakarya Üniversitesi.*

Debik, E. M. (2017). Biyolojik Temel İşlemler Ders Notları. Retrieved from CEV3392 BTI:file:///C:/Users/90554/Downloads/CEV3392-BTI-Ders%20Notu%20(1).pdf

Dynamita. (2022, 08 1). *Sumo.* Retrieved from http://www.dynamita.com

El-Din, A. (2002). Dynamic Modelling of Wastewater Treatment Processes. *Alberta: University of Alberta.*

EPA. (1999). Wastewater Technology Fact Sheet Sequencing Batch Reactors. *Washington, D.C.: United States Environmental Protection Agency Office of Water.*

Gülhan, H. E. (2018). Tam ölçekli bir ileri biyolojik evsel atıksu arıtma tesisinin matematiksel modellemesi. *Çukurova University Journal of the Faculty of Engineering and Architecture*, 33(4), ss. 213-224.

Gürtekin, E. &. (2006). Aktif çamur proseste aşırı çamur üretimini azaltmak için kullanılan yöntemler. *Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi,* Cilt11, Sayı 1., Retrieved from https://dergipark.org.tr/tr/pub/uumfd/issue/21684/233388.

Hauduc, H. W. (2019). Incorporating sulfur reactions and interactions with iron and phosphorus into a general plant-wide model. *Water Science & Technology*, 26-34 https://doi.org/10.2166/wst.2018.482.

Henze, M. G. (1995). The Activated Sludge Model No. 2: Biological phosphorus removal. *Water Science and Technology*, 1-11.

Hug, T. B. (2009). Wastewater treatment models in teaching and training: the mismatch between education and requirements for jobs. *Water Science & Technology*, 745-753.

İbadullayeva, J. J. (2019). Çevre kirliliğinin insan sağlığı üzerindeki etkileri. *Türk Tıp Öğrencileri Araştırma Dergisi*, 52-58.

İnsel, H. G. (2021). Kentsel Atıksu Arıtma Tesisleri Proses Seçimi, Tasarımı ve Modellenmesi El Kitabı. *İstanbul: İSKİ.*

Irvine, R. K. (1988). Sequencing batch reactors for biological wastewater treatment. *Critical Reviews in Environmental Control*, 225-294.

Juergen, W. S. (2003). A Case-Based Predictive Sequencing Batch Reactor Controller. *Conference: 18TH International Joint Conference on Artificial Intelligence, Workshop on Environmental Decision Support Systems (EDSS'2003).* Barcelona: Universitat Politecnica De Catalunya.

Karlikanovaite, A. B. (2019). Nitrogen Removal and Microbial Community Shift in Oxic Settling - Anoxic Sludge Reduction Process. *Istanbul: Istanbul Technical University, PhD Thesis.*

Kavak N. (2016). Kayseri ili örneğinde, atıksu arıtma tesislerinde uygulanan arıtma yöntemlerinin incelenmesi ve optimum yöntemin belirlenmesi (Yüksek lisans tezi). *Nevşehir Hacı Bektaşi Veli Üniversitesi, Fen Bilimleri Enstitüsü, Nevşehir.*

Kırım, G. (2015). Atıksu Arıtma Tesislerinin Model Desteği ile İyileştirilmesi ve Optimizasyonu. *İstanbul: İstanbul Teknik Üniversitesi.*

Koyuncu, İ. Ö. (2013). Atıksu Arıtma Tesisleri Tasarım Rehberi. *Ankara: T.C. Orman ve Su İşleri Bakanlığı.*

Kukul, Y., Çalışkan, Ü.A.D. & Anaç, S. (2007). Arıtılmış atık suların tarımda kullanılması ve insan sağlığı yönünden riskler. *Ege Üniversitesi Ziraat Fakültesi Dergisi,* 101-116.

Low, E. W. (1990). Uncoupling of metabolism to reduce biomass production in the activated sludge process,. *Water Research,* 34, 3204-3212.

Mara, D. (2003). Domestic Wastewater Treatment in Developing Countries. *London: Routledge.*

Ndeba-Nganongo, L. A.-T. (2018). The Application of ADM/ASM Interface in Sumo Wide Plant Model. *Int'l Conference on Advances in Science, Engineering, Technology & Healthcare,* (pp. 237-241). Cape Town, November 19-20.

Okutman, T. T. (2010). Geleneksel ve çok bileşenli modelleme yöntemlerindeki içsel solunum katsayısının çamur üretimine etkisinin karşılaştırılması. *İtü Dergisi/e,* 79-88.

Olcay, D. (2014). Characterization and modelling of activated sludge process pharmaceutical industry wastewaters (M.Sc. thesis). *İstanbul Technical University, Graduate School of Science Engineering and Technology, İstanbul.*

Orhon, D. A. (1994). Modelling of Activated Sludge Systems. *USA: Technomic Publishing Company, Inc.*

Özyıldız, G. (2017). Aktif Çamur Sistemlerinde Çamur Yaşının Sistem Kinetiğine ve Biyolojik Arıtılabilirliğine Olan Etkisinin Belirlenmesi. *İstanbul: İstanbul Teknik Üniversitesi.*

Patel, A. A. (2021). Physico-chemical and biological treatment strategies for converting municipal wastewater and its residue to resources. *Chemosphere, 282.*, https://doi.org/10.1016/j.chemosphere.2021.130881.

Porges, N. J. (1953). Aerobic Treatment of Dairy Wastes. *Eastern Regional Research Laboratory, Philadelphia 18, Pennsylvania.*

Rathore, K. (2018). Dynamic Modeling of an Advanced Wastewater Treatment Plant. *Florida: University of South Florida.*

Sabri, D. Y. (2017). Dynamic simulation for wastewater treatment plants management: Case of Souk-Ahras region, north-eastern Algeria. *Journal o Water and Land Development, 34, 221-231*, doi: 10.1515/jwld-2017-0057.

Scholz, M. (2016). Activated Sludge Processes. *Salford: Elsevier B.V.*

Smith, D. S. (2008). Phospate complexation model and its implications for chemical phosphorus removal. *Water Environment Research*, 428-438.

Stott, R. (2003). Fate and behaviour of parasites in wastewater treatment systems. In D. H. Mara, *Handbook of Water and Wastewater Microbiology* (pp. 491-521). Leeds: Elsevier Ltd.

Svennevik, O. S. (2019). Effects of post anaerobic digestion thermal hydrolysis on dewaterability and moisture distribution in digestates. *Water Science & Technolog*, DOI:10.2166/wst.2019.379.

Taşkınoğlu, O. (2008). Atıksu arıtma tesislerindeki yan akımların arıtma sistemine etkisi (Yüksek lisans tezi). *İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.*

Thiel, D. J. (2002). Activated Sludge: Manual of Practice OM-9, 3rd Edition. *Virginia: Water Environment Federation.*

Toprak, H. (2006). Aktif Çamur Sürecinin Tasarım Uygulamaları Cilt-II. *İzmir: Dokuz Eylül Üniversitesi Mühendislik Fakültesi Basım Ünitesi.*

Varga, E. (2018). Recent advances in bio-P modelling – a new approach verified by full-scale observations . *Water Science & Technology*, 2119 - 2130 https://doi.org/10.2166/wst.2018.490.

Wärff, C. (2019). Developing A Process Model For Ängens WWTP. *Sweden: RISE Research Institutes of Sweden.*

Wett, B. &. (2003). Impact of seperate rejection water treatment on the overall plant performance. *Water Science & Technology*, 139-146.

Wulan, D. H. (2022). Domestic wastewater in Indonesia: generation, characteristics and treatment. *Environmental Science and Pollution Research*, 32397–32414.

Yahui, S. H.-H. (2022). Emerging biological wastewater treatment using microalgal-bacterial granules: A review. *Bioresource Technology, 351.*, https://doi.org/10.1016/j.biortech.2022.127089.

# APPENDICES

## APPENDIX A:

| Model Parameter | Symbol | Unit | $CAS_{13\text{-}NH}$ | $CAS_{13}$ | $OSA_{13\text{-}NH}$ | $OSA_{13}$ | OSA-$SR_{13}$ | $SR_{13}$ | $CAS_{20\text{-}NH}$ | $CAS_{20}$ | $OSA_{20\text{-}NH}$ | $OSA_{20}$ | OSA-$SR_{20}$ | $SR_{20}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Characteristics of respirometric tests* | | | | | | | | | | | | | | |
| Sludge age | - | d | 13 | 13 | 13 | 13 | 13 | 13 | 20 | 20 | 20 | 20 | 20 | 20 |
| Origin of the sludge | - | - | CAS-SBR | CAS-SBR | OSA-SBR | OSA-SBR | OSA-SBR & SR | SR | CAS-SBR | CAS-SBR | OSA-SBR | OSA-SBR | OSA-SBR & SR | SR |
| ATU addition | - | - | Yes | No | Yes | No | No | No | Yes | No | Yes | No | No | No |
| Volume of sludge | $V_{sl}$ | mL | 1250 | 1250 | 1250 | 1250 | 1150 | 96 | 1250 | 1250 | 1250 | 1250 | 1180 | 63 |
| Volume of the mixture of wastewater | $V_{ww}$ | mL | 330 | 330 | 330 | 330 | 330 | 1400 | 330 | 330 | 330 | 330 | 330 | 1400 |
| Biomass from CAS-SBR | $X_{CAS}$ | mgCOD/L | 852 | 852 | - | - | - | - | 852 | 852 | - | - | - | - |
| Biomass from OSA-SBR | $X_{OSA}$ | mgCOD/L | - | - | 710 | 710 | 795 | - | - | - | 1120 | 1120 | 1035 | - |
| Biomass from SR | $X_{SR}$ | mgCOD/L | - | - | - | - | 200 | 1910 | - | - | - | - | 178 | 2270 |
| Total biomass conc. | $X_T$ | mgCOD/L | 852 | 852 | 710 | 710 | 995 | 1919 | 852 | 852 | 1120 | 1120 | 1213 | 2270 |
| *Wastewater characteristics (conventional)* | | | | | | | | | | | | | | |
| Total COD of the mixture of real wastewater and glucose | tCOD | mgCOD/L | 570 | 570 | 480 | 480 | 480 | 480 | 480 | 480 | 630 | 630 | 630 | 480 |
| Soluble COD of the mixture of real wastewater and glucose | sCOD | mgCOD/L | 418 | 418 | 303 | 303 | 303 | 303 | 365 | 365 | 491 | 491 | 491 | 365 |
| tCOD of supplementary glucose | tCOD | mgCOD/L | 243 | 243 | 130 | 130 | 130 | 130 | 160 | 160 | 245 | 245 | 245 | 160 |
| *Wastewater characteristics (from OUR data)* | | | | | | | | | | | | | | |
| Readily biodegradable COD | $S_{SI}$ | mgCOD/L | 273 | 273 | 181 | 181 | 181 | 181 | 200 | 200 | 300 | 300 | 300 | 200 |
| Readily hydrolysable COD | $S_{HI}$ | mgCOD/L | 72.5 | 72.5 | 63 | 63 | 63 | 63 | 70 | 70 | 123 | 123 | 123 | 70 |
| Slowly hydrolysable COD | $X_{SI}$ | mgCOD/L | 95 | 95 | 110 | 110 | 110 | 110 | 115 | 115 | 76 | 76 | 76 | 115 |
| Particular inert COD | $X_I$ | mgCOD/L | 57 | 57 | 55 | 55 | 55 | 55 | 48 | 48 | 63 | 63 | 63 | 48 |
| Soluble inert COD | $S_I$ | mgCOD/L | 72.5 | 72.5 | 70 | 70 | 70 | 70 | 50 | 50 | 67.2 | 67.2 | 68 | 50 |
| Total COD of mixture of real wastewater and glucose | $C_T$ | mgCOD/L | 570 | 570 | 479 | 479 | 479 | 479 | 483 | 483 | 629,2 | 629,2 | 630 | 483 |

**Figure A:** Characteristics of respirometric test and wastewater.

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