Zajednica izvršitelja

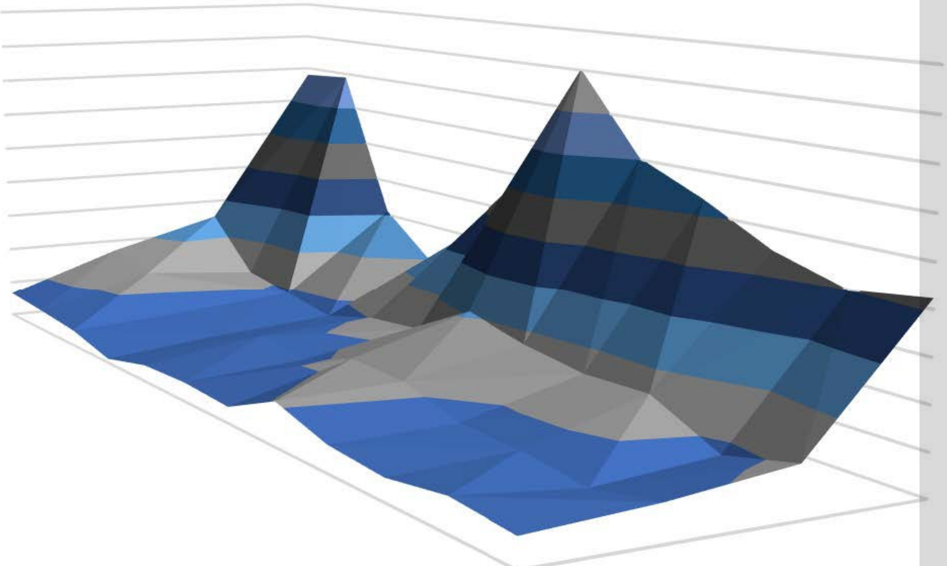
Naručitelj

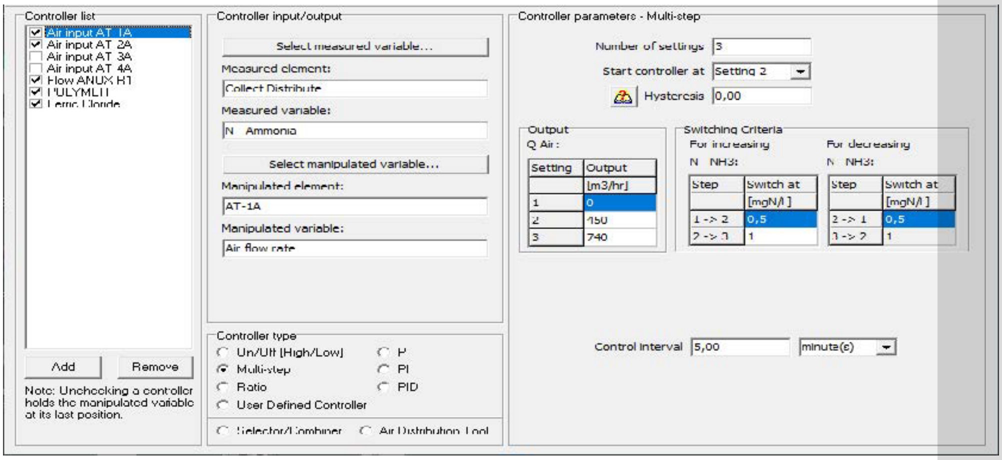
Krajnji korisnik

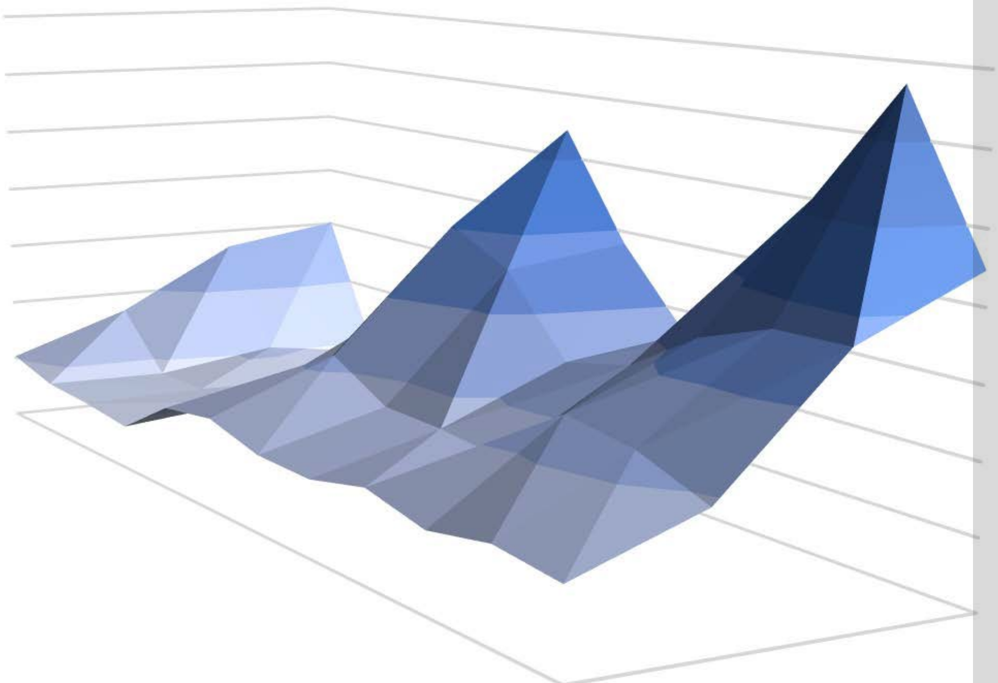
IZVJEŠĆE 7c Modeliranje UPOV-a – Analiza scenarija :UPOV Lanterna

studeni 2021

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA
IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA
ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – STUDIJA POREČ







STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 7 dio 3/ 4

MODELIRANJE UPOVa:

ANALIZA SCENARIJA - UPOV LANTERNA

Studeni 2021

Zajednica izvršitelja

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STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 7 dio 3/ 4

MODELIRANJE UPOVa:

ANALIZA SCENARIJA - UPOV LANTERNA

13. studeni 2021

10. studeni 2021

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1 Sažetak izvješća

1.1 Uvod

Infrastrukturno ulaganje "Postrojenja za odvodnju i pročišćavanje otpadnih voda Grada Poreča" – Projekt Poreč, sufinanciran od strane Europske unije, jedna je od najvećih investicija u javnom sektoru u Republici Hrvatskoj. Uključuje sanaciju i proširenje postojećeg kanalizacijskog sustava te izgradnju četiri nova uređaja za pročišćavanje otpadnih voda (UPOV). Cilj je bolja zaštita okoliša u i oko porečkog priobalja. Komplementarno se razvija projekt pod nazivom „Integrirano modeliranje infrastrukturnog sustava otpadnih voda Grada Poreča" – Projekt modeliranja. Ovaj projekt je integrirana procjena utjecaja na okoliš radi boljeg razumijevanja utjecaja performansi sustava na okoliš koji se ocjenjuje u nizu radnih uvjeta. Studija scenarija je razvijena korištenjem najsuvremenijih "state-of-the-art" (modelskih) alata i metoda koje omogućuju holističku procjenu sustava otpadnih voda. Rezultati ovog istraživanja služe kao pomoć budućem poslovanju i gospodarenju otpadnim vodama u regiji te se koriste za podizanje znanja i profesionalnih vještina stručnjaka lokalnog vodnog sektora.

Projekt modeliranja sastoji se od 4 glavne komponente, i to:

• 1. dio: Modeliranje sustava prikupljanja i transporta otpadnih voda Grada Poreča,

• 2. dio: Modeliranje rada i rezultata pročišćavanja na 4 UPOV-a Grada Poreča,

• 3: dio: Model procjene utjecaja morskih ispusta na kvalitetu morske vode,

• 4. dio: Uspostava eksperimentalnog laboratorija za praćenje i optimizaciju upravljanja i rada otpadnih voda.

Uključujući trening organizira se kako bi se proširili kapaciteti stručnjaka u vodnom gospodaarstvu u korištenju modeliranja sustava otpadnih voda za buduće procjene.

Projekt modeliranja ima holistički sustavni pristup koji pokriva skupljanje, obradu i ispuštanje otpadnih voda u morsko okruženje, međuodnos između različitih sustava otpadnih voda i utjecaj na okoliš, javno zdravlje i kvalitetu obalne morske vode.

Nekoliko scenarija proračunato je kako bi se istražio utjecaj Projekta Poreč na prethodno navedene čimbenike te kako bi se uspostavile najbolje metode upravljanja sustavima otpadnih voda iz integrirane perspektive.

Modeliranjem se demonstrira kako nadogradnja porečkog sustava otpadnih voda poboljšava okoliš. Razvija se daljnji uvid u cjelokupnu interakciju podsustava o kvaliteti morske vode.

Kroz projekt se razvija i znanje o tome kako upravljati i optimizirati različite sustave otpadnih voda, s najboljim ukupnim rezultatima.

1.2 Ciljevi projekta

Opći cilj projekta modeliranja Poreča je pokazati kako nadogradnja ukupnog sustava otpadnih voda poboljšava kvalitetu morske vode u porečkom primorju.

Stoga se modelira ukupni sustav otpadnih voda koji se sastoji od nekoliko podsustava. Modeliranjem uređaja za pročišćavanje otpadnih voda u različitim (ekstremnim) uvjetima istražuje se kako će opterećenje i kvaliteta otpadnih voda utjecati na kvalitetu morske vode. Za svaki proučavani scenarij izračunavaju se koncentracija efluenta i profili protoka. Ti se podaci naknadno koriste kao ulazni podaci za modeliranje kakvoće morske vode iz kojeg se izračunava utjecaj na okoliš.

Prvo izvješće u ovoj seriji je početno izvješće i statičko modeliranje detaljnog dizajna. Relevantni podaci za modeliranje PPOV i studiju scenarija se prikupljaju, organiziraju, izvještavaju procesi za modeliranje i statički model. Objašnjene su metode korištene za ovo istraživanje i napravljeno je opće planiranje izvođenja radova.

U ovom izvješću, statički modeli se dalje razvijaju prema dinamičkim modelima uključujući dinamičku aeraciju i kontrolu procesa. Ocjenjuje se kako se rješenja iz detaljnog projekta ponašaju u realnim utjecajnim i operativnim uvjetima. Kvaliteta efluenta iz dinamičkih simulacija koristi se za daljnju analizu i modeliranje kvalitete obalne vode.

1.3 Upute za čitatelja

Ovo izvješće odnosi se na Projekt modeliranja 2. dio: Modeliranje rada i rada 4 UPOV Grada Poreča. Svaki UPOV se modelira i izvještava zasebno. Projekt modeliranja 2. dio razvijen je u četiri koraka, jedno izvješće po koraku za svako pojedinačno UPOV.

• Korak 1: Statičko modeliranje UPOV na temelju detaljnog projekta. U ukupnom projektu ovo je izvješće broj 5, koje se sastoji od 4 pod-izvješća po jedno za svaki UPOV (izvješće broj 5.1 do 5.4).

• Korak 2: Dinamičko modeliranje UPOV na temelju dinamičkog mjerenja influenta tijekom zime i ljeta. U ukupnom projektu ovo je izvješće broj 6, koje se sastoji od 4 podizvješća po jedno za svaki UPOV (izvješće broj 6.1 do 6.4).

• Korak 3: Analiza operativnih scenarija UPOV. Ovo izvješće uzima rezultate prethodnih studija te je niz operativnih scenarija razvijeno i kvantificirano po opterećenjima i koncentracijama obalnog protoka (izvješće broj 7).

• Korak 4: Validacija modela na temelju operativnih mjerenja. U ukupnom projektu ovo je izvješće broj 8, koje se sastoji od 4 podizvješća po jedno za svaki UPOV (izvješće broj 8.1 do 8.4).

Ovo podizvješće prikazuje dinamičke proračune scenarija ljeta i zime ekstrapolirane na uvjete opterećenja u 2045. godini. U 3. poglavlju objašnjena je postavka dinamičkog modeliranja uključujući funkcioniranje regulatora. Primijenjeni dinamički model je identičan za sve simulirane uvjete, no upravljanje radom i procesom može se prilagoditi kako bi se dobili odgovarajući standardi za otpadne vode. U 4. poglavlju je na temelju ekstrapolacije dotoka razrađena prognoza za ljetne i zimske uvjete opterećenja u 2045. godini. To se radi na temelju dinamičkih profila izmjerenih u 2019. U poglavljima 5 i 6 prikazani su rezultati simulacije za zimu i ljeto 2045. godine. Studija je zaključena u 7. poglavlju.

Za svako godišnje doba pokazuje se da uređaji za pročišćavanje mogu pročišćavati otpadne vode do željene razine i imaju dovoljnu fleksibilnost da se nose s različitim uvjetima otpadnih voda. Rezultati efluenta ove studije koriste se kao indikacija za opterećenje i koncentracije obalnog protoka tijekom vremena. Ovi se podaci koriste za razvoj scenarija u koraku 3 i modeliranje kvalitete morske vode.

1.4 Opći zaključci

• Simulacija modela pokazuje da se zahtjevi za efluent mogu zadovoljiti i za ljetne i za zimske uvjete punjenja do 2045. godine.

• Model je simuliran u dinamičkim uvjetima. Dinamički profili protoka izračunati su na način da predstavljaju ljetne i zimske uvjete u godini 2045. Za modeliranje realnog scenarija, izmjereni podaci dinamičkog protoka iz 2019. ekstrapoliraju se prema 2045. Profili protoka za 2045. zimski i ljetni dobiveni su linearnom ekstrapolacijom na temelju procijenjenog rasta kućanstava i turističke gospodarske djelatnosti. Brojevi rasta prilagođeni su iz detaljnog projekta. Ekstrapolacija profila protoka radi se na satnoj bazi. Stoga se pretpostavlja da se koncentracija otpadnih voda, učestalost vršnih ispuštanja i padavina neće mijenjati prema 2045.

• Simulacije pokazuju da je projekt sposoban pročišćavati otpadne vode na željenu razinu efluenta i da postoji dovoljna operativna fleksibilnost da se nosi s različitim sezonskim uvjetima opterećenja.

• Potrebe za otpadnim vodama mogu se zadovoljiti u svim modeliranim uvjetima uključujući zimske kišne događaje te ljetno i zimsko vršna opterećenja.

• Simulacije pokazuju da rezultati efluenta uvelike ovise o načinu rada i kontrole. Ova studija pokazuje da se postrojenje može učinkovito kontrolirati korištenjem jednostavnih, ali realističnih kontrola procesa.

• Tijekom ljeta, UPOV uklanja fosfor biološki, na temelju Bio-P procesa. Tijekom zime može se dozirati ograničena količina željeza za kemijsko uklanjanje P-a. Povećanje PO_4 u efluentu može biti uzrokovano nedostatkom kisika i nitrata za unos Bio-P.

• Zimski rad udovoljava projektnim zahtjevima, međutim, rad nije tipičan s obzirom na visoki SRT, dugi anaerobni i anoksični HRT, visoke interne stope recikliranja proporcionalne utjecaju i visok otopljeni kisik u sustavu aktivnog mulja.

• Točke pažnje za (zimski) rad su:

o Duga vremena zadržavanja hidraulike i mulja.

o Prekomjerna aercija i uklanjanje CO_2 u MBR-u, mogući pad alkalnosti i potencijalno ograničenje pH.

o Premali kapacitet recikliranja protoka što rezultira dugim anaerobnim vremenom zadržavanja, propadanjem anaerobne biomase i smanjenjem nitrifikacije i kapaciteta Bio-P.

o P-oslobađanje u spremniku WAS s operativnim HNL-om > 2-3 sata.

o Premalo WAS proizvodnje mulja (dugi SRT) da bi se zadovoljio Bio-P zahtjev.

• Ljetni rad je klasična vrsta rada unutar tipičnog radnog raspona. Dinamičke simulacije pokazuju da je pod ljetnim vršnim opterećenjem kapacitet aeracije i anaerobni SRT može postati ograničavajući. Međutim, u prosjeku je sve unutar predviđenog raspona.

1.5 Glavna preporuka

Preporuča se nastaviti s daljnjim razvojem studije scenarija i modeliranja morske vode uzimajući u obzir prikazane rezultate i zaključke.

Evaluation and efficiency monitoring of the new implemented sewage network and wastewater treatment construction in the larger city of Poreč.

Report 7.3 – Model scenario wastewater treatment prognosis 2045: Winter and summer conditions.

WWTP Lanterna

2021 08 15

Definitive Concept

innovative wastewater solutions

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Responsibility

Project Title	:	Evaluation and efficiency monitoring of the new implemented sewage network and wastewater treatment construction in the larger city of Poreč. Dynamic modelling the detailed design of WWTP Lanterna based on 2019 influent flow and concentration measurements under summer and winter conditions.
Working Title	:	Report 7.3 – WWTP Lanterna – Model scenario wastewater treatment prognosis 2045: Winter and summer conditions.
Project Description:	:	Study of the environmental impact as the result of upgrading and operation of the wastewater system of the larger city of Poreč on coastal sea water quality. Integrated evaluation of the sewer system, wastewater treatment systems, coastal discharge, and sea water quality based on modelling tools.
Document number	:	ASM-20210815-RAP111
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Content

1 Management summary

1.1 Introduction

The infrastructural investment “Sewerage and Wastewater Treatment Plants of City of Poreč”– Project Poreč, co-funded by European Union, is one of the largest investments in the public sector in Republic of Croatia. It involves rehabilitation and extension of the existing sewerage system and construction of four new wastewater treatment plants (WWTPs). The goal is to better protect the environment in and around the Poreč coastal area. Complementary a project is developed titled “Integrated Modelling of Wastewater Infrastructure System of City of Poreč” – Modelling Project. This project is an integrated environmental assessment to obtain a better understanding of the environmental impact of the system performance which is evaluated under range of operational conditions. A scenario study is developed using state-of-the-art (modelling) tools and methods which allows a holistic assessment of the wastewater system. The results of this study are in assistance of future operations and wastewater management in the region and used to elevate knowledge and professional skills of local water sector professionals.

The Modelling Project consists of 4 main components, namely:

- Part 1: Modelling the sewage collecting and transport system of City of Poreč,
- Part 2: Modelling of operation and performance of 4 WWTPs of City of Poreč,
- Part 3: Model assessment impact offshore outlets on aquatic water quality,
- Part 4: Establishment of the experimental laboratory setup for monitoring and optimization of wastewater management and operation.

Including a training is organized to extend the capacity of water professionals in the use of wastewater modelling for future assessments.

The Modelling project has a holistic system approach covering collection, processing, and aquatic discharge of wastewater, the interrelation between the different wastewater systems and impact on the environment, public health, and coastal seawater quality.

Several scenarios are calculated to explore the impact of Project Poreč on the previous mentioned factors and to and establish the best methods for management of the wastewater systems from an integrated perspective.

Modelling is used to demonstrate how upgrade of the Poreč wastewater system improves the environment. Further insight is developed in the overall interaction of the sub-systems on seawater quality. Knowledge is developed on how to operate and optimize the different wastewater systems, with the best overall results.

1.2 Project goals

The overall objective of the Poreč modelling project is to demonstrate how upgrading the total wastewater system improves the sea water quality in the Poreč costal region. Therefore, the total wastewater system is modelled consisting of several sub-systems. By modelling the WWTP under different (extreme) conditions it is investigated how effluent discharge load and quality will affect the sea water quality. For each studied scenario, effluent concentration and flow profiles are calculated. These data are subsequently used as input for sea water quality modelling from which the environmental impact is calculated.

The first report in this series is the inception report and static modelling of the detailed design. Relevant data for the WWTP modelling and scenario study is collected, organized, processes for modelling and a static model is reported. The methods used for this research are explained and a general planning is made for the execution of the work.

In this report, the static models are further developed towards dynamic models including dynamic aeration and process control. It is evaluated how the detailed design performs under realistic influent and operational conditions. The effluent quality of the dynamic simulations is used for further analysis and modelling of coastal seawater quality.

1.3 Reader

This report concerns Modelling project Part 2: Modelling of operation and performance of 4 WWTPs of City of Poreč. Each WWTP is modelled and reported separately. Modelling project Part 2 is developed in four steps, one report per step for each individual WWTP.

- Step 1: Static WWTP modeling based on the detailed design. In the total project this is report number 5, consisting of 4 sub-reports one for each WWTP (report number 5.1 to 5.4).
- Step 2: Dynamic WWTP modeling based on dynamic winter and summer influent measurements. In the total project this is report number 6, consisting of 4 sub-reports one for each WWTP (report number 6.1 to 6.4).
- Step 3: Analysis of operational WWTP scenarios. This report takes the results of the previous studies, and a series of operational scenarios are developed and quantified on the coastal discharge loads and concentrations (report number 7).
- Step 4: Model validation based on operational measurements. In the total project this is report number 8, consisting of 4 sub-reports one for each WWTP (report number 8.1 to 8.4).

This sub-report presents dynamic scenario calculations of the summer and winter extrapolated to the loading conditions in the year 2045. In chapter 3 the dynamic modelling setup is explained including the functioning of the controllers. The applied dynamic model is identical for all simulated conditions however the operation and process controls may be adapted to obtain the appropriate effluent standards. In chapter 4 the prognosis for the summer and winter loading conditions in the year 2045 is developed based on extrapolation of the influent flow. This is done based on the dynamic profiles measured in 2019. In chapters 5 and 6 the simulation results for winter and summer 2045 are presented. The study is concluded in chapter 7.

For each season it is shown that the treatment plants can treat wastewater to the desired level and has sufficient flexibility to cope with different wastewater conditions. The effluent results of this study are used as an indication for the coastal discharge loads and concentrations over time. These data are used for scenario development in Step 3 and sea water quality modelling.

1.4 General conclusions

- Model simulation shows that the effluent requirements can be met for both summer and winter loading conditions up to the year 2045.
- The model is simulated under dynamic conditions. Dynamic flow profiles are calculated representing summer and winter conditions in the year 2045. For realistic scenario modelling, 2019 measured dynamic flow data is extrapolated towards 2045. The 2045 winter and summer flow profiles are obtained by linear extrapolation based on an estimated growth of households and tourist economic activity. Growth numbers are adapted from the detailed design. Extrapolation of flow profiles is done on an hourly basis. It is thereby assumed that the wastewater concentration, frequency of peak discharges and rain events do not change towards 2045.
- Simulations indicate that the design is capable of treating wastewater to the desired effluent level and that there is sufficient operational flexibility to cope with different seasonal loading conditions.
- The effluent requirement can be met under all modelled conditions including winter rain events and summer and winter peak loading.
- Simulations show that effluent results strongly depend on the method of operation and control. This study shows that the plant can be controlled effectively using simple however realistic process controls.
- During summer, the WWTP removes phosphorus biologically, based on the Bio-P process. During the winter, a limited amount of Iron may be dosed for chemical P-removal. Effluent PO_4 increases may be caused by shortage of oxygen and nitrate for Bio-P uptake.
- Winter operation meets the design requirements however, operation is not typical in respect to a high SRT, long anaerobic and anoxic HRT, high internal recycle rates proportional to the influent and high DO in the activated sludge system.
- Points of attention for (winter) operation are:
    - Long hydraulic and sludge residence times.
    - Over aeration and CO_2 stripping in the MBR, possible drop in alkalinity and potentially pH limitation.
    - Too little flow recycle capacity resulting in long anaerobic residence time, anaerobic biomass decay and reduction of nitrification and Bio-P capacity.
    - P-release in the WAS storage tank with operational HRT > 2-3 hours.
    - Too little WAS sludge production (long SRT) to meet the Bio-P requirement.
- Summer operation is a classical type of operation within typical operational range. Dynamic simulations indicate that under summer peak loading the aeration capacity

and aerobic SRT can become limiting. On average however, all is within the designed range.

1.5 Main recommendation

It is recommended to proceed with further development of the scenario study and sea water modelling taking in account the presented results and conclusions.

2 Introduction

This project is an integrated environmental assessment to obtain a better understanding of the environmental impact of the system performance which is evaluated under range of operational conditions. The four WWTPs of City of Poreč are modelled based on their detailed design and measured influent flows and concentrations in the summer and winter of 2019. In a previous report number 5 the static model is developed for evaluation of the average performance. In report number 6 dynamic models are developed to validate the operation under more realistic dynamic conditions. In this report the projected conditions in 2045 are simulated in a dynamic scenario study. The dynamic simulations are used to assess the impact of the new wastewater facilities on the costal seawater quality. Several extreme scenarios will be developed based to explore the impact of Project Poreč on the seawater quality.

This report presents the scenario calculations of the year 2045 loading conditions being the projected life span of the developed WWTPs. The flow prognosis is calculated based on extrapolation of dynamic influent data measured in 2019 under summer and winter conditions. The flow prognosis is coming from the population growth and increase of tourists and used from the detailed design. It is assumed that the concentration of the wastewater remains the same as well as the frequency and magnitude of concentration peaks and rain events.

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3 Dynamic modelling of WWTP Lanterna

3.1 Introduction

The dynamic model is developed from the static model which is developed in report number 5 of this research. There also all model details are presented in the appendix. All design conditions are adapted from the detailed design documentation. A summary of the detailed design with relevant data for modelling is also presented in report number 5.

In report number 6 the dynamic model is developed. To accommodate dynamic calculations, process control needs to be developed as well as an effective way of operating the plant to accommodate the effluent requirements. Therefore, some assumptions are made based on expert judgement. No changes are made to the model parameters. All operational settings and applied controllers could be applied in practice. Two 7-day calculation runs are presented; one for winter and one for summer.

During summer (high season), all parallel activated sludge lanes are in operation. During the winter (low season), the wastewater quantity is much smaller. To accommodate the low loading conditions parallel lanes may be taken out of operation. In the presented models this is indicated by dashed lines. In the model, when treatment lines are out of operation, no flow is applied to the tanks and the tanks are not aerated. Idle treatment lines are not taken in account in any calculation.

All simulated models use identical parameter settings which are all the default BioWin settings. No specific calibration was used nor required to simulate the plants. Model differences are the loading conditions, temperature of the wastewater, operational settings, and applied control settings. Summer and winter influent is specified separately (influent characterization parameters) and calculated based on the measured concentrations. Examples of operational setting that are changed are internal flow recycle, aeration control and setpoints, the amount of parallel lines operated, operated SRT, waste sludge and MLSS concentration and the amount of MBRs in operation. Especially the use of process control makes a difference between static and dynamic modeling results. More about this is explained in the next section.

3.2 Methodology

The dynamic modelling is based on the previous developed static model of the detailed design report number 5. Measured dynamic flow and concentration profiles are used for the model influent input. For the prognosis towards 2045 the wastewater flow of 2019 is extrapolated taking approximately 21% growth of domestic wastewater from households and 15% growth of touristic activity mainly during summer. It is assumed the influent is unchanged towards 2045. Influent concentration measurements applied in the model are total COD, total phosphorus, TKN and ISS. Based on these 4 parameters, the model calculates all other influent parameters including soluble and non-soluble fractions and biodegradable and non-biodegradable fractions. This is done based on the influent specification calculation presented in report number 5. pH is a directly measured dynamic model input. Influent Calcium and Magnesium are assumed constant and estimated from drinking water quality measurements. Winter conditions are simulated with a constant temperature of 12 °C. Summer simulations with 20 °C.

Application of process control strongly affects the process dynamics and effluent results. A simple however realistic control strategy is applied in the model thereby obtaining the required effluent standards. The developed control strategy is as much as possible the same for all 4 WWTPs modelled in this project. This is done to compare dynamic operations. Process control is adapted to winter and summer conditions to accommodate the effluent requirements and more specific nitrification and P-removal. The same controls are adapted to the 2045 loading conditions. Under peak loading conditions effluent can be calculated temporarily higher than allowed. However, the 7-day average effluent requirements are met under all simulated conditions (winter and summer both for maximum loading conditions projected in the year 2045).

3.3 Process control applications

The following dynamic process controllers are used identically for parallel lines:

- Aeration control of the first aerated tank (AT-A)
- Aeration control of the second aerated tank (AT-B)
- Control of the anoxic recycle (ANOX-R).
- Control of Iron dosage for P-removal (FECL3)
- Control of polymer dose (PE) for dewatering.
- Control of the WAS flow and related dewatering.
- Control of the return sludge recycle from the MBR.

Additional tot the standard BioWin control options, the BioWin controller application is used for advanced process control development of the air input of AT-A, the anoxic recycle flow based on nitrate in the anoxic tank, polymer based on the TSS load entering the centrifuge and iron dosage based on the PO4 concentration in the MBR. The control setting may be adjusted for summer and winter conditions to accommodate the effluent requirements. Standard BioWin controls that are applied are table controls (for the 10 hour daily operated WAS pump) and (influent) proportional control (for example the MLSS return flow, grit removal and screening removal) and regular aeration DO setpoint control in AT-B.

To model aeration in AT-A and AT-B, aeration parameters are used from the detailed design. This includes the type of aeration system, number of diffusers, reactor dimensions, installation height of diffusers, bubble rise height, maximum installed air flow capacity, maximum air flow per diffuser, surface per diffuser and water temperature.

For the second aeration tank (AT-B) DO is set-point controlled on 2,0 mgO2/L based on the air flow of AT-B. For the first aeration tank (AT-A) the air flow is controlled using a 3-step table controller which switches the air input of AT-A based on measurement of NH4 in the outflow of the aeration. Alternative control under winter conditions of AT-A is using a DO setpoint control or shutting of the aeration of AT-A completely to reduce CO2 stripping and drop of the pH. During the summer the MBR's are fully aerated. During the winter DO in the MBR may be setpoint controlled (to 6 mgO2/L) to reduce CO2 stripping. Oxygen rich water may be recycled from the MBR to AT-A, resulting in the DO control reducing the air flow of AT-A.

3.4 Other model assumptions

- Under winter conditions the plant loading may become too low for the designed reactor volumes. This results in long SRT and HRT negatively affecting nitrification and Bio-P. Very long anaerobic HRT causes anaerobic decay of biomass. A (partial) operational solution would be to apply the maximum available internal recycle flow under low loading conditions even when effluent nitrate is already low.
- The volume of the waste sludge (WAS) storage tank is high relative to the WAS production and theoretically allows a long storage. Storage of Bio-P sludge longer that 2-3 hours however, results in significant P-release which after dewatering is recycled via the dirty water to the activated sludge line. This causes an increasing effluent phosphorus concentration. To avoid P-release in the WAS tank the hydraulic residence time should be kept shorter than 2-3 hours. In the model this is realized by reducing the tank volume of the storage. This is a simple approach of controlling the residence time. However, in practice the large WAS tank should not be used for storage of activated sludge and only used as feeding tank for when the dewatering is operated.
- Dewatered sludge is assumed to be produced 10 hours of each day of the week. Dewatered sludge is set to approximately 23% dry matter according to the design. The solids removal efficiency is set to 97%. Solids in the centrate return to the waterline via an internal drainage.
- It is modelled that PE is dosed before dewatering. The dosage ratio comes from the detailed design. PE is assumed particulate biodegradable COD and therefore slightly contributes to the dewatered sludge production.
- The TSS load of grit and screening production is estimated from the detailed design as a percentage relative to the influent flow. The dry weight and volume of grit and screening before and after the press is unknown and estimated in the model. This does not affect other model results. It is assumed grit and screening is stored separately from the secondary sludge production.
- The MLSS return sludge recycle from the MBR reactors is assumed proportional the influent according to the recycle factor to influent (according to the detailed design 500%). This high influent proportional recycle results in a relative stable TSS concentration in the activated sludge tanks and MBR and in the waste sludge concentration and has practical benefit for operating the dewatering and controlling the PE dosage.

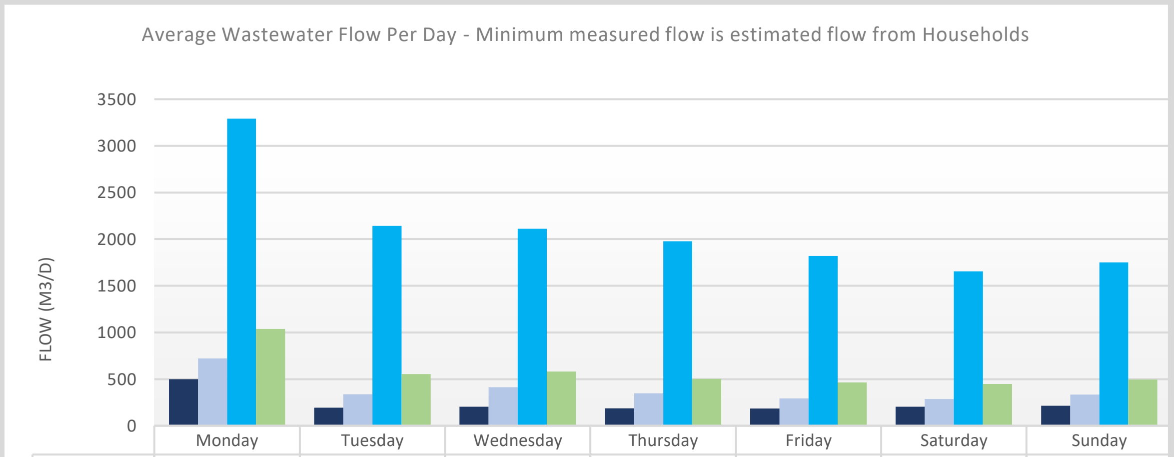
- It is assumed that during the summer the MBR is fully aerated, and the airflow is not controlled. During the winter, the total aerated volume can become too high, resulting in stripping of CO_2 and drop in alkalinity and possibly pH. Therefore during winter, parallel MBR reactors may be taken out of operation, or limited in the aeration by setting a maximum DO to 6 mgO_2/l. MBR reactors out of operation are indicated by dashed lines.
- For the operation of the MBRs it is assumed that there is a trace of solids in the effluent of 0,01% as well as a trace of colloidal materials of 0,1%. Therefore, solids removal of the membranes is set to remove 99,9% of solids and 99,99% of colloidal materials. VSS in the effluent is a measure for fecal bacteria and used for sea water quality modeling.
- The effluent storage tank is assumed to be always 100% filled with a constant volume and overflow. The storage volume is large compared to the total wastewater flow. This results in a strong buffering effect on the effluent concentration especially in winter and low flow conditions when effluent concentration fluctuations over the day are virtually absent. However, variations in the effluent flow will result in load variations over the day. The load variations at the effluent discharge points are used for seawater quality modelling.

4 Influent flow scenario 2045

4.1 Introduction and methods for scenario development

The prognosis simulation of the 2045 loading condition is based on extrapolation of 2019 dynamic summer and winter influent measurement data. These flow profiles are measured during winter from Monday 21-01-2019 9:00 till Monday 28-01-2019 7:00 and during summer from Friday 19-07-2019 9:00 till Friday 26-07-2019 7:00. Measurement points are recorded every 2 hours for all 4 treatment locations. For modelling, measurements are interpolated on an hourly basis. The original measurements are presented in reports 5 and 6. In this chapter the 2019 flow profile is extrapolated towards 2045 conditions. Distinction is made between the flow produced by households, by touristic activity and by rain and other peak events. For the flow from households, the best estimation is the minimum measured flow-day in the winter of 2019. This flow is assumed to largely exclude rain and touristic activity and extrapolated towards 2045 based on the estimated population growth.

The flow is extrapolated to a date in 2045 corresponding to a winter timeseries starting on Monday (23-1-2045) and a summer timeseries starting on Friday (Friday 21-7-2045). In the model, flow measurements every 2 hours are interpolated on an hourly basis.



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Lanterna	499	194	203	188	184	205	213
Vrsar	722	339	412	349	294	287	336
Poreč-North	3.290	2.141	2.112	1.976	1.820	1.656	1.750
Poreč-South	1.037	554	580	501	465	448	495

Figure 1. Winter 2019 - Average Wastewater Flow per WWTP per Day - Minimum DWA estimated from Households. Based on 7-day dynamic flow data measured in the winter of 2019. It is assumed that the minimum flow during winter relates to households only. This is Friday for Lanterna and Saturday for the other plants. This flow is extrapolated based on the estimated population growth.

Table 1. WWTP Lanterna – Wastewater Flow prognosis.

WWTP Lanterna - Data for Lanterna WWTP sizing				
	Population (PE)	Tourist Overnights Average	Households	Non-Households
Months	2011	2009-2011	2009-2011 (m3/month)	2009-2011 (m3/month)2
1	1860	100	6800	1200
2	1860	0	6200	1600
3	1860	1200	6200	5200
4	1860	31200	8800	17400
5	1860	96800	10200	32900
6	1860	232400	14100	56900
7	1860	472000	15900	75500
8	1860	507600	17600	93900
9	1860	175200	12800	50700
10	1860	6600	8200	9600
11	1860	100	6700	1600
12	1860	100	5500	800
Estimated growth of tourist overnights from 2011 to 2045				0,15
Permanent population 2045				2262

The increase of household comes from the detailed design as presented in the table above and is approximately 21%. It is assumed that occurrence of peak loading events and rain will not change towards 2045 and that the flow increase is only the result of increasing population and increasing economic activity mainly during summer.

For summer, the flow contribution of touristic activity is calculated by subtracting the flow related to households from the total flow. This is done on an hourly basis. Growth of touristic activity in the summer is assumed 15% towards 2045.

On winter measurement day 28-1-2019 a large rain event occurred. For more realistic dynamic simulation results and to be able to compare the 2029 and 2045 performance the exact similar event has been included in the winter simulation of 2045.

4.2 Winter influent flow measurement results

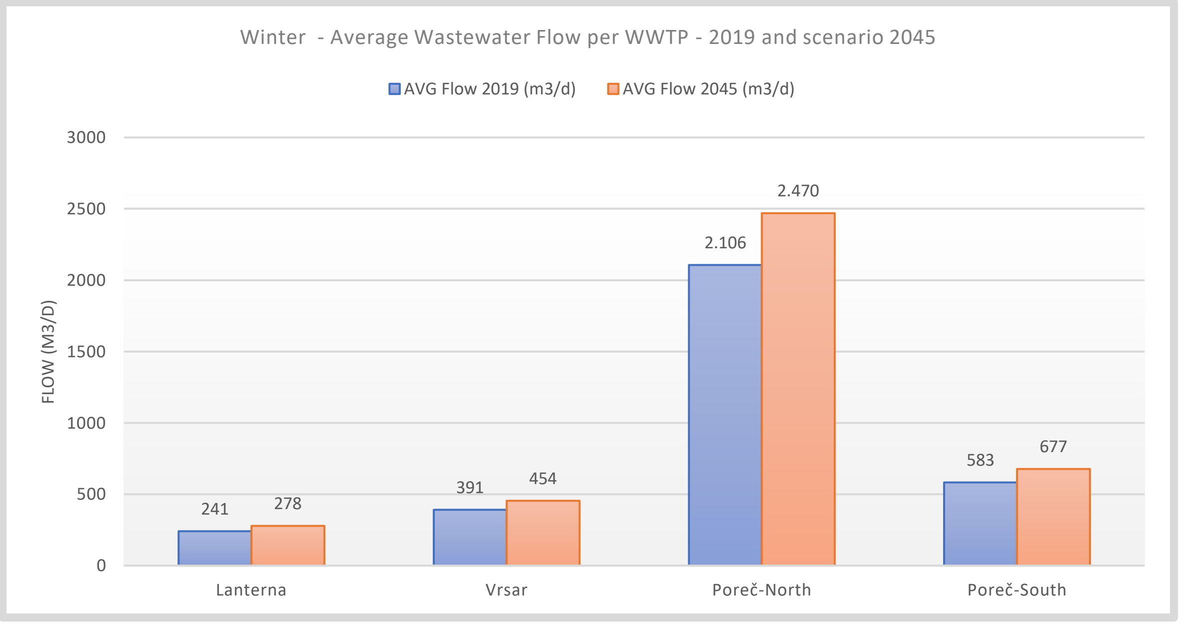


Figure 2. Winter – Average Wastewater Flow per WWTP – 2019 and scenario 2045. Average of measured 2019 dynamic influent flow data extrapolated towards 2045. The flow difference is the combination of growth of households by approximately 21% per community and assumed 15% growth of touristic activity during the summer.

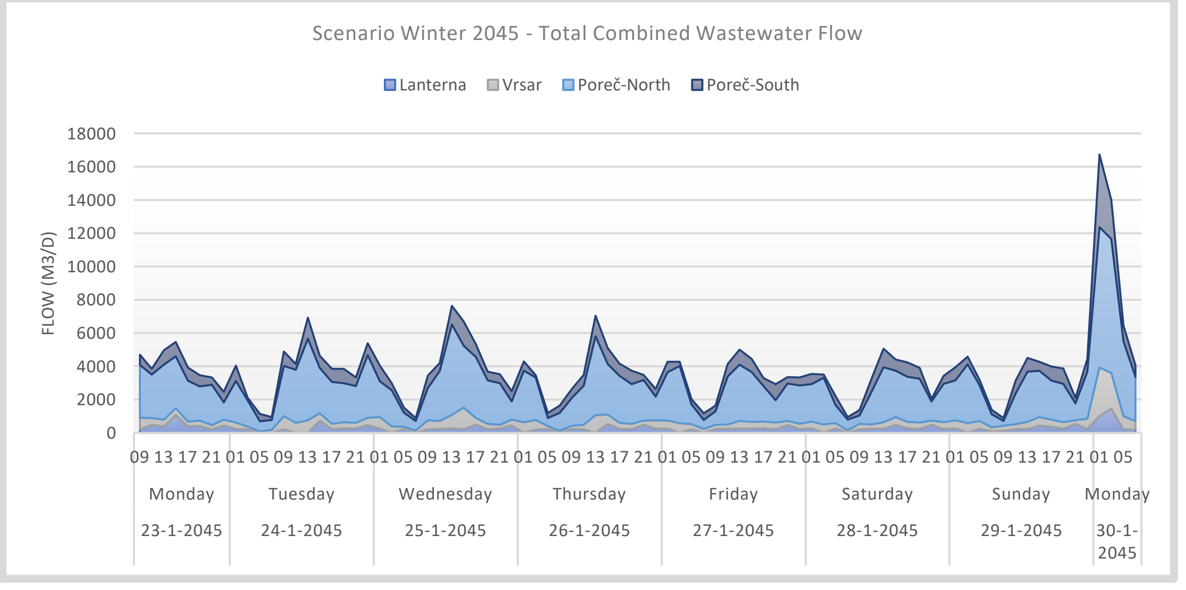


Figure 3. Scenario Winter 2045 – Total Combined Wastewater Flow of all WWTP's. The 2045 prognosis includes the same rain event measured in 2019. The 2019 and 2045 flow dynamics are largely identical however, the 2045 flow is larger resulting from increasing households and touristic activity.

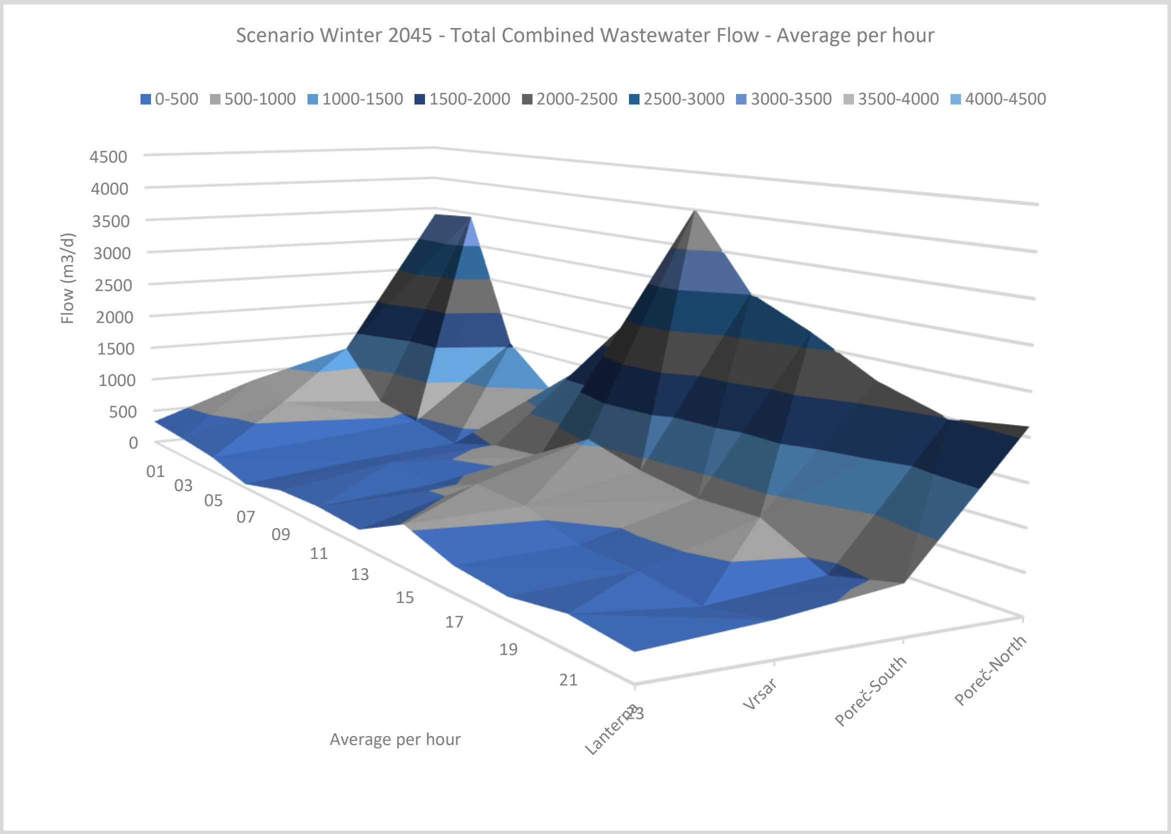
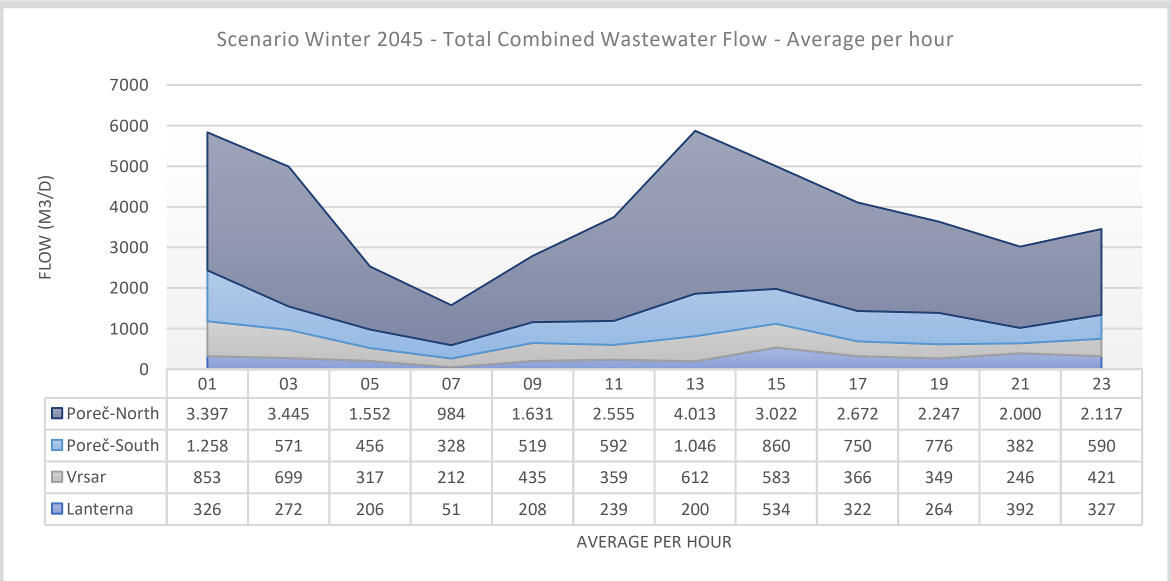
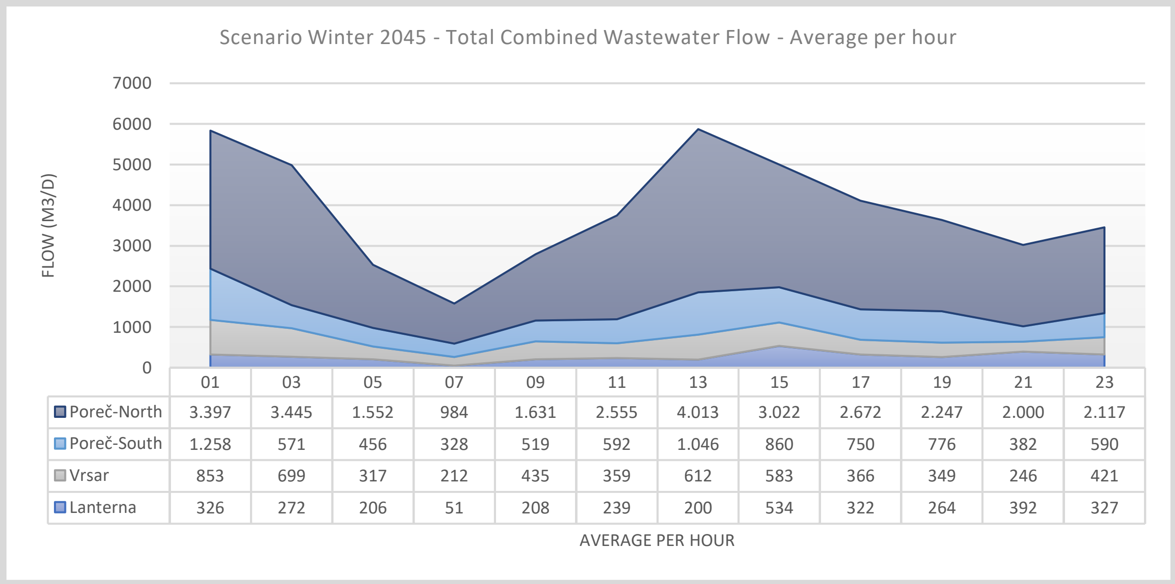


Figure 4. Scenario Winter 2045 – Surface plot Dry weather Total Combined Wastewater Flow 24-hour average hourly measurements. The data excludes the rain event at day 7. The plot order is from lowest to highest wastewater producing community.



	01	03	05	07	09	11	13	15	17	19	21	23
Poreč-North	3.397	3.445	1.552	984	1.631	2.555	4.013	3.022	2.672	2.247	2.000	2.117
Poreč-South	1.258	571	456	328	519	592	1.046	860	750	776	382	590
Vrsar	853	699	317	212	435	359	612	583	366	349	246	421
Lanterna	326	272	206	51	208	239	200	534	322	264	392	327

Figure 5. Scenario Winter 2045 – Mixed weather Total Combined Wastewater Flow 24-hour average hourly measurements. Including the rain event on day 7.



	01	03	05	07	09	11	13	15	17	19	21	23
Poreč-North	3.397	3.445	1.552	984	1.631	2.555	4.013	3.022	2.672	2.247	2.000	2.117
Poreč-South	1.258	571	456	328	519	592	1.046	860	750	776	382	590
Vrsar	853	699	317	212	435	359	612	583	366	349	246	421
Lanterna	326	272	206	51	208	239	200	534	322	264	392	327

Figure 6. Scenario Winter 2045 – Dry weather Total Combined Wastewater Flow 24-hour average hourly measurements. Excluding the rain event day 7. These data are used to reconstruct missing measurements in the flow data time series.

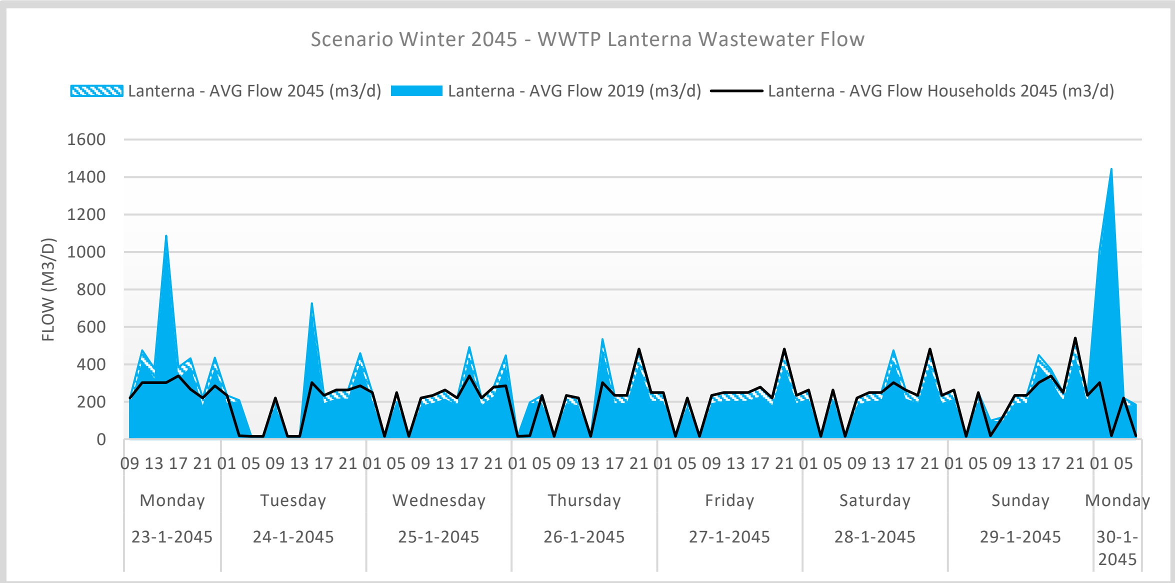


Figure 7. Scenario Winter 2045 – WWTP Lanterna Wastewater Flow 24-hour 7-day dynamic 2019 measurements and 2045 prognosis. Both the 2019 and 2045 flow data are modelled and included in the scenario study.

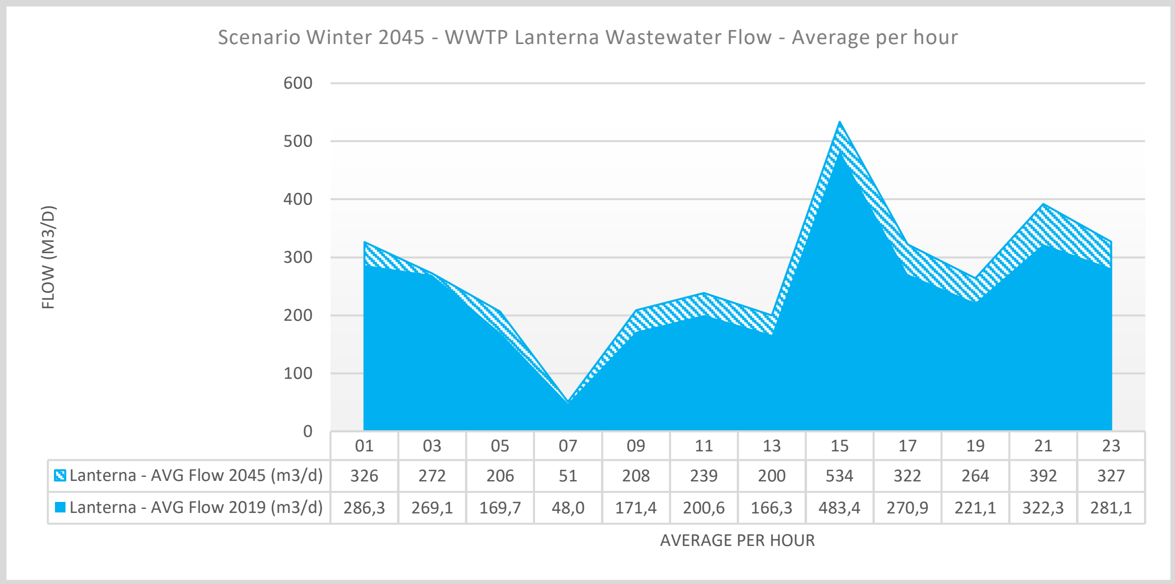


Figure 8. Scenario Winter 2045 – WWTP Lanterna Wastewater Flow 24-hour average hourly 2019 measurements and 2045 prognosis. Data are used to reconstruct missing data in the flow measurements and for development of scenarios.

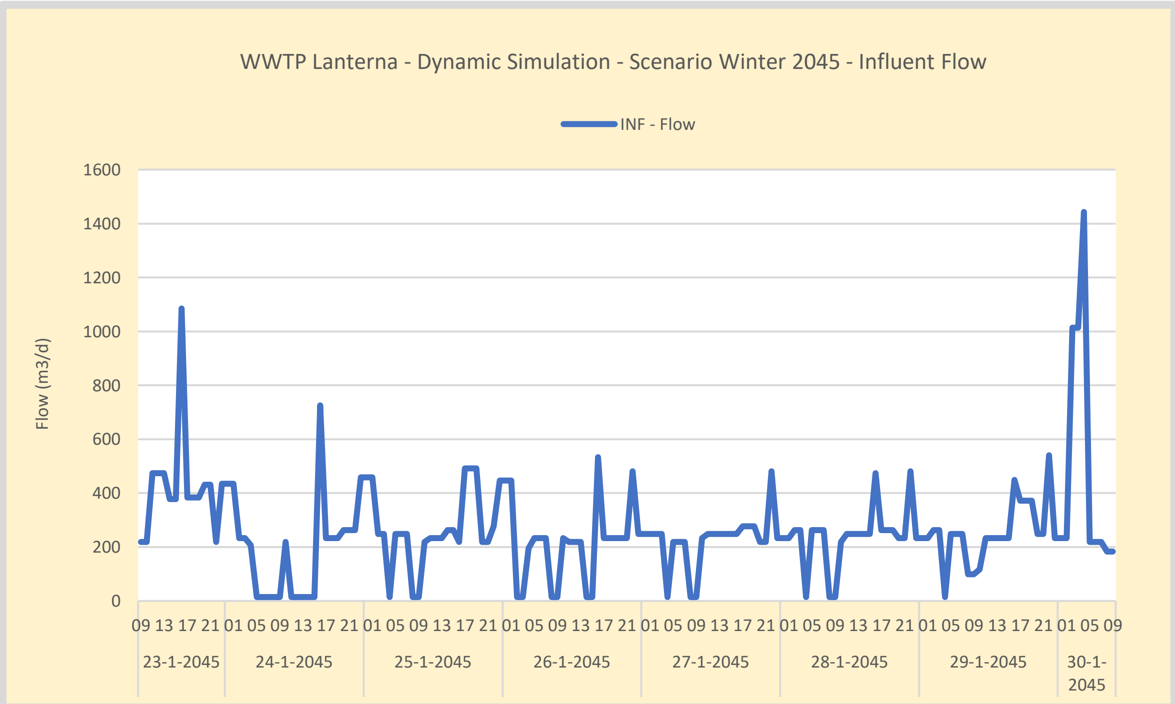


Figure 9. Scenario Winter 2045 – BioWin modelling WWTP Lanterna: Wastewater Influent Flow 24-hour 7-day dynamic model input data. Some datapoint are reconstructed form 24-hour average hourly measurements. The data is interpolated in the model from measurements every 2 hours to an hourly basis. The flow dynamics are adapted from the 2019 measurements extrapolated towards 2045. A similar rain event is simulated in 2045 as measured in 2019.

4.3 Summer influent flow measurement results

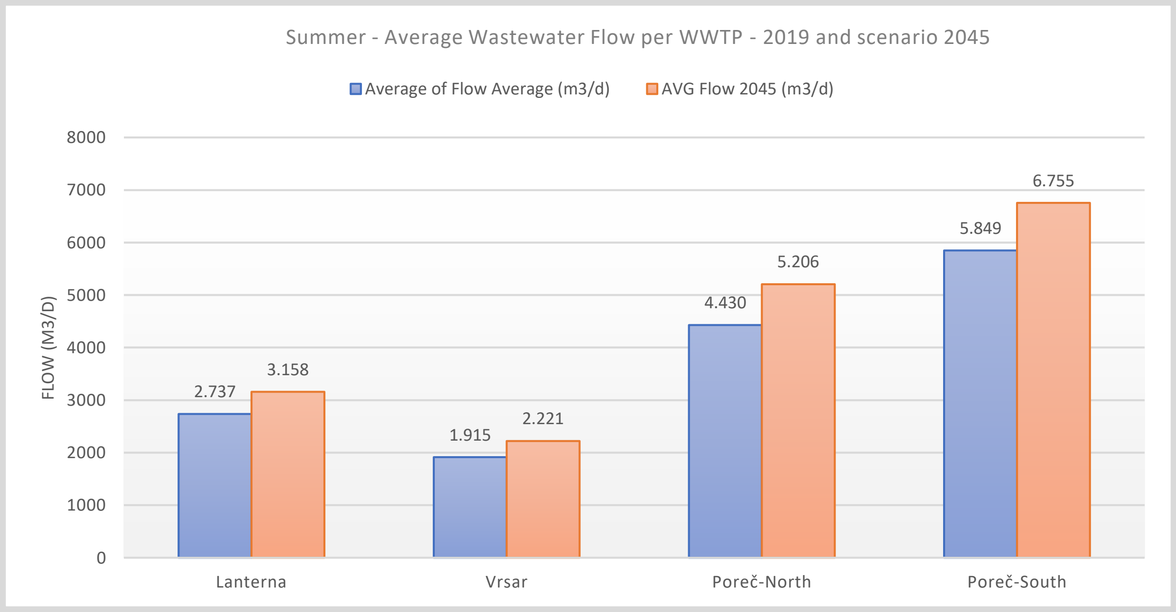


Figure 10. Summer - Average Wastewater Flow per WWTP – 2019 and scenario 2045. Average of measured 2019 dynamic influent flow data extrapolated towards 2045.

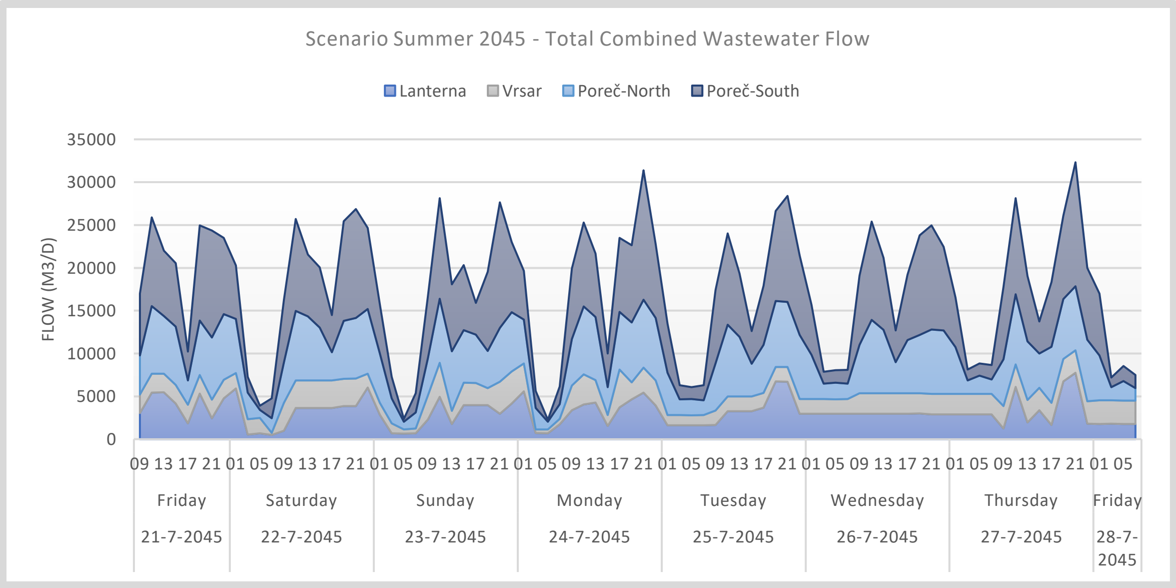
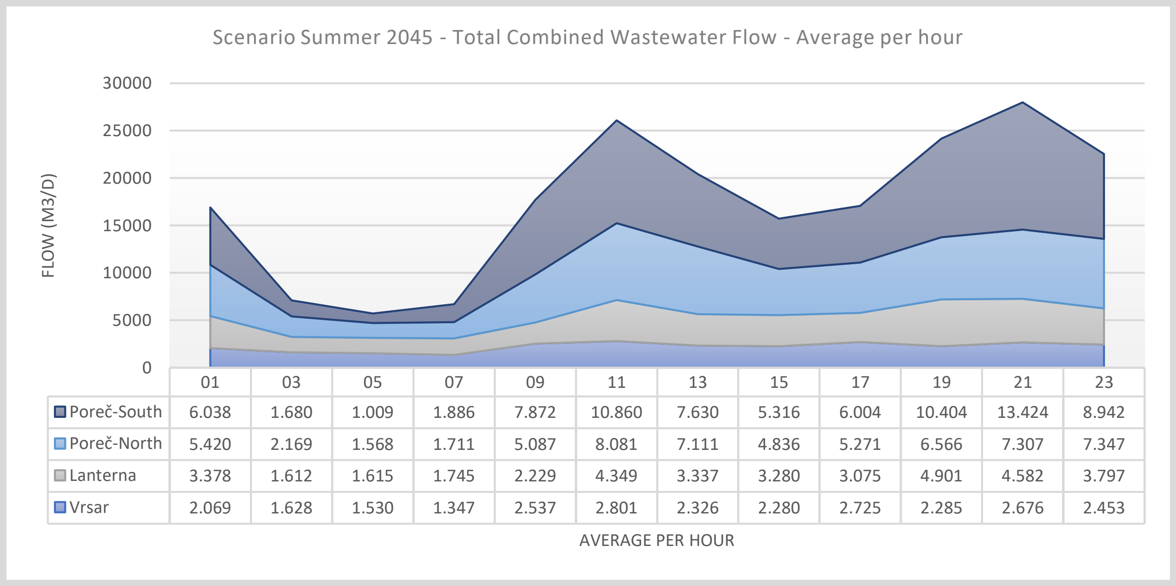


Figure 11. Scenario Summer 2045 – Total Combined Wastewater Flow 24-hour 7-day dynamic measurements. No rain event occurred during the measurement period.



	01	03	05	07	09	11	13	15	17	19	21	23
Poreč-South	6.038	1.680	1.009	1.886	7.872	10.860	7.630	5.316	6.004	10.404	13.424	8.942
Poreč-North	5.420	2.169	1.568	1.711	5.087	8.081	7.111	4.836	5.271	6.566	7.307	7.347
Lanterna	3.378	1.612	1.615	1.745	2.229	4.349	3.337	3.280	3.075	4.901	4.582	3.797
Vrsar	2.069	1.628	1.530	1.347	2.537	2.801	2.326	2.280	2.725	2.285	2.676	2.453

Figure 12. Scenario Summer 2045 – Total Combined Wastewater Flow 24-hour average hourly measurements. No rain event occurred during the measurement period.

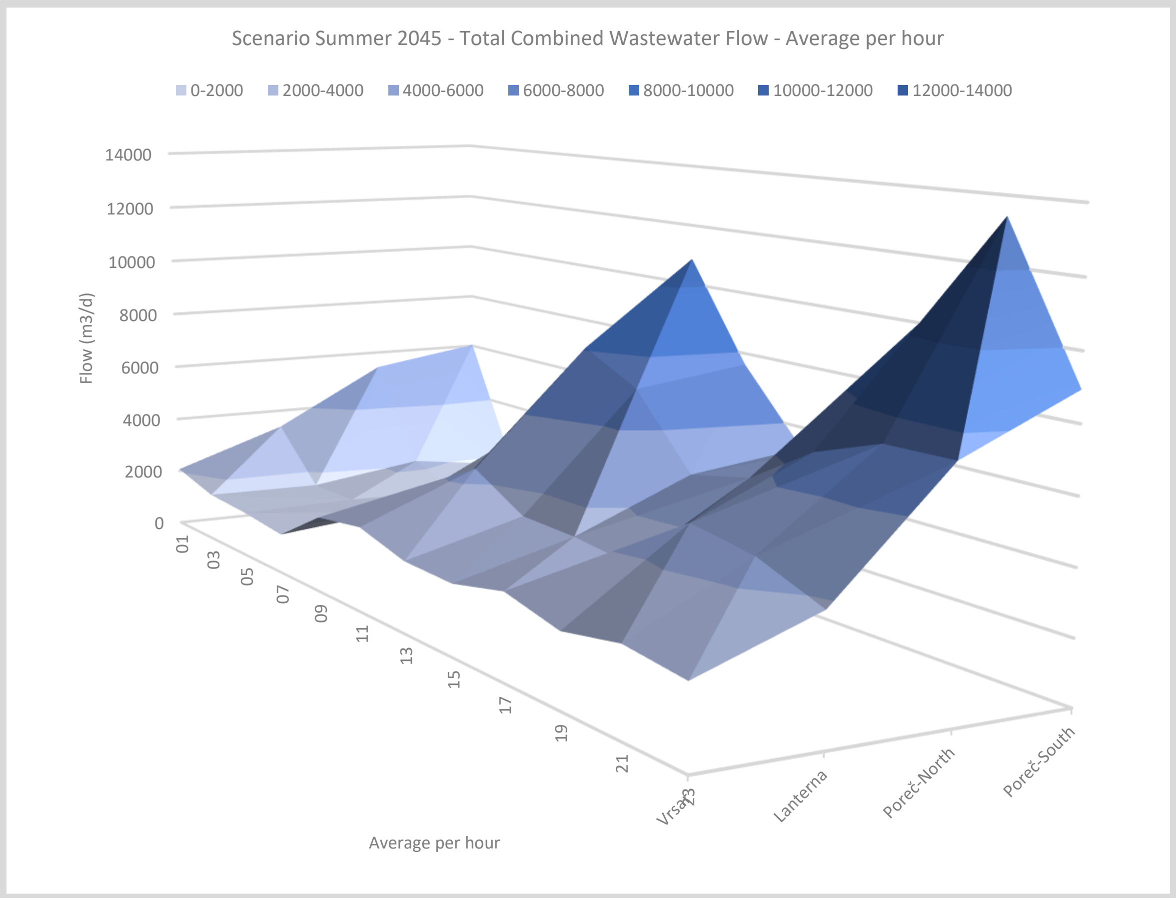


Figure 13. Scenario Summer 2045 – Surface plot Total Combined Wastewater Flow 24-hour average hourly measurements. No rain event occurred during the measurements. The plot order is from lowest to highest wastewater producing community.

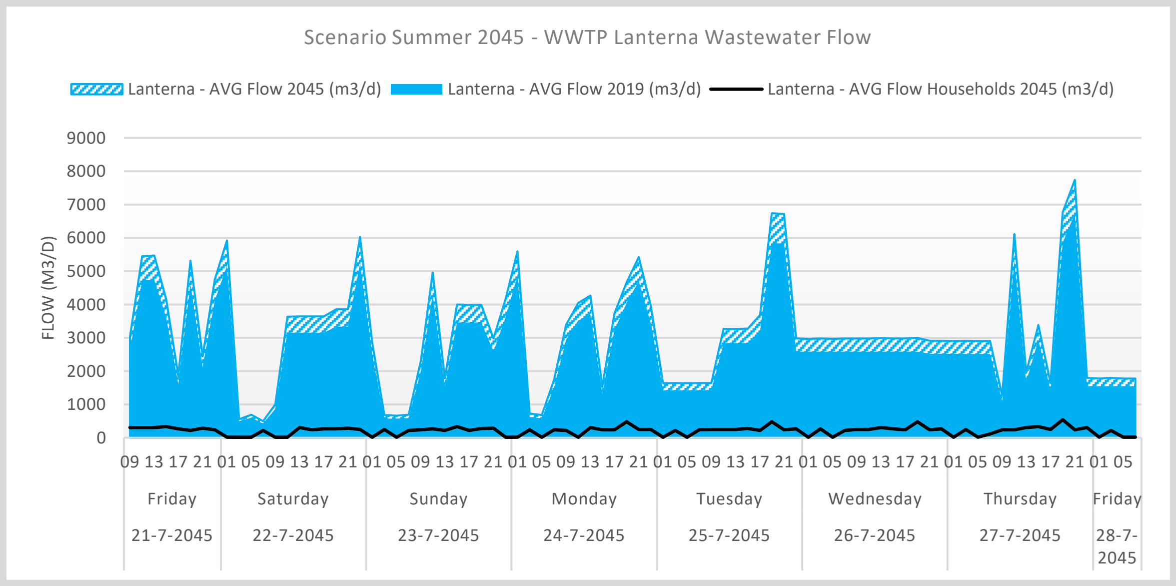
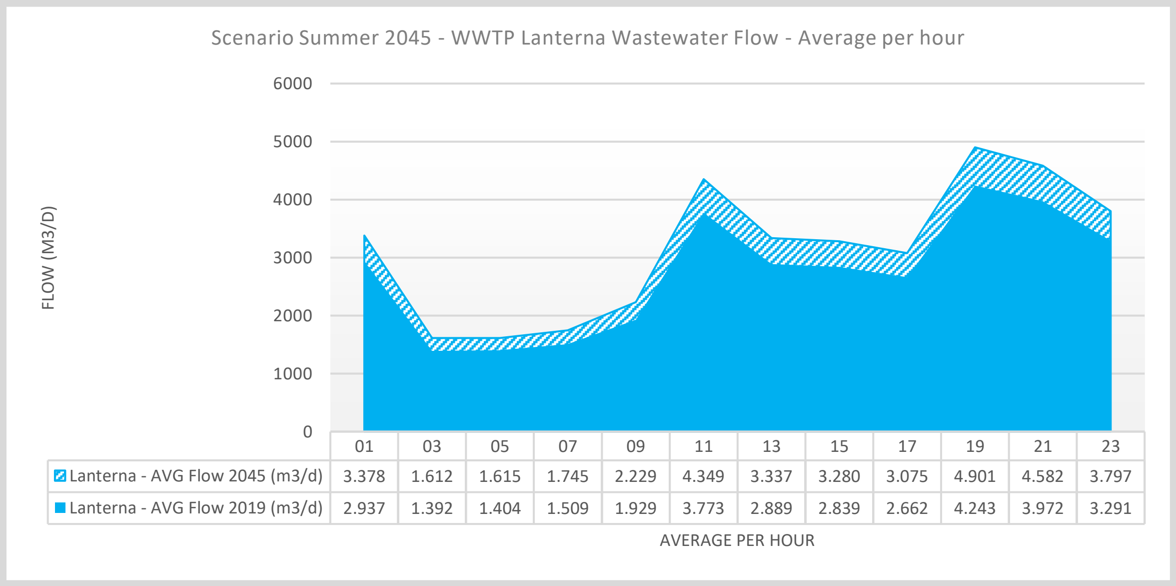


Figure 14. Scenario Summer 2045 – WWTP Lanterna Wastewater Flow 24-hour 7-day dynamic 2019 measurements and 2045 prognosis. Both the 2019 and 2045 flow data are used for dynamic modelling.



	01	03	05	07	09	11	13	15	17	19	21	23
Lanterna - AVG Flow 2045 (m3/d)	3.378	1.612	1.615	1.745	2.229	4.349	3.337	3.280	3.075	4.901	4.582	3.797
Lanterna - AVG Flow 2019 (m3/d)	2.937	1.392	1.404	1.509	1.929	3.773	2.889	2.839	2.662	4.243	3.972	3.291

Figure 15. Scenario Summer 2045 – WWTP Lanterna Wastewater Flow 24-hour average hourly 2019 measurements and 2045 prognosis. Data are used to reconstruct missing data in the flow measurements and for development of scenarios.

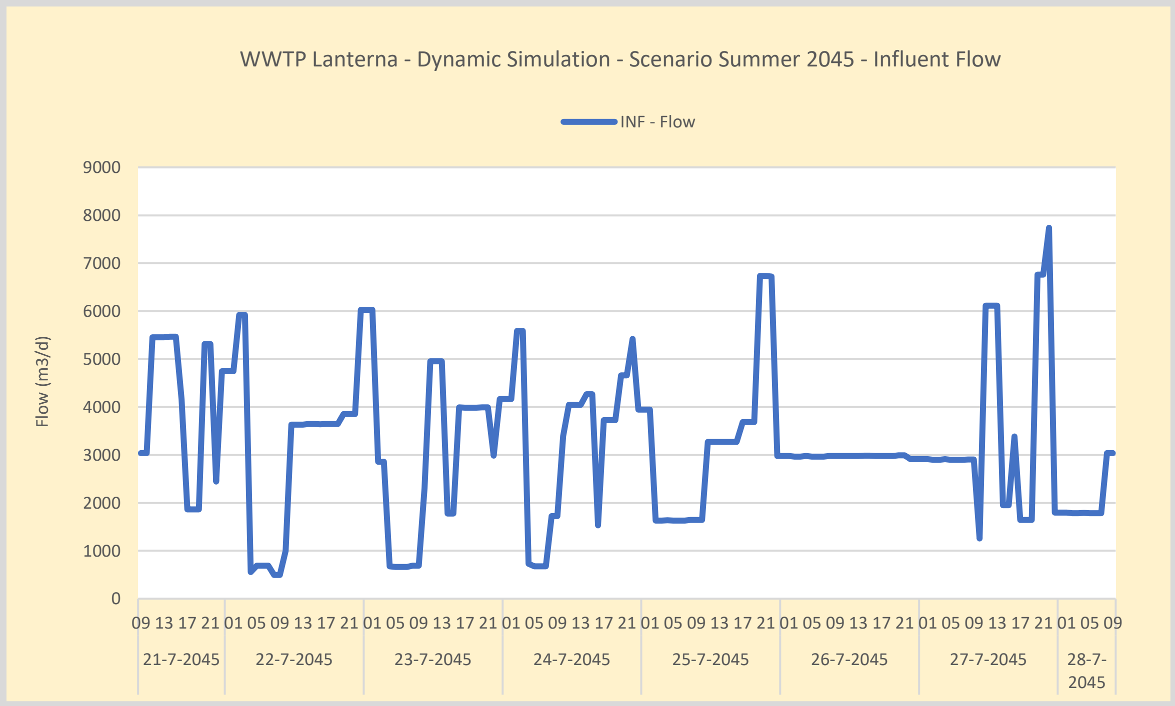


Figure 16. Scenario Summer 2045 – BioWin modelling WWTP Lanterna: Wastewater Flow 24-hour 7-day dynamic model input data. In the model 2 hourly measurements are interpolated to an hourly basis. The flow dynamics are adapted from the 2019 measurements extrapolated towards 2045.

4.4 Conclusions flow extrapolation

- Dynamic flow profiles from the year 2019 are calculated towards flow profiles representing summer and winter conditions for the year 2045.
- Dynamic flow data is extrapolated towards 2045 on an hourly basis based on the estimated flow from households and touristic activity. This method results in a dynamic flow profile like the actual profile measured in 2019.
- The fraction of the total flow coming from households is estimated by taking the lowest flow day in winter. The fraction of the total flow coming from tourists is calculated by subtracting the summer flow with the flow from households.
- Extrapolation of the flow towards 2045 is done using growth numbers from the detailed design.
- It is assumed that the concentration of the wastewater is not changed.
- It is assumed that rain events and the frequency of peak discharges are unchanged over time.
- The model can be simulated based on the new flow time series.

5 Scenario winter 2045 results dynamic modelling

5.1 Winter operation process flow diagram

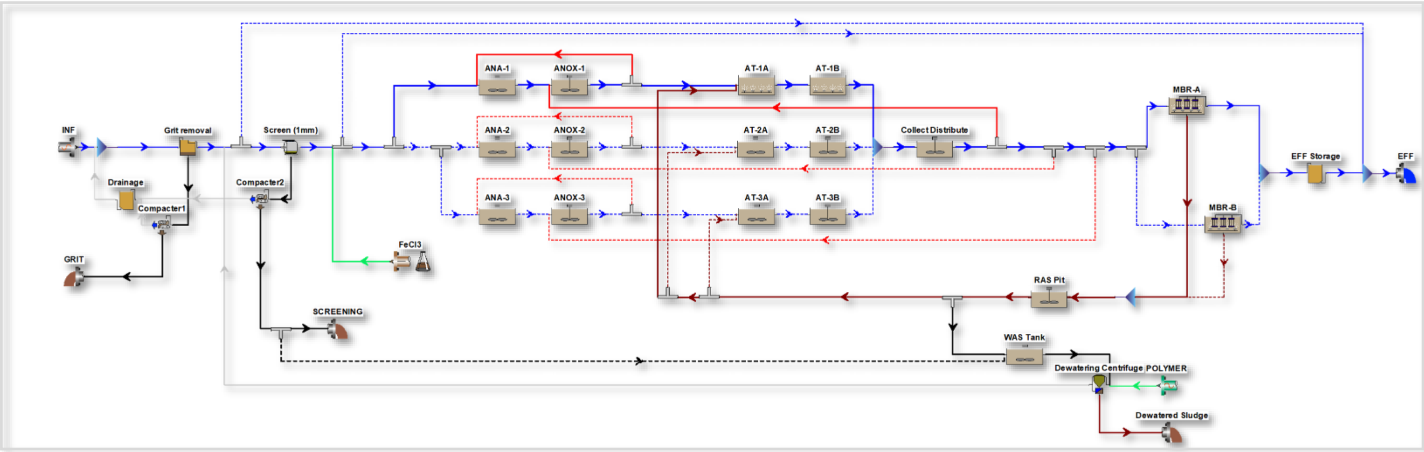


Figure 17. Simulation WWTP Lanterna - BioWin model winter operation. Two lines and one MBR are taken out of operation (dashed lines are not operated). Operational adjustments are made to accommodate dynamic modelling. MBR-B is taken out of operation to avoid stripping of alkalinity.

5.2 Performance overview 7-day average

Based on the total dataset including peak loading and rain events, the average WWTP performance of 7-days of simulation is calculated and presented in the tables below. In average, for the simulated period and using simplified process control, the effluent performance and aerobic SRT is in accordance with the design criteria.

Table 2. Dynamic average effluent concentration simulation results (mg/L)

WWTP Lanterna - Scenario Winter 2045 - Dynamic average effluent concentration (mg/L)			
EFF	Temperature	Concentration	12,0
EFF	COD - Total	Concentration	27,5
EFF	N - Total N	Concentration	10,4
EFF	P - Total P	Concentration	1,0
EFF	Total suspended solids	Concentration	0,2

Table 3. Dynamic average Air flow rate simulation results (m3/h)

WWTP Lanterna - Scenario Winter 2045 - Dynamic average Air flow rate (m3/h)			
AT-1A	Air flow rate	Flow	72,0
AT-1B	Air flow rate	Flow	73,2
AT-2A	Air flow rate	Flow	0,0
AT-2B	Air flow rate	Flow	0,0
AT-3A	Air flow rate	Flow	0,0
AT-3B	Air flow rate	Flow	0,0
MBR-A	Air flow rate	Flow	224,9
MBR-B	Air flow rate	Flow	0,0

Table 4. Dynamic average Flow simulation results (m3/d)

WWTP Lanterna - Scenario Winter 2045 - Dynamic average Flows (m3/d)			
ANA-R1	Flow (S)	Flow	2.000,0
ANA-R2	Flow (S)	Flow	0,0
ANA-R3	Flow (S)	Flow	0,0
ANOX-R1	Flow (S)	Flow	3.980,3
ANOX-R2	Flow (S)	Flow	0,0
ANOX-R3	Flow (S)	Flow	0,0
AS Emergency Bypass	Flow (S)	Flow	0,0
Dewatering Centrifuge	Flow (U)	Flow	0,3
Grit removal	Flow (U)	Flow	0,1
MBR-A	Flow (U)	Flow	1.325,6
MBR-B	Flow (U)	Flow	0,0
Screen (1mm)	Flow (U)	Flow	0,1
Screen Emergency Bypass	Flow (S)	Flow	0,0
WAS Splitter	Flow (U)	Flow	27,7
	Flow (S)	Flow	27,7

Table 5. Dynamic average sludge production SRT and HRT simulation results

WWTP Lanterna - Scenario Winter 2045 - Dynamic average SRT and HRT		
Temperature	12	°C
Average waste sludge production	57,4	kgTSS/d
SRT Total	29,4	d
SRT Aerobic	11,1	d
SRT AT+ANOX	16,2	d
WAS Tank HRT	0,9	hour
ANA HRT to influent	18,1	hour

Table 6. Dynamic average Iron and PE simulation results (mg/L, kg/d, m3/d)

WWTP Lanterna - Scenario Winter 2045 - Dynamic average Iron and Polymer (mg/L & kg/d)			
FeCl3	Flow	Flow	0,032
FeCl3	Total iron (all forms)	Concentration	150.000
FeCl3	Total iron (all forms)	Load	4,811
POLYMER	COD - Total	Concentration	18.180
POLYMER	COD - Total	Load	0,658
POLYMER	Flow	Flow	0,036

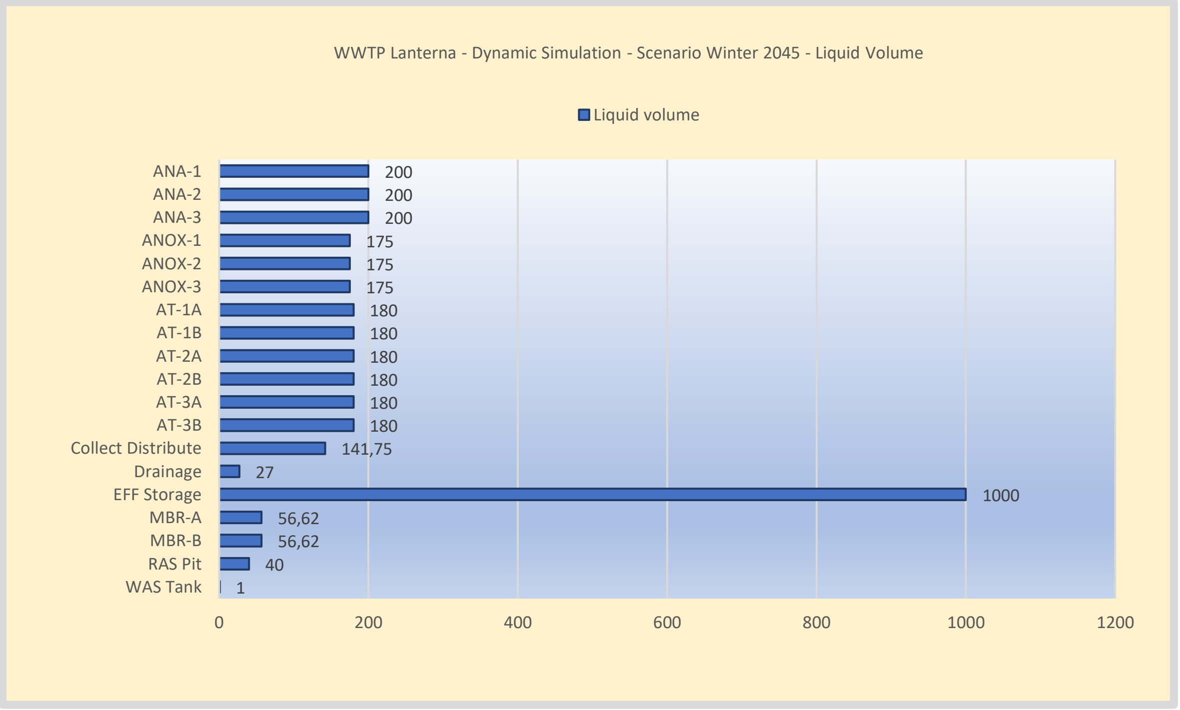


Figure 18. Simulation WWTP Lanterna - Scenario Winter 2045 - Volume distribution of modelled reactor elements. The actual WAS tank is 150 m3 however the sludge volume is modelled based on an HRT < 2,5 hours to avoid P-release. From the model it is concluded the WAS tank should not be used for longer storage of Bio-P sludge.

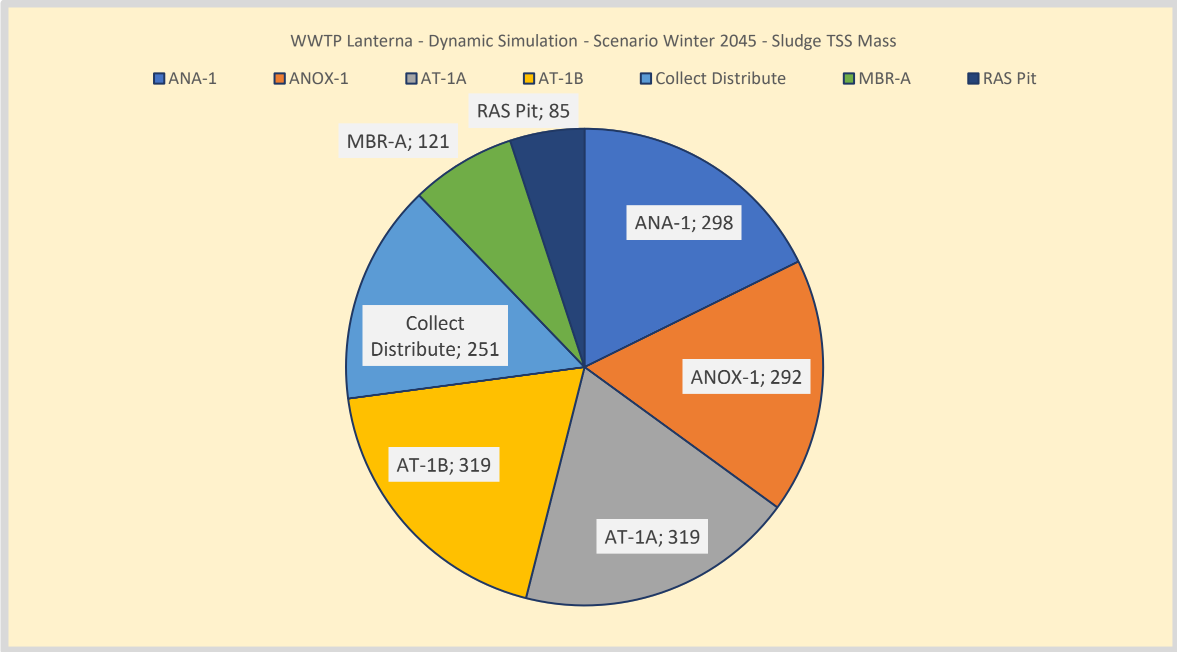


Figure 19. Simulation WWTP Lanterna - Scenario Winter 2045 - Sludge mass distribution (kgTSS) in the activated sludge reactors. This data is used to calculate the SRT of the WWTP. Idle reactors are not included in SRT calculations.

5.3 Process controllers: Winter

The winter operation of WWTP Lanterna uses a DO setpoint control for both aeration tanks instead of the AT-A table controller based on NH4 measurements. This is done to maintain a as low as possible air flow to reduce CO2 stripping.

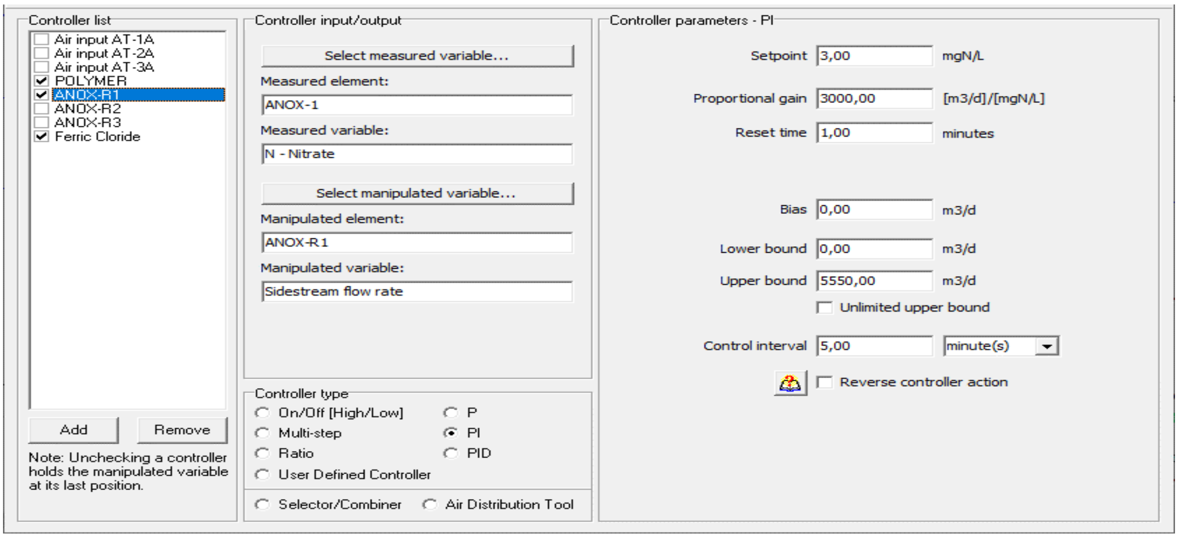


Figure 20. Simulation WWTP Lanterna - Scenario Winter 2045 - BioWin controller toolbox used for controlling the anoxic recycle ANOX-R. Indicated are the measured variable being NO3 in the anoxic tank and manipulated variable the recycle flow ANOX-R. The PI controller has an upper bound of 5.550 m3/d (150% proportional to influent flow) according to the maximum installed pump capacity per lane.

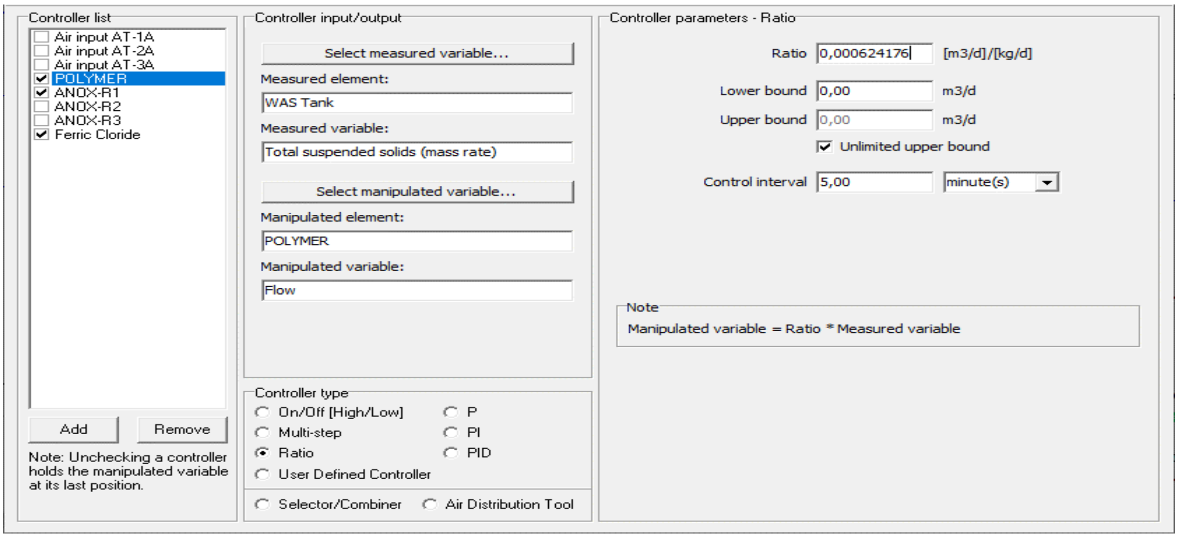


Figure 21. Simulation WWTP Lanterna - Scenario Winter 2045 - BioWin controller toolbox used for controlling the polymer dosage of the dewatering. Indicated are the measured variable being the TSS load entering the dewatering and manipulated variable the PE flow. The applied control ratio is 8 kg PE per 1000 kg TSS based on dry weight. PE is assumed to be particulate substrate with a COD/VSS ratio of 1,42.

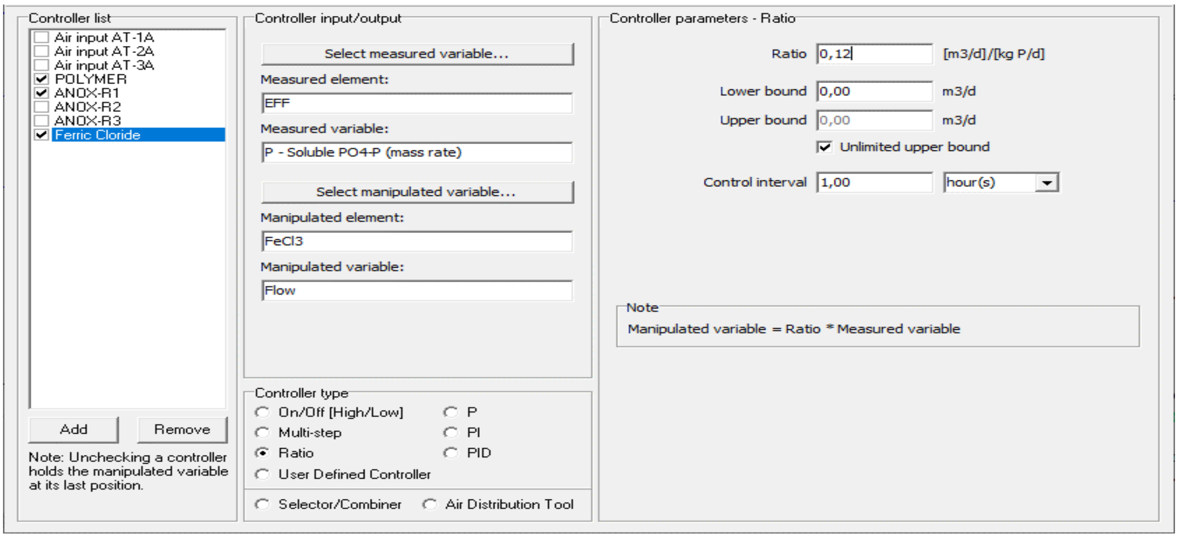


Figure 22. Simulation WWTP Lanterna - Scenario Winter 2045 - controller toolbox used for controlling the Iron dosage for P-removal. A small dosage is used to maintain effluent standards.

5.4 Influent modelling results

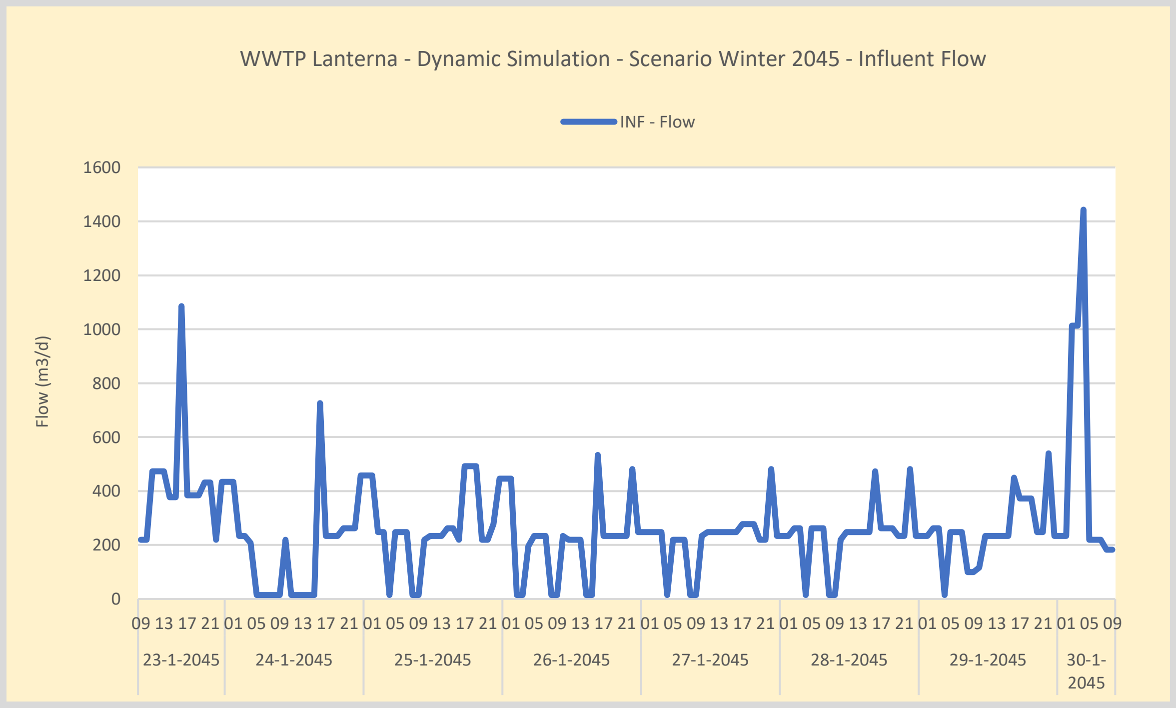


Figure 23. Simulation WWTP Lanterna - Scenario Winter 2045 - Influent flow. The profile is based on data measured in 2019 extrapolated towards 2045. A rain event is simulated on day 7.

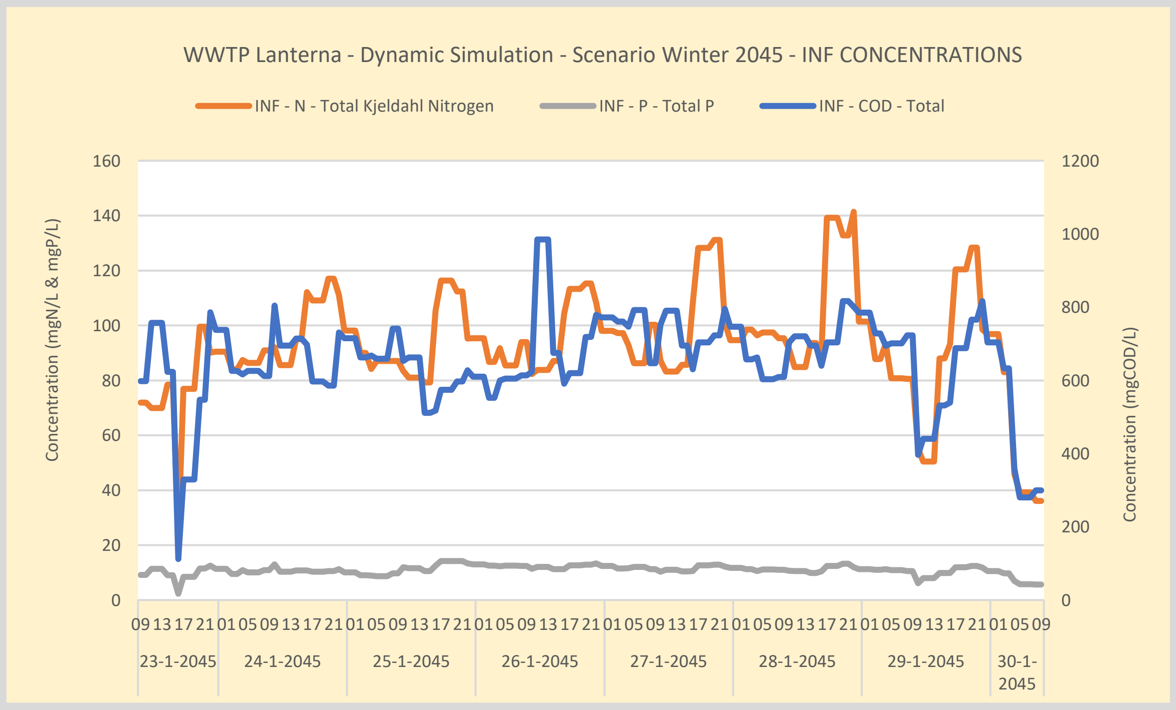


Figure 24. Simulation WWTP Lanterna - Scenario Winter 2045 - Influent loads COD, TKN and TP. The profile is based on data measured in 2019 extrapolated towards 2045.

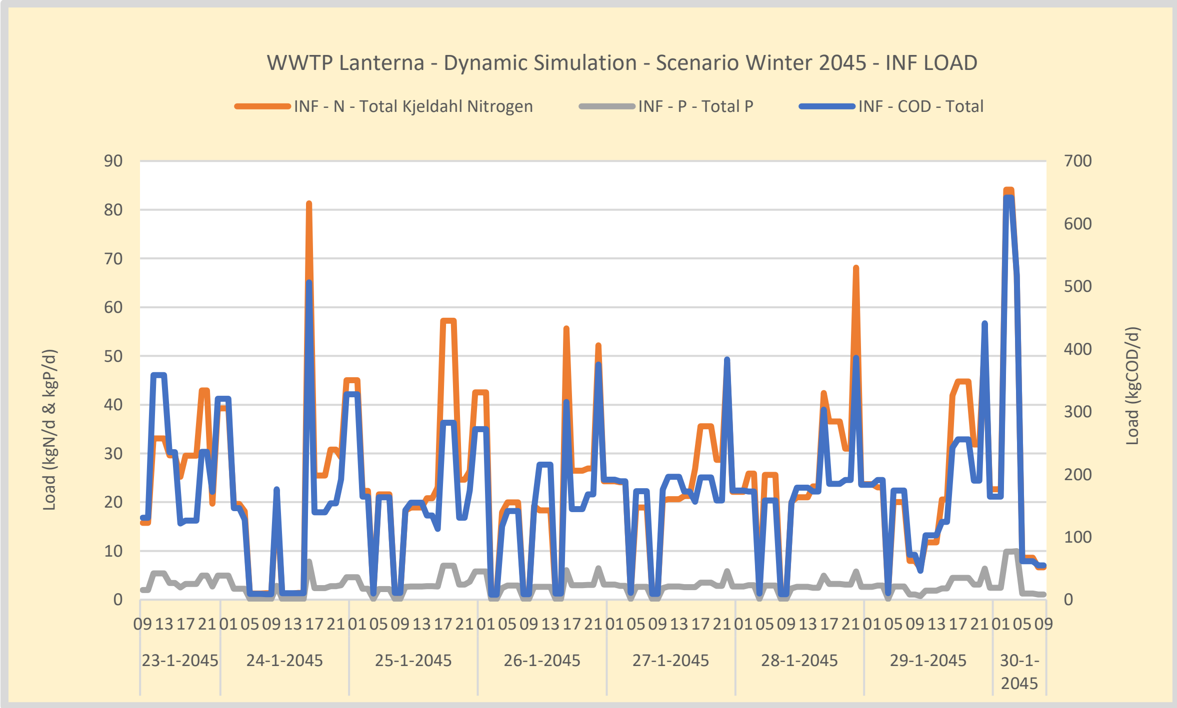


Figure 25. Simulation WWTP Lanterna - Scenario Winter 2045 - Influent loads COD, TKN and TP. The profile is based on data measured in 2019 extrapolated towards 2045.

5.5 Process and recycle flows modelling results

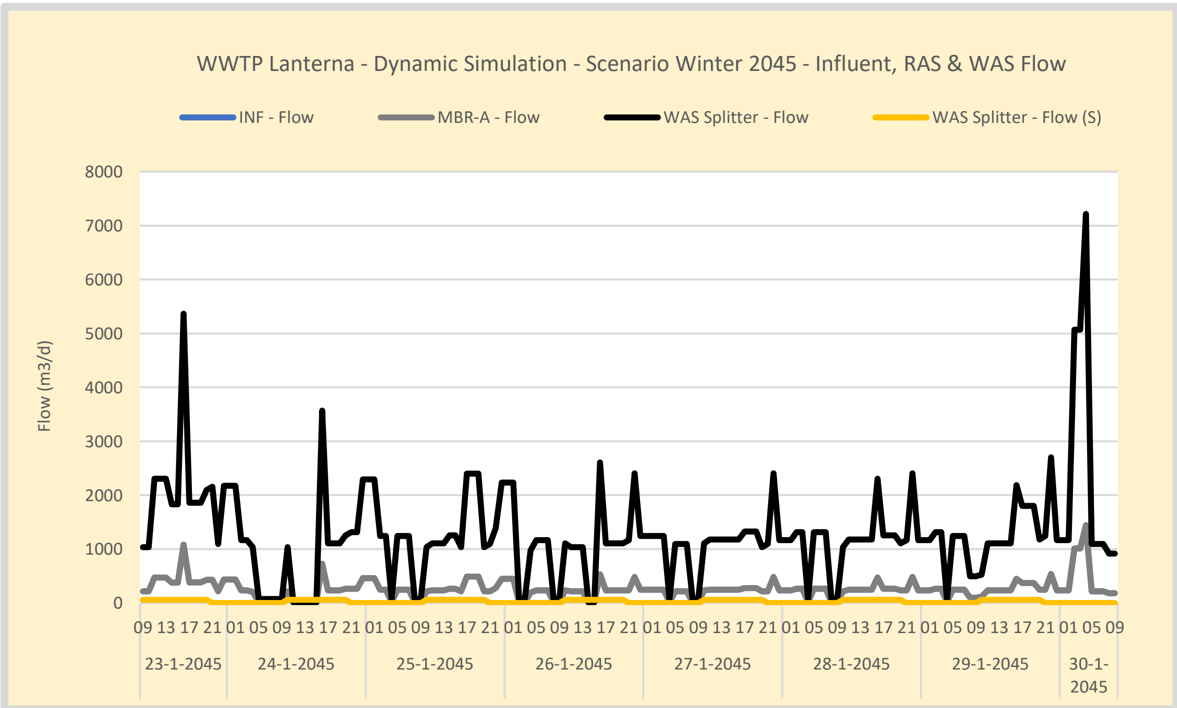


Figure 26. Simulation WWTP Lanterna - Scenario Winter 2045 - flow rate settings and control. The MLSS sludge return flow is controlled proportional to the influent. This results in a more stable TSS concentration in the reactors. The WAS flow is operated 10 hours a day on a constant flow to the dewatering.

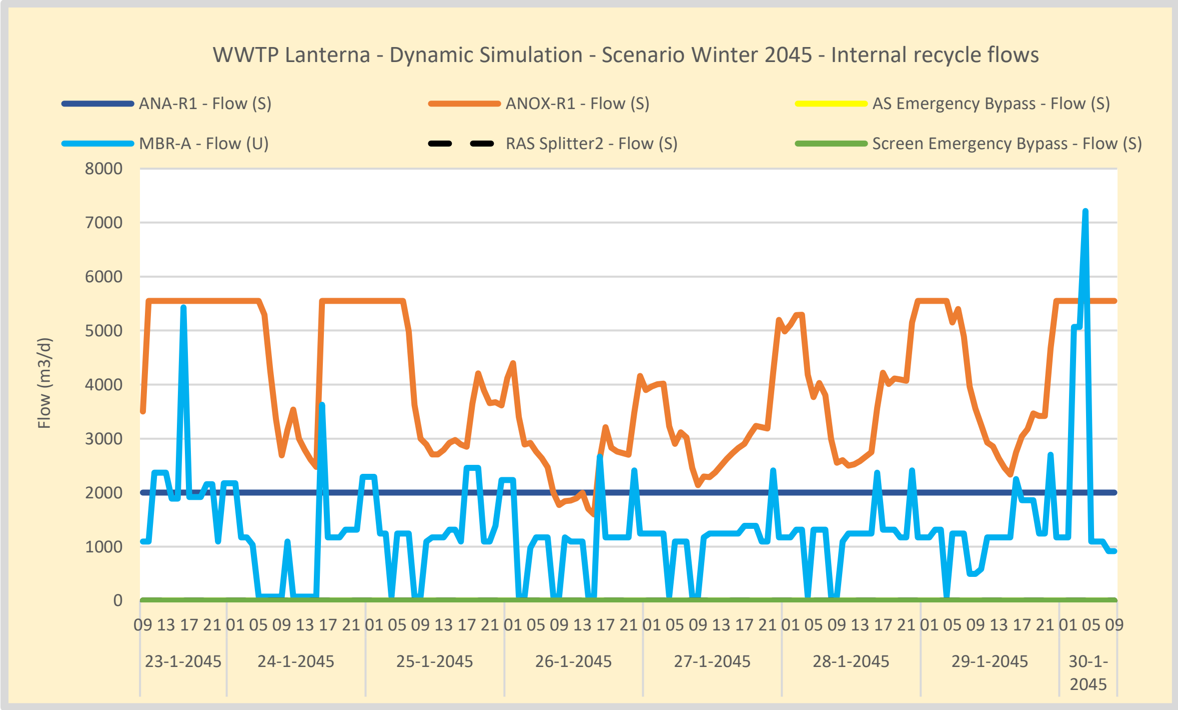


Figure 27. Simulation WWTP Lanterna - Scenario Winter 2045 - flow rate settings and control. The bypasses are not used. The anaerobic recycle is set to the maximum flow to reduce anaerobic conditions. The sludge return is controlled proportionally with the influent. The anoxic recycle is controlled on 3 mgNO/L in the anoxic tank.

5.6 Waterline operation modelling results

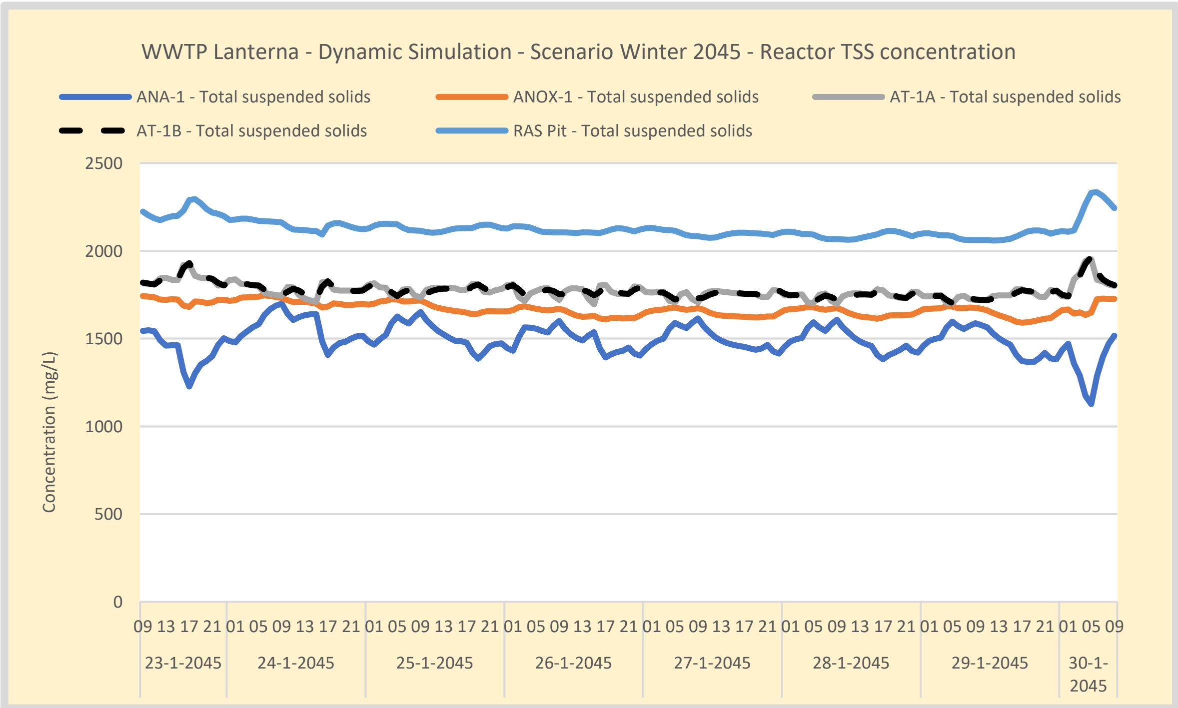


Figure 28. Simulation WWTP Lanterna - Scenario Winter 2045 - TSS profile in the waterline. TSS in the MBR is controlled on approximately 2 gTSS/L by adjusting the WAS flow and SRT. In the winter, the reactor volume relative to the influent loading is high. This results in low sludge production and long SRT. The process is therefore operated with a lower TSS concentration.

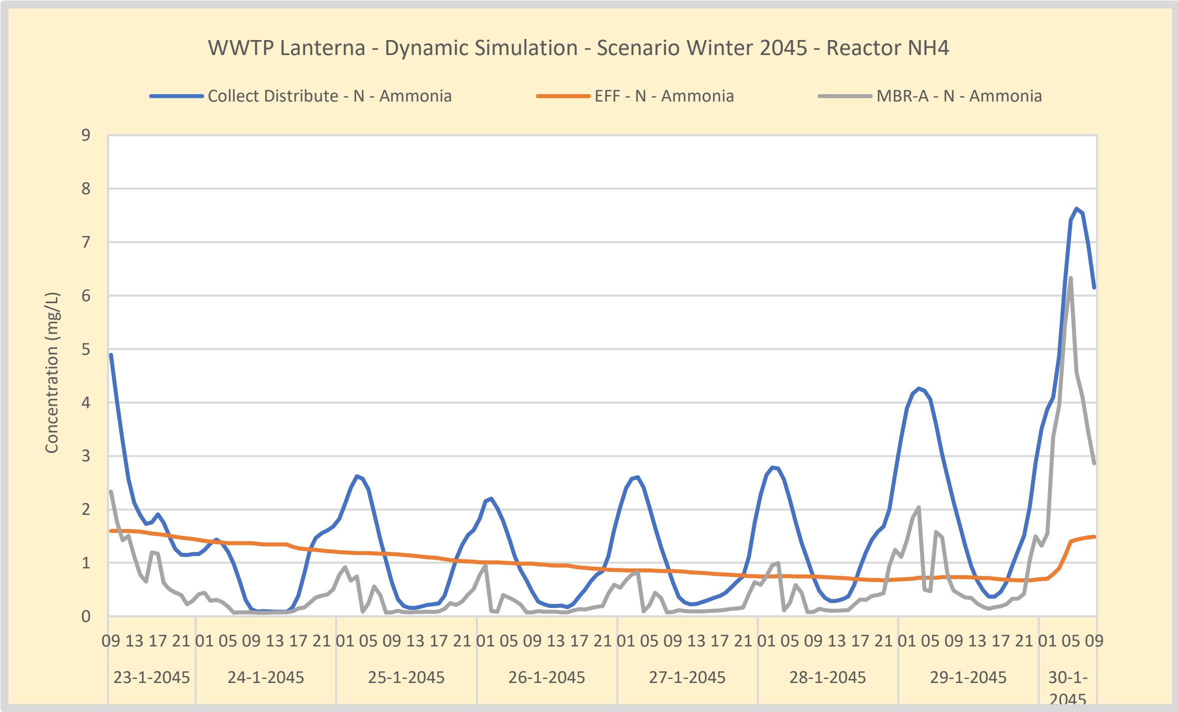


Figure 29. Simulation WWTP Lanterna - Scenario Winter 2045 - ammonium profile in the waterline. The air input of AT-A and AT-B is DO controlled based on a setpoint of 2 mgO2/L.

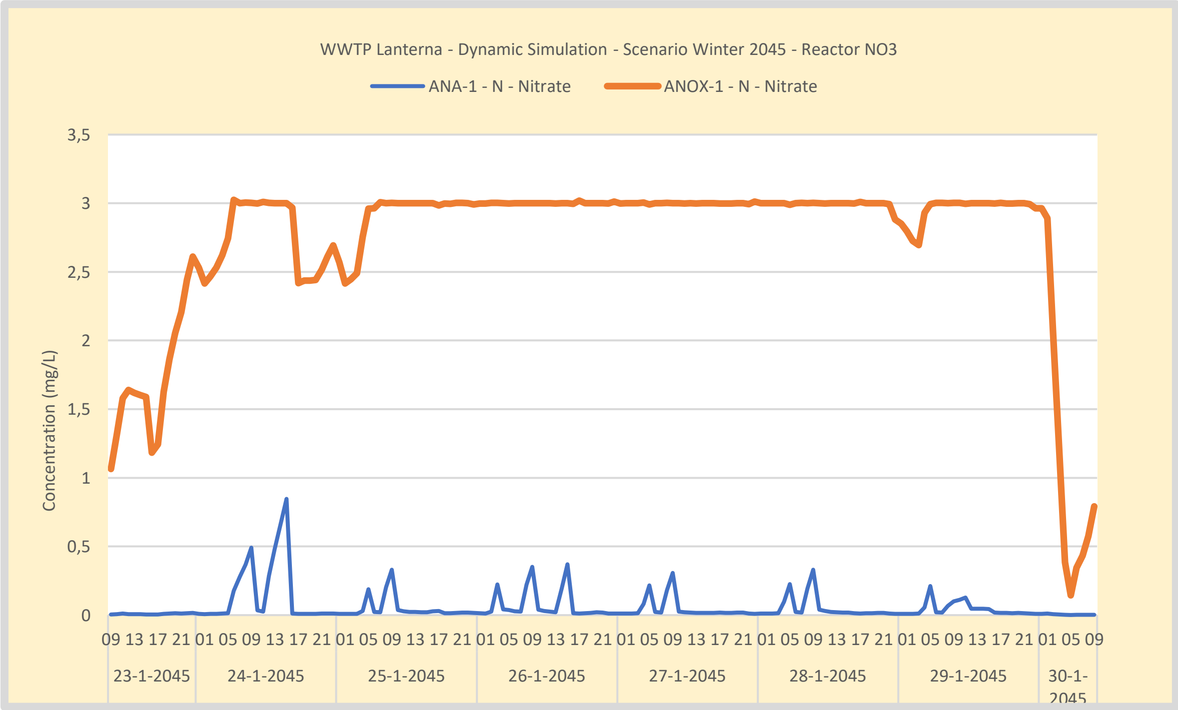


Figure 30. Simulation WWTP Lanterna - Scenario Winter 2045 - nitrate in the anoxic tank. The anaerobic recycle rate is set to a maximum flow to reduce the effective anaerobic volume. The anoxic recycle is controlling nitrate in the anoxic tank on 3 mgNO3/L. This is done to avoid too long anaerobic HRT and decay of biomass.

5.7 Waterline concentration profiles modelling results

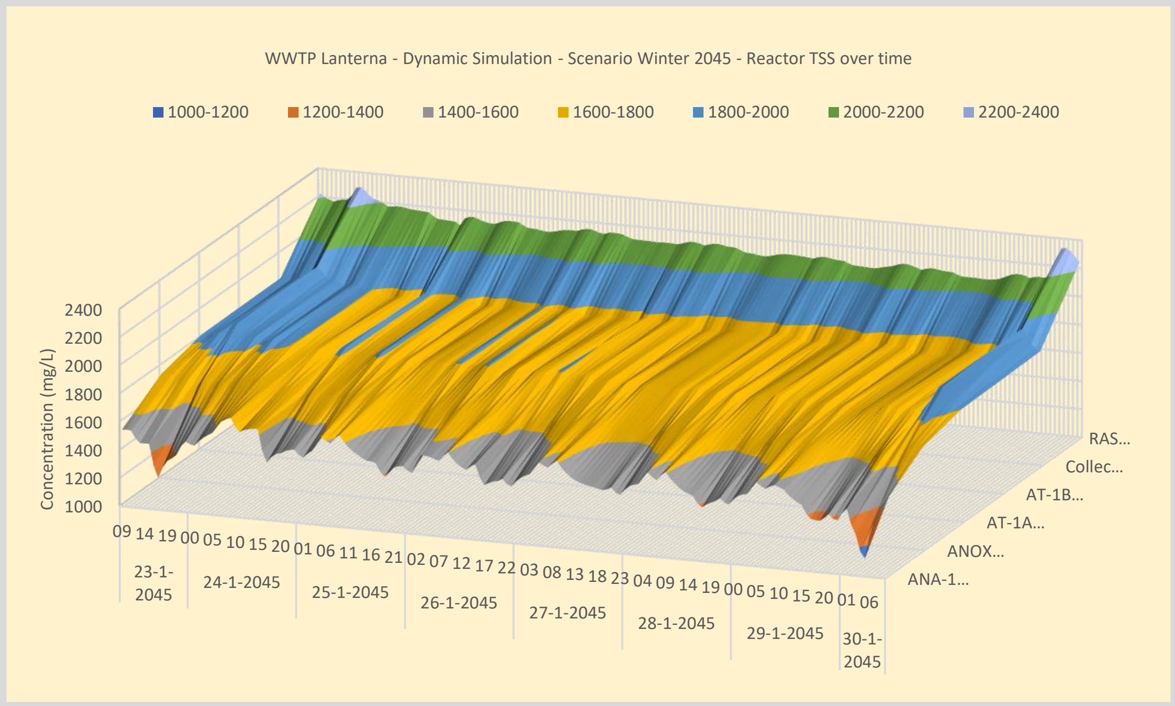


Figure 31. WWTP Lanterna - Scenario Winter 2045 - TSS concentration profile over the waterline.

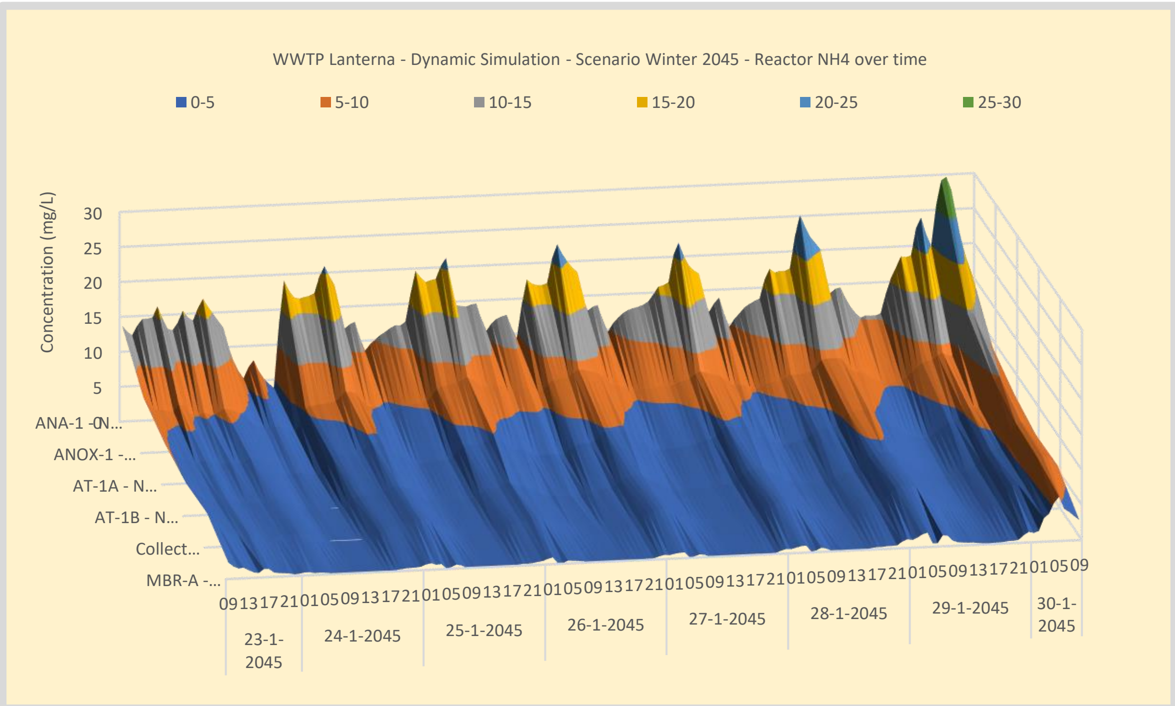


Figure 32. Simulation WWTP Lanterna - Scenario Winter 2045 - NH4 concentration profile over the waterline.

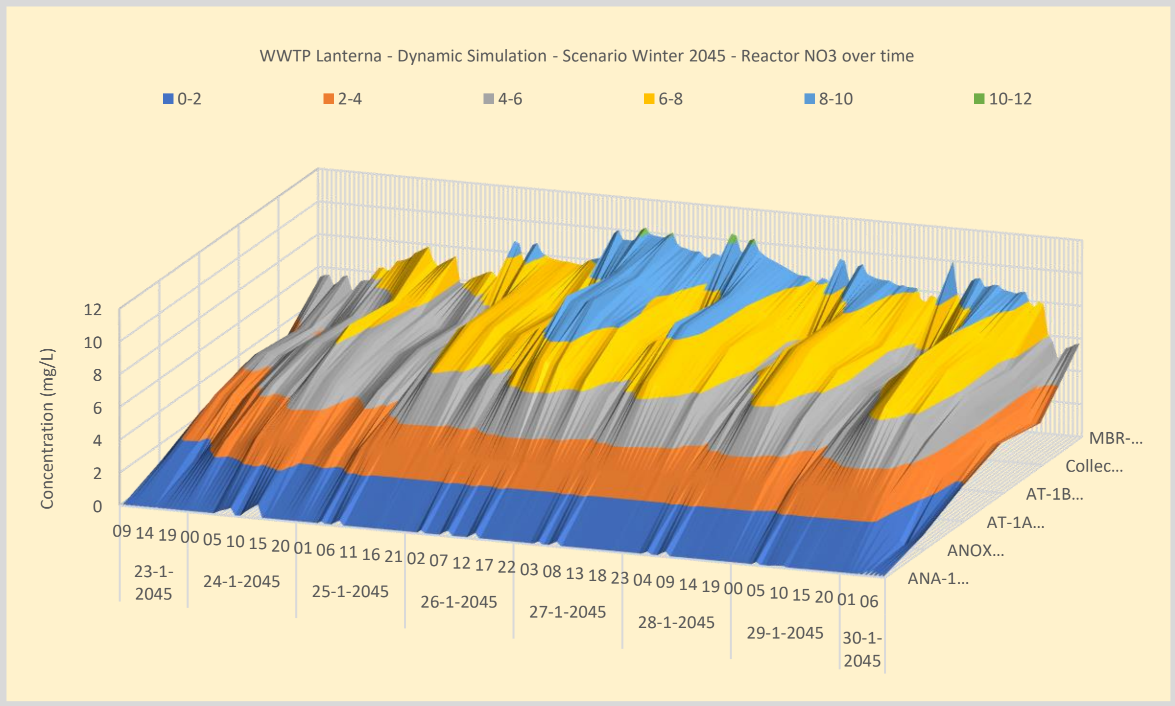


Figure 33. Simulation WWTP Lanterna - Scenario Winter 2045 - NO3 concentration profile over the waterline.

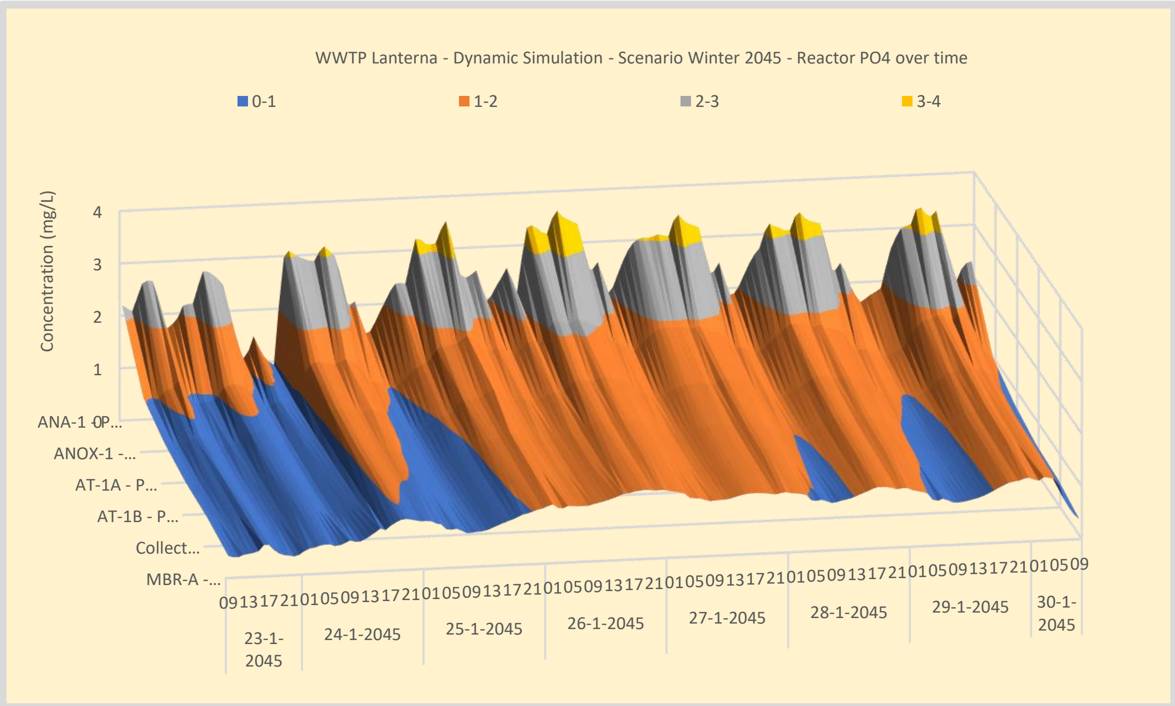


Figure 34. Simulation WWTP Lanterna - Scenario Winter 2045 - PO4 concentration profile over the waterline.

5.8 Aeration and DO concentration modelling results

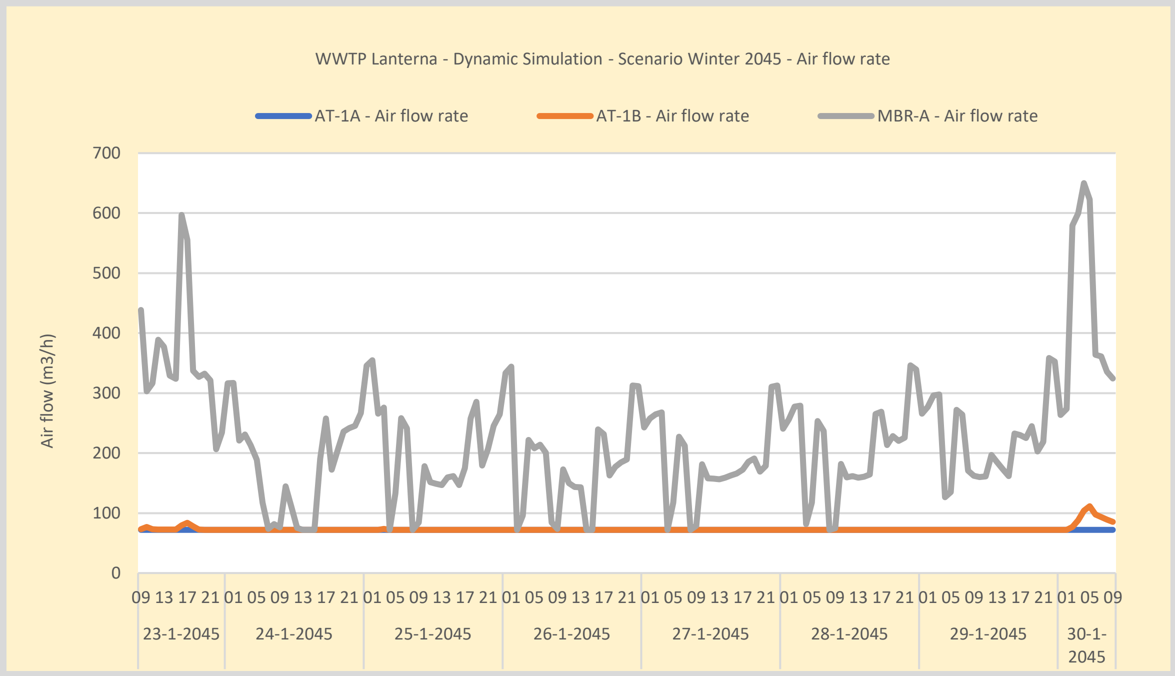


Figure 35. Simulation WWTP Lanterna - Scenario Winter 2045 - Air flow of the aerated reactors. AT-A and B are setpoint controlled on 2 mgO2/L. The MBR is setpoint controlled on 6 mgO2/L to avoid over-aeration. Oxygen rich water is recycled to the AT and sufficient to reach the setpoint in AT-A and B. The DO controllers in AT-A and B mostly fall back on a minimum operational value.

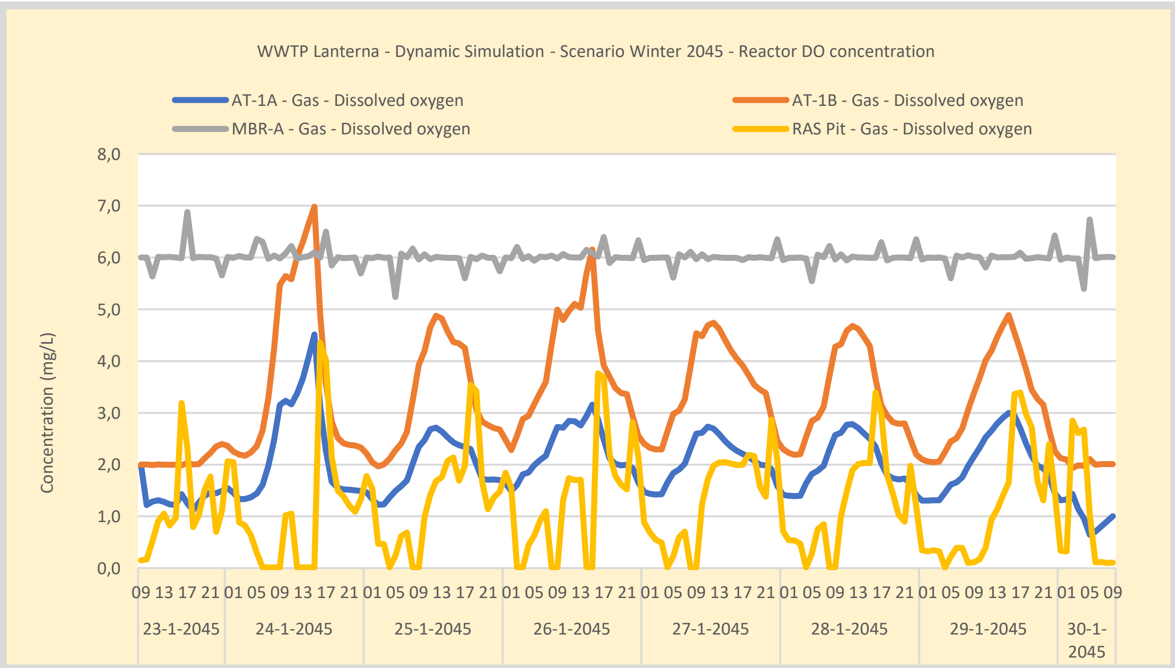


Figure 36. Simulation WWTP Lanterna - Scenario Winter 2045 - DO concentration gradients. DO is controlled in the AT at 2 mgO2/L. In the MBR the DO is controlled on 6 mgO2/L. Oxygen is recycled over the reactors causing accumulation of DO in the AT during periods of low influent loading.

5.9 pH and alkalinity profiles modelling results

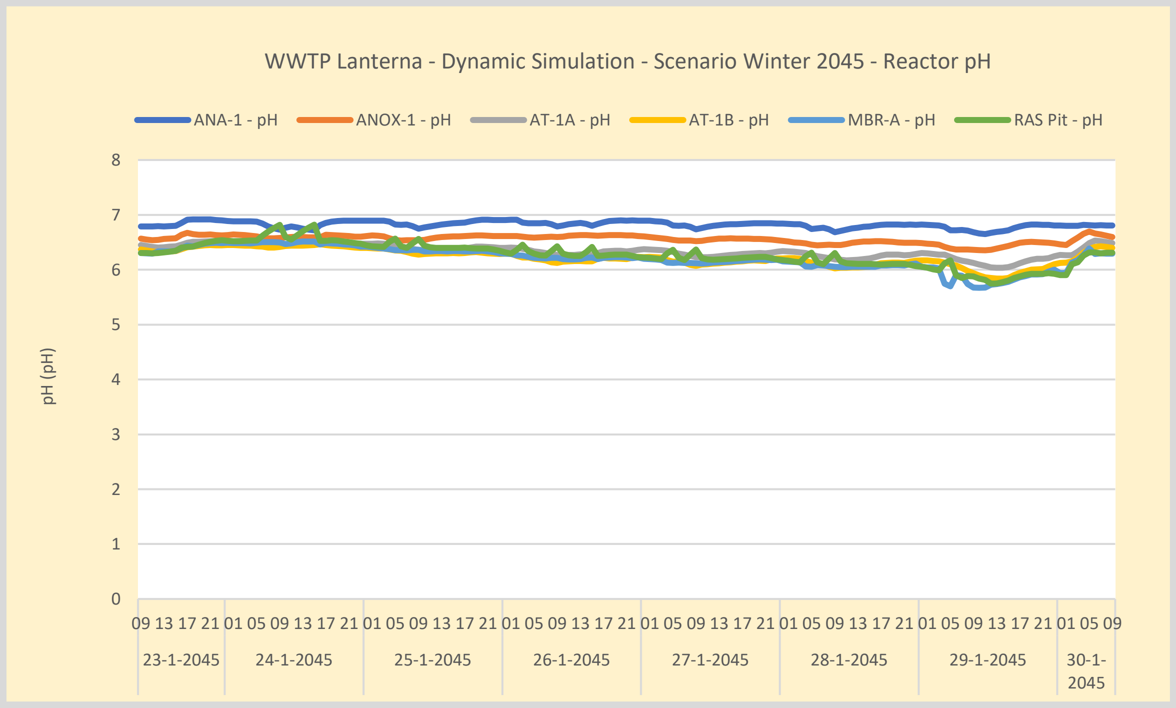


Figure 37. Simulation WWTP Lanterna - Scenario Winter 2045 - pH profile over the activated sludge reactors. Influent pH is measured continuously and is not limiting however, alkalinity is dropping.

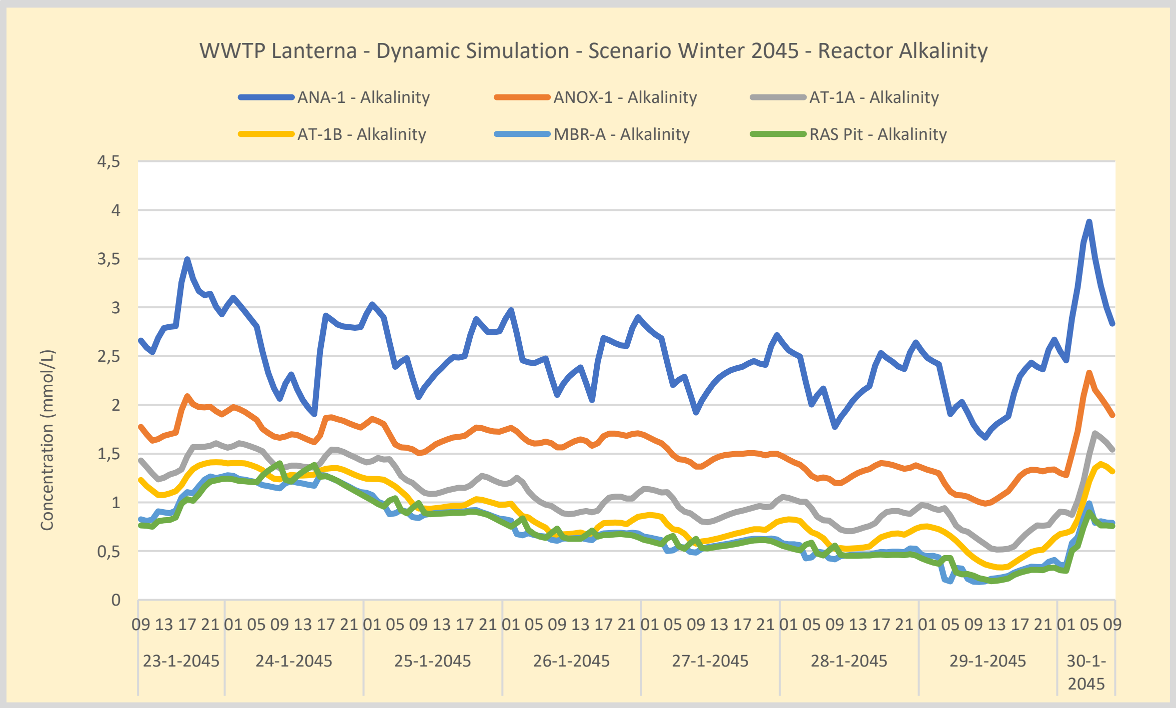


Figure 38. Simulation WWTP Lanterna - Scenario Winter 2045 - alkalinity profile over the activated sludge reactors. Influent alkalinity is estimated from local drinking water quality measurements at 7,46 mmol/L. Potentially there is a limitation of alkalinity in the winter due to CO2 stripping caused by over aeration.

5.10 Chemical load and flow modelling results

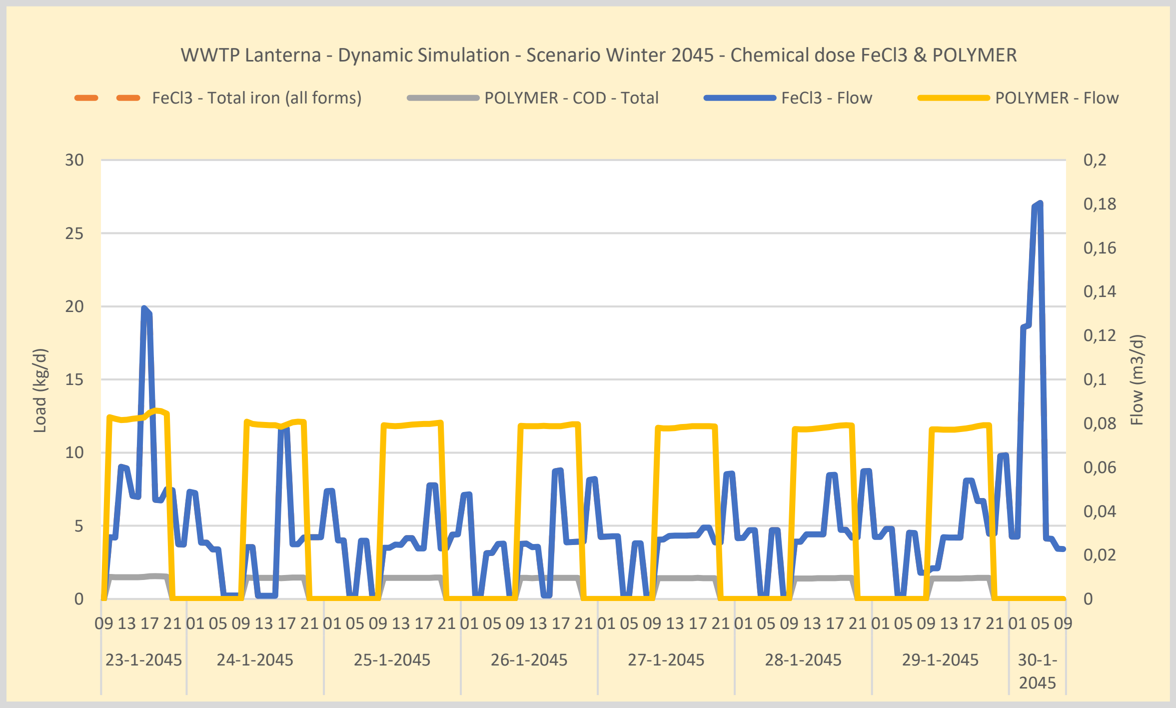


Figure 39. Simulation WWTP Lanterna - Scenario Winter 2045 - load and flow of Iron and PE. Iron is dosed proportionally to the effluent PO4-concentration. PE is assumed particulate biodegradable COD with a COD/VSS ratio of 1,42 gCOD/gTSS and dosed proportional to the WAS load based on 8 kg PE (dry weight) dosed per 1000 kg WAS (dry weight) flowing in the dewatering.

5.11 Sludge line operation modelling results

In the figures below the dynamic operation of the sludge line including dynamic WAS control is presented under winter conditions projected towards the loading conditions in the year 2045. The last day of the simulation includes a major rain event.

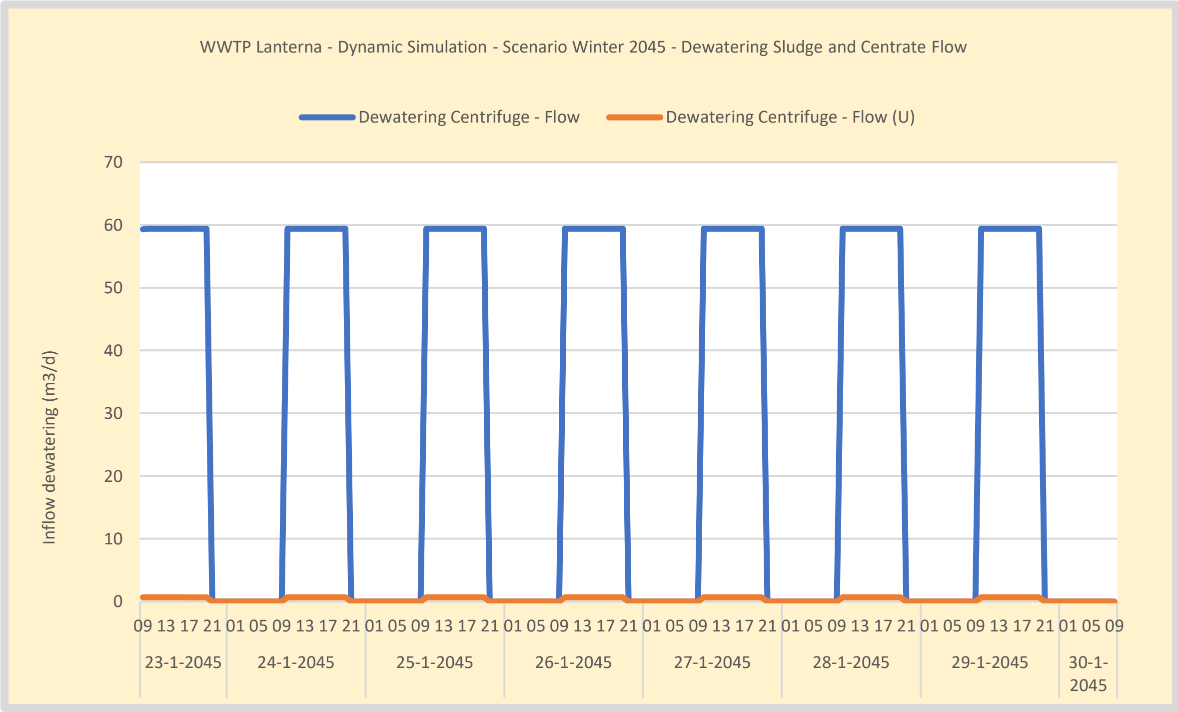


Figure 40. Simulation WWTP Lanterna - Scenario Winter 2045 - dewatered sludge and centrate flow.

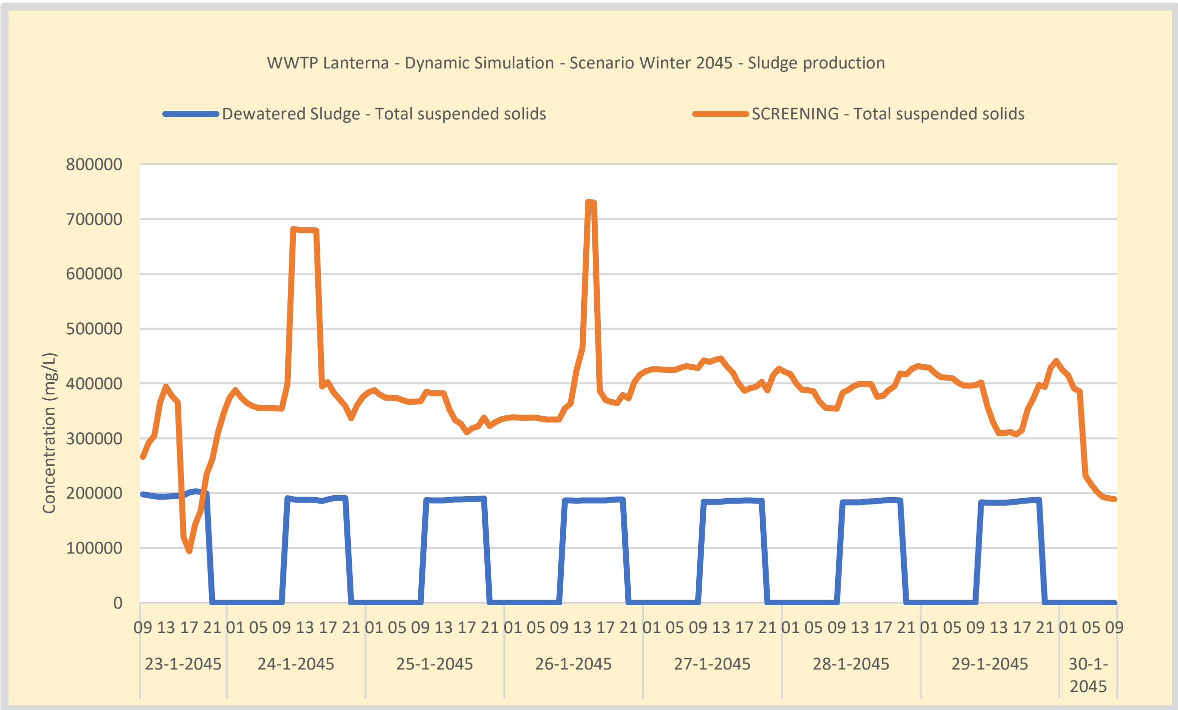


Figure 41. Simulation WWTP Lanterna - Scenario Winter 2045 - dewatered sludge and screening sludge concentration. The design assumes dewatered sludge at approximately 23% dry matter. Screening is an estimated concentration as the result of the press operation.

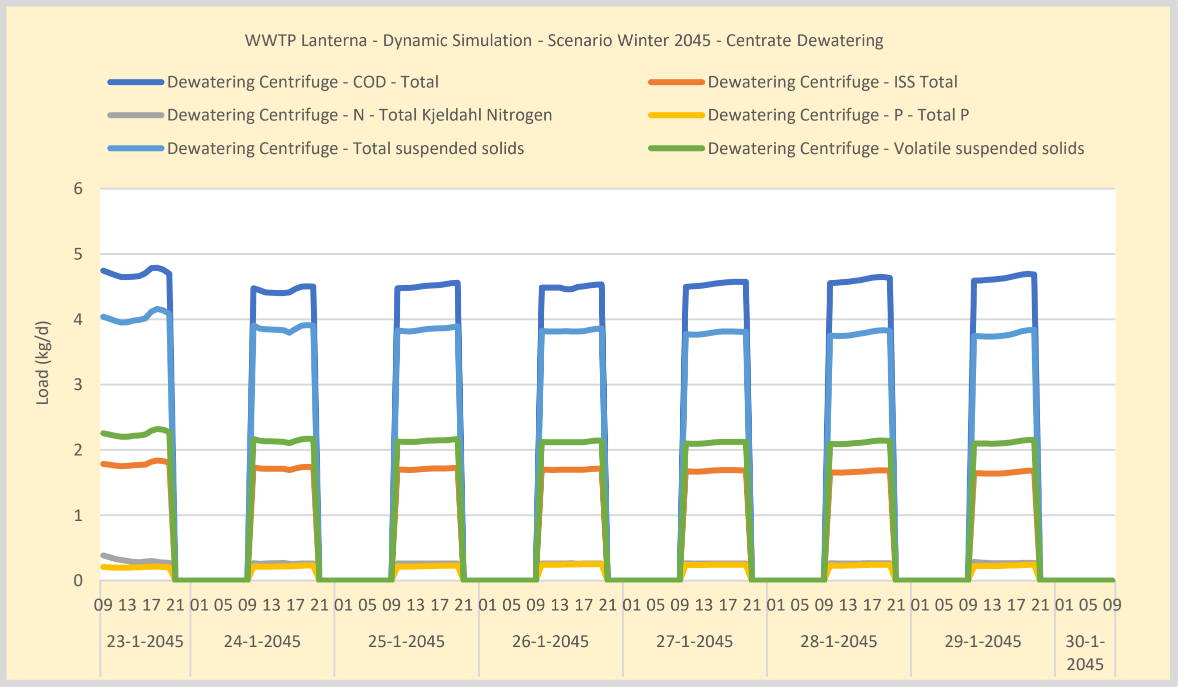


Figure 42. Simulation WWTP Lanterna - Scenario Winter 2045 - Centrate load dewatering.

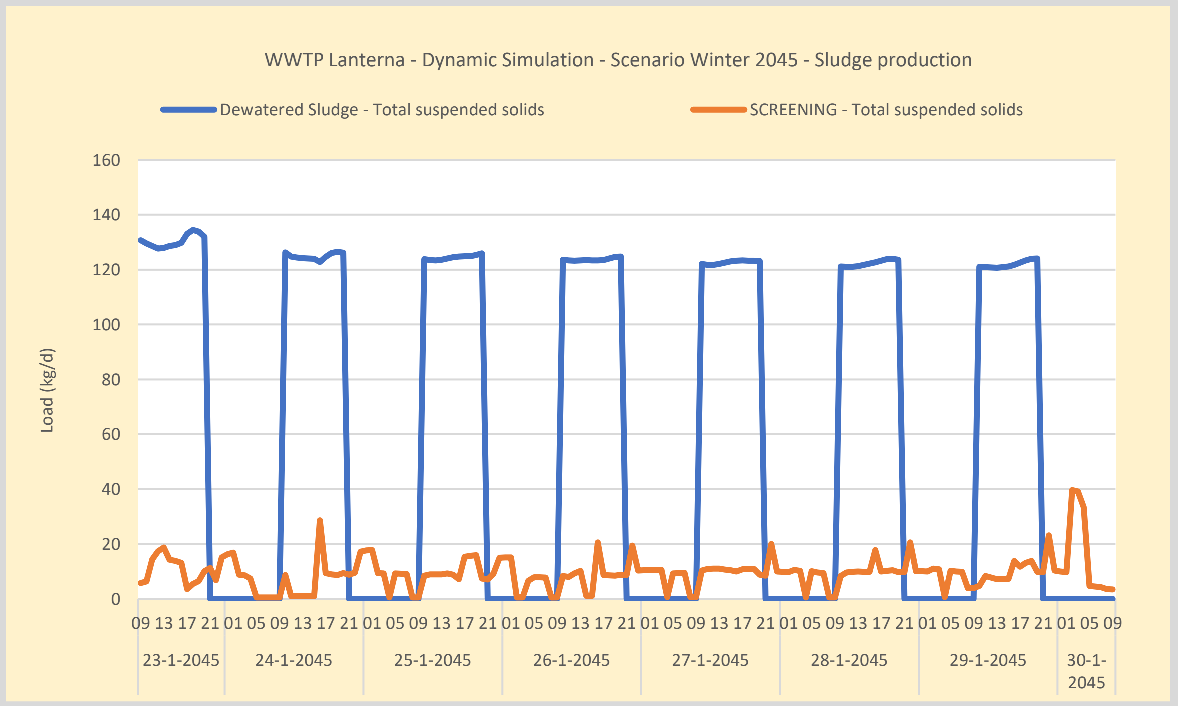


Figure 43. Simulation WWTP Lanterna - Scenario Winter 2045 - dewatered sludge load and compacted screening load. Dewatered sludge is operated 10 hours a day at approximately 23%. Screening is produces continuously as a factor of the influent.

5.12 Effluent modelling results

In the figures below the dynamic effluent quality of the plant is presented under winter conditions projected to the loading conditions in 2045. The last day included a major rain event. Effluent results are from the effluent buffer and have a reduced dynamic profile.

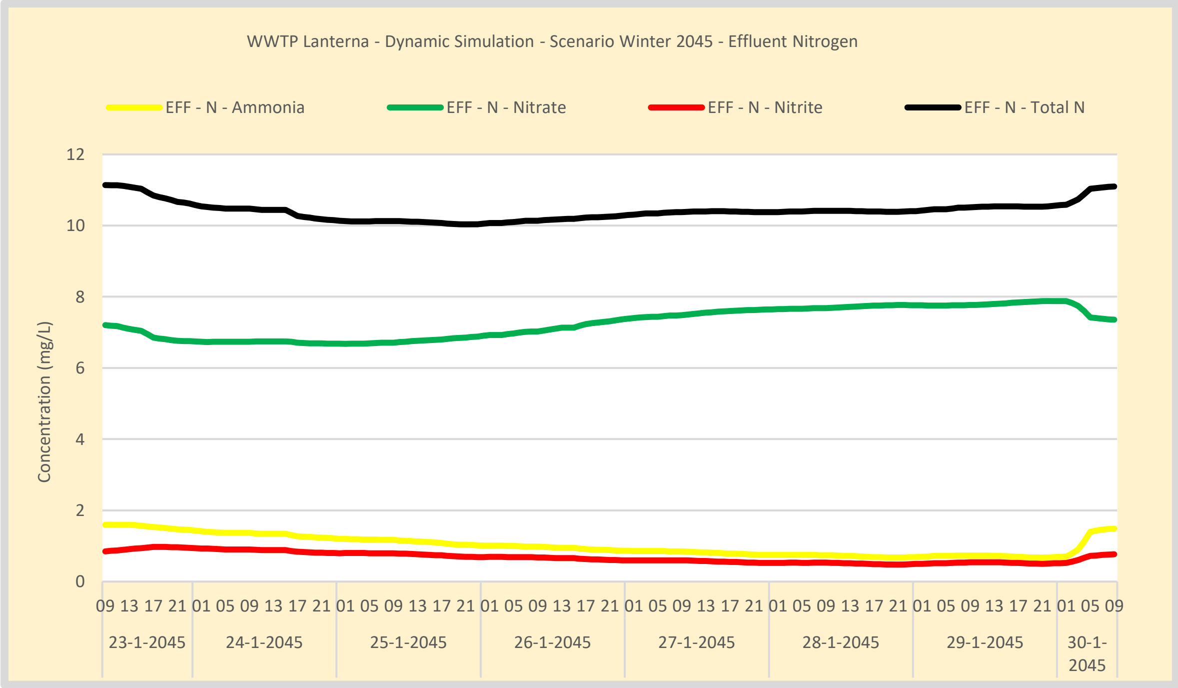


Figure 44. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent nitrogen concentration. Effluent is measured in the outflow of the effluent buffer.

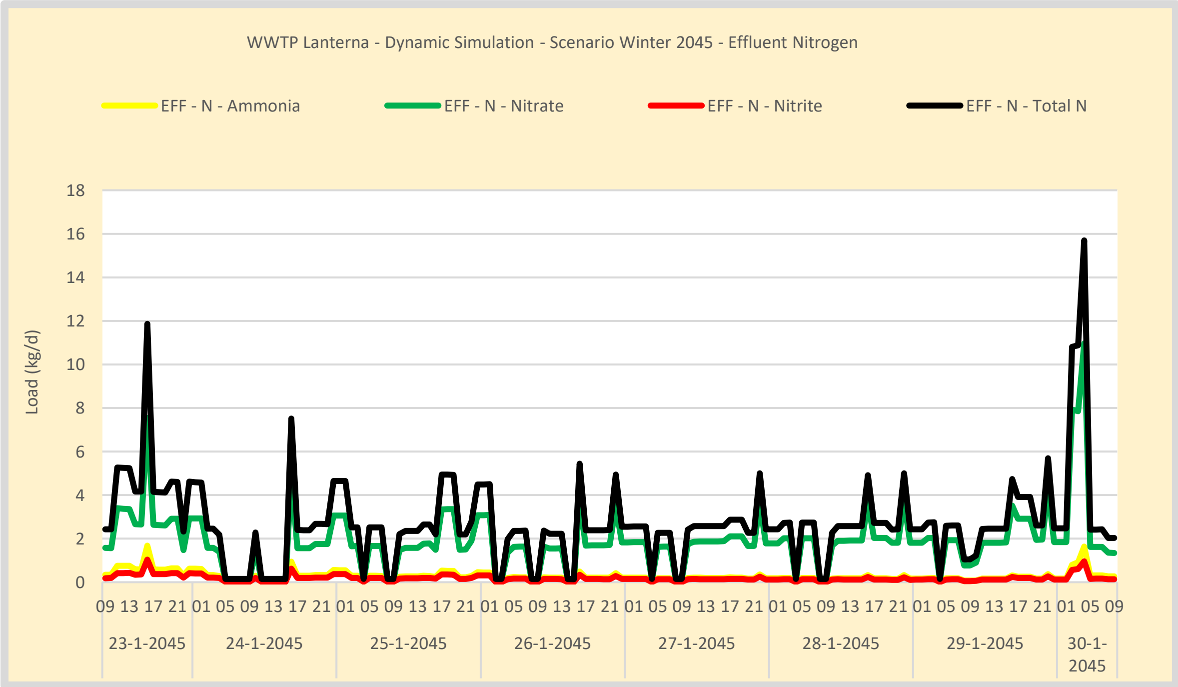


Figure 45. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent nitrogen load. Effluent is measured in the outflow of the effluent buffer. Variations in the effluent load are mainly the result of variations the flow.

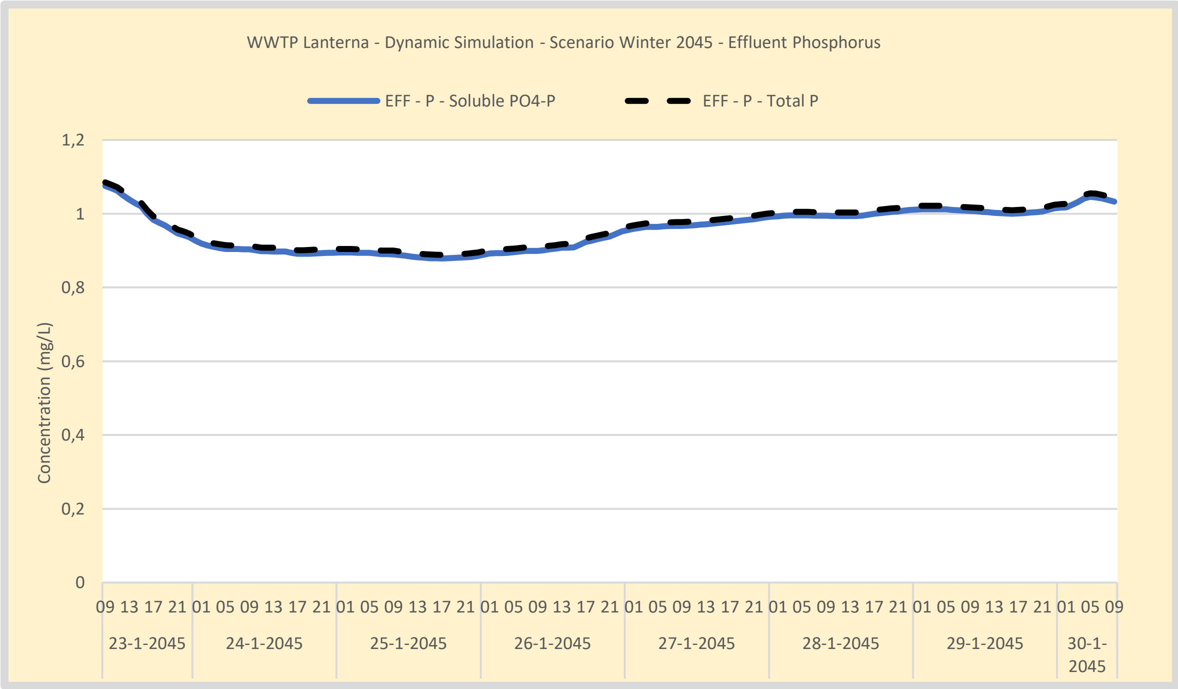


Figure 46. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent phosphorus concentration. Effluent is measured in the outflow of the effluent buffer. The last day is a major rain event negatively affecting P-removal.

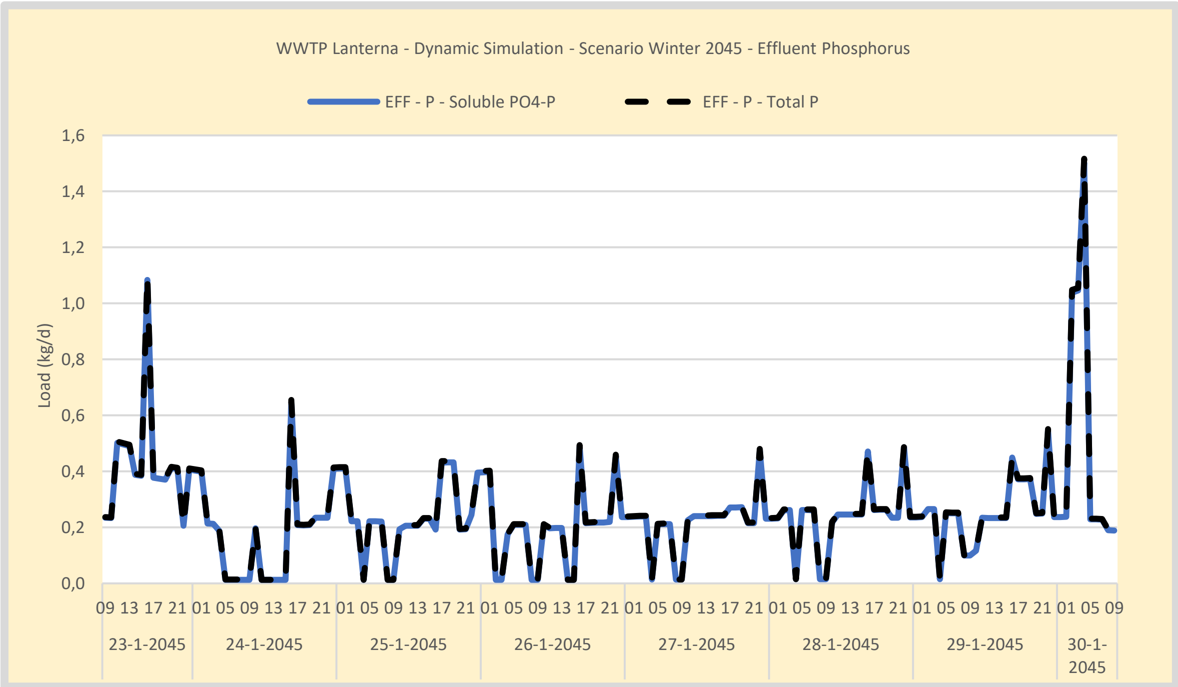


Figure 47. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent phosphorus load. The last day is a major rain event negatively affecting P-removal. Effluent is measured in the outflow of the effluent buffer. Variations in the effluent load are mainly the result of variations the flow.

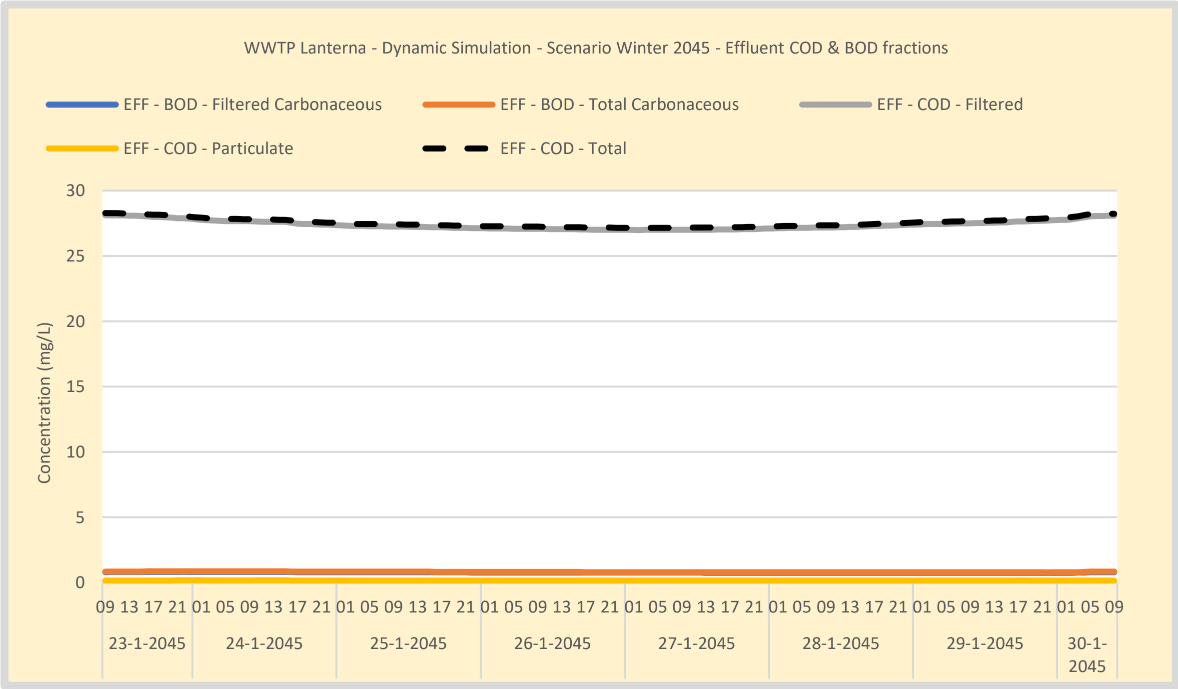


Figure 48. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent COD and BOD concentration. Effluent is measured in the outflow of the large effluent buffer.

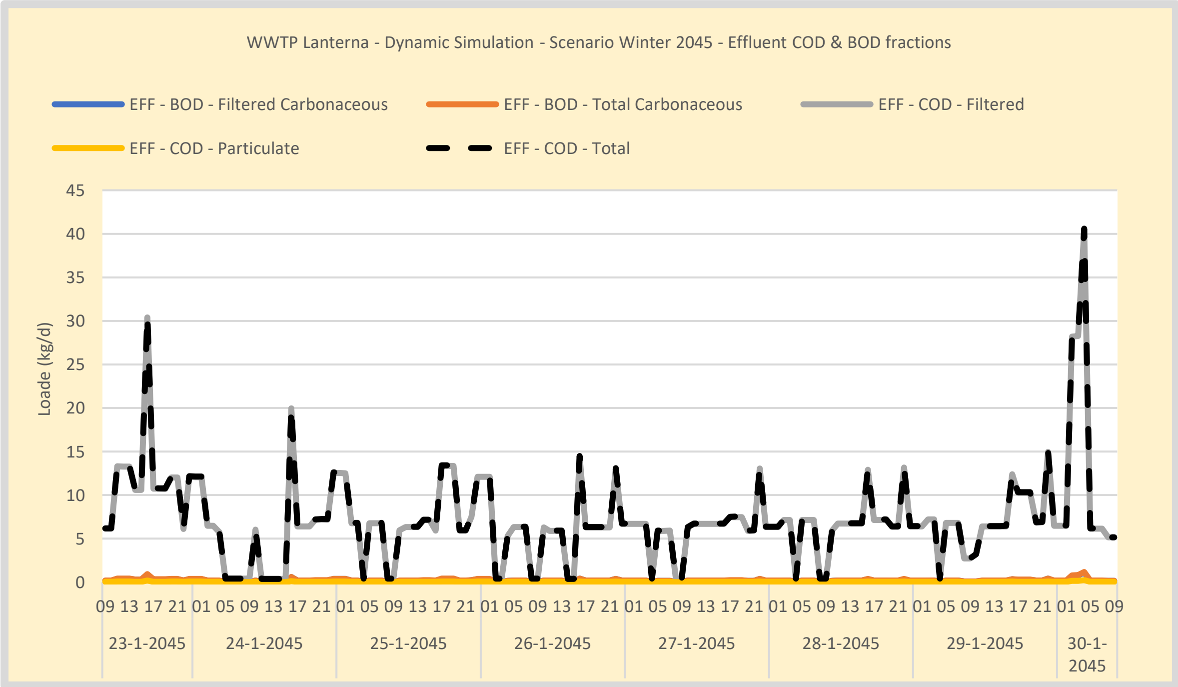


Figure 49. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent COD and BOD load. Effluent is measured in the outflow of the large effluent buffer. Variations in the load are largely the result of flow variations. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material.

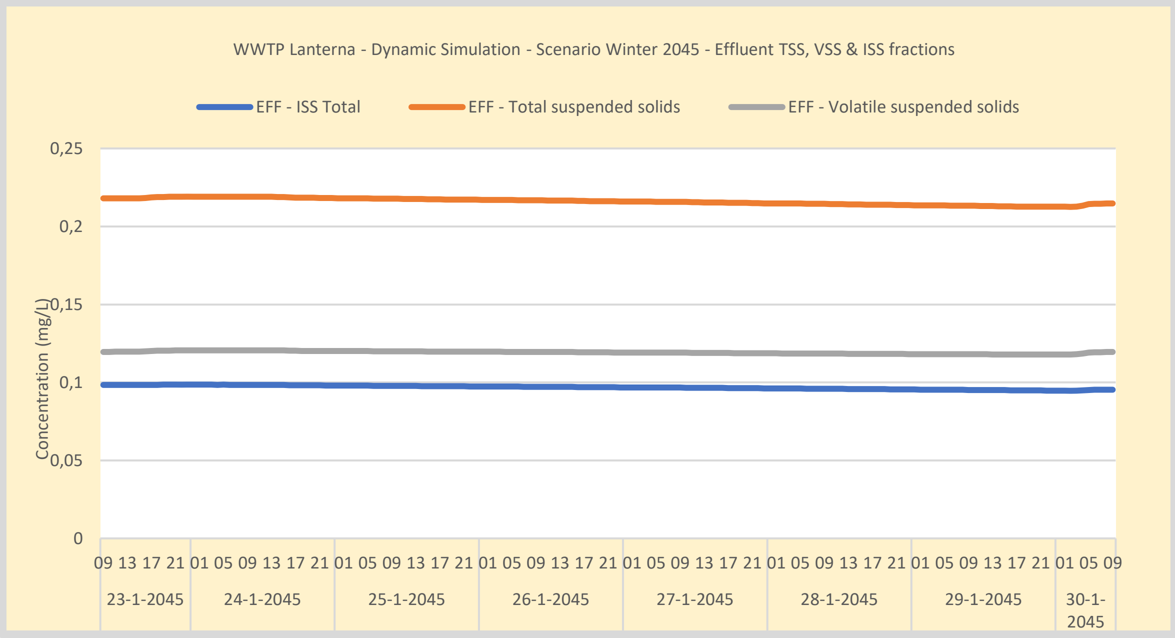


Figure 50. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent suspended solids concentration. Effluent is measured in the outflow of the effluent buffer. It is assumed that the MBR has a 99,9% removal efficiency for solids and 99,99% for colloidal material and that this performance is not affected in time.

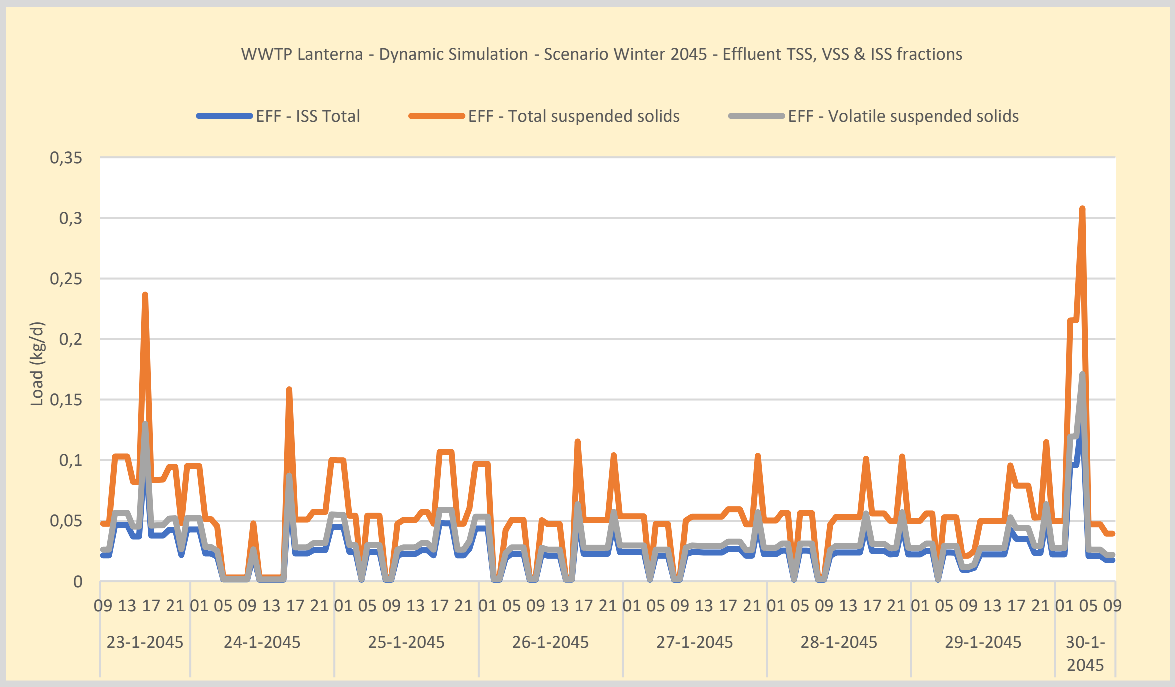


Figure 51. Simulation WWTP Lanterna - Scenario Winter 2045 - Effluent suspended solids load. Effluent is measured in the outflow of the effluent buffer. The effluent load dynamics are the result of the flow dynamics. It is assumed that the MBR has a 99,9% removal efficiency for solids and 99,99% for colloidal material. Effluent VSS is related to the fecal load for sea water quality modelling.

5.13 Conclusion dynamic simulations winter period 2019

The WWTP operates according to the detailed design based on the influent loading extrapolated towards the loading conditions in the year 2045. The effluent requirement for all parameters is within the required design limits.

The model is simulated based on typical default settings and no biological parameter adjustments are required to obtain these results.

During winter the aerobic SRT of the plant is not limiting for nitrification. The aeration of the MBR may be minimized to avoid over-aeration of the system. Reduced air flow however can affect the efficiency of the membranes.

During low loading conditions the unaerated (anaerobic and anoxic) volume may become too large negatively affecting biological growth, nitrification, and P-removal. It is therefore advised to use the maximum internal recycle flow, also during low loading conditions and low effluent nitrate.

During the winter loading conditions the plant requires a limited dosage of Iron to remove phosphate chemically.

The choice of operation is very much determining the plant and effluent results. The selected control strategy for modelling is a simplified strategy however realistic and effective in maintaining the effluent requirements also in the winter.

The large effluent buffer reduces effluent fluctuations.

A trace of solids (0,01%) and colloidal material (0,1%) in the effluent is modelled to be used for sea water quality modeling. This fraction is related to the presence of fecal bacteria and viruses in the effluent.

Winter operation meets the requirements, however, is not typical in respect to a high SRT, long anaerobic and anoxic HRT, high internal recycle rates proportional to the influent and high DO in the activated sludge system.

Specific potential problems of winter operation are:

- Operation under long hydraulic and sludge residence time.
- CO2 stripping in the MBR caused by over-aeration, a drop in alkalinity and possible pH limitation.
- Too low influent alkalinity.
- Too low internal recycle flows resulting in anaerobic zones, decay of biomass and reduction of nitrification and Bio-P capacity.
- P-release in the WAS storage tank operated at HRT > 2-3 hours.
- Too little WAS sludge production (too long SRT) for Bio-P requirement.

6 Scenario summer 2045 results dynamic modelling

6.1 Summer operation process flow diagram

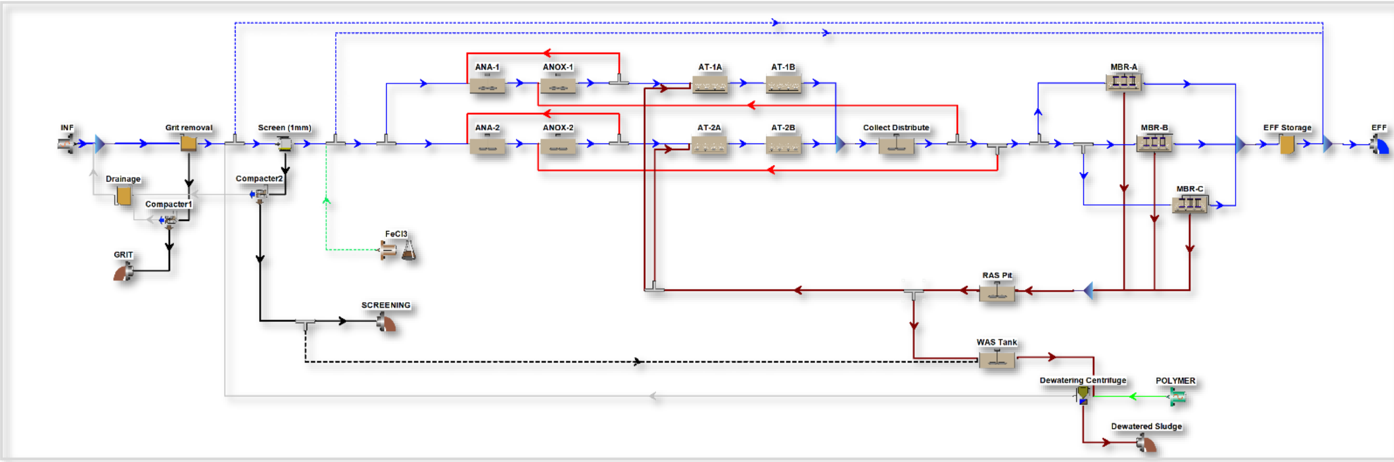


Figure 52. WWTP Lanterna - BioWin model summer operation. One line and one MBR are taken out of operation (dashed lines not operated). Operational adjustments are made to accommodate dynamic modelling. MBR-C is taken out of operation to avoid stripping of alkalinity.

6.2 Performance overview 7-day average

Based on the total dataset including peak loading and rain events, the average WWTP performance of 7-days of simulation is calculated and presented in the tables below. In average, for the simulated period and using simplified process control, the effluent performance and aerobic SRT is in accordance with the design criteria.

Table 7. Dynamic average effluent concentration simulation results (mg/L)

WWTP Lanterna - Scenario Summer 2045 - Dynamic average effluent concentration (mg/L)			
EFF	Temperature	Concentration	20,0
EFF	COD - Total	Concentration	37,1
EFF	N - Total N	Concentration	5,5
EFF	P - Total P	Concentration	0,4
EFF	Total suspended solids	Concentration	1,1

Table 8. Dynamic average Air flow rate simulation results (m3/h)

WWTP Lanterna - Scenario Summer 2045 - Dynamic average Air flow rate (m3/h)			
AT-1A	Air flow rate	Flow	273,2
AT-1B	Air flow rate	Flow	581,5
AT-2A	Air flow rate	Flow	273,2
AT-2B	Air flow rate	Flow	581,5
AT-3A	Air flow rate	Flow	273,2
AT-3B	Air flow rate	Flow	581,5
MBR-A	Air flow rate	Flow	650,0
MBR-B	Air flow rate	Flow	650,0

Table 9. Dynamic average Flow simulation results (m3/d)

WWTP Lanterna - Scenario Summer 2045 - Dynamic average Flows (m3/d)			
ANA-R1	Flow (S)	Flow	1.233,0
ANA-R2	Flow (S)	Flow	1.233,0
ANA-R3	Flow (S)	Flow	1.233,0
ANOX-R1	Flow (S)	Flow	5.550,0
ANOX-R2	Flow (S)	Flow	5.550,0
ANOX-R3	Flow (S)	Flow	5.550,0
AS Emergency Bypass	Flow (S)	Flow	0,0
Dewatering Centrifuge	Flow (U)	Flow	3,1
Grit removal	Flow (U)	Flow	1,6
MBR-A	Flow (U)	Flow	8.048,8
MBR-B	Flow (U)	Flow	8.048,8
Screen (1mm)	Flow (U)	Flow	0,6
Screen Emergency Bypass	Flow (S)	Flow	0,0
WAS Splitter	Flow (U)	Flow	69,2
	Flow (S)	Flow	69,2

Table 10. Dynamic average SRT and HRT simulation results

WWTP Lanterna - Scenario Summer 2045 - Dynamic average SRT and HRT		
Temperature	20	°C
Average waste sludge production	739,2	kgTSS/d
SRT Total	26,6	d
SRT Aerobic	13,4	d
SRT AT+ANOX	18,9	d
WAS Tank HRT	2,4	hour
ANA HRT to influent	4,5	hour

Table 11. Dynamic average Iron and PE simulation results (mg/L, kg/d, m3/d)

WWTP Lanterna - Scenario Summer 2045 - Dynamic average Iron and Polymer (mg/L & kg/d)			
FeCl3	Flow	Flow	0,0
FeCl3	Total iron (all forms)	Concentration	150.000
FeCl3	Total iron (all forms)	Load	0,0
POLYMER	COD - Total	Concentration	18.180
POLYMER	COD - Total	Load	18,4
POLYMER	Flow	Flow	1,5

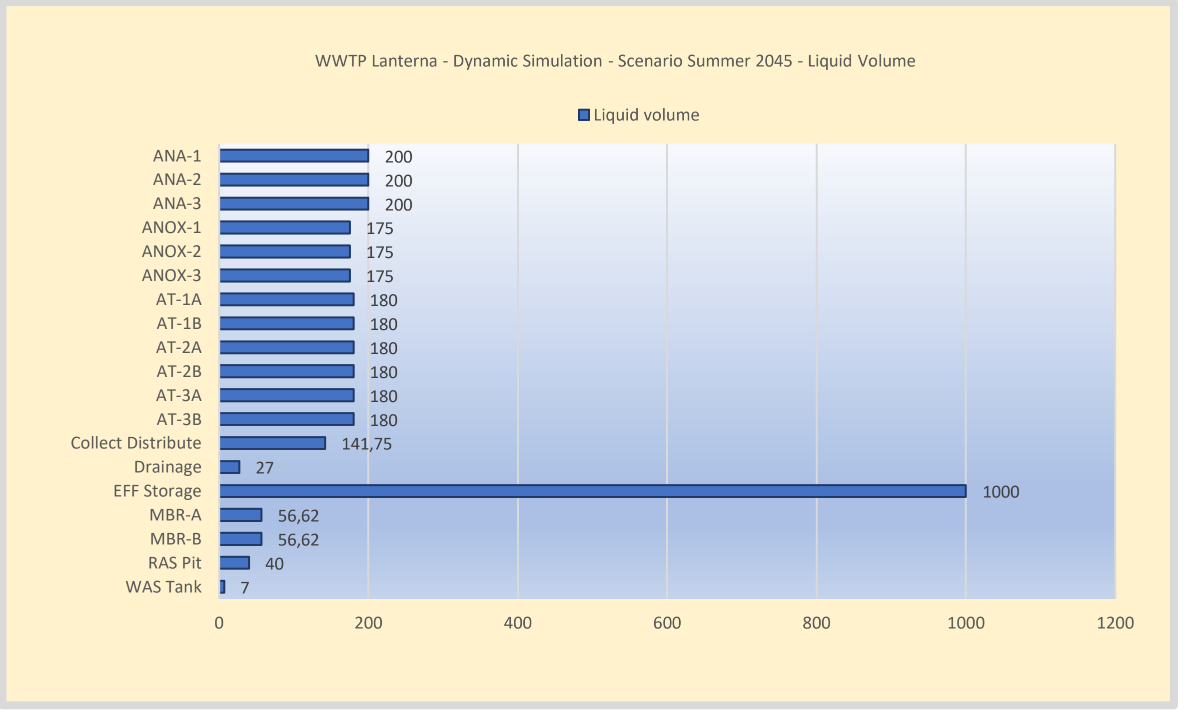


Figure 53. Simulation WWTP Lanterna - Scenario Summer 2045 - Volume distribution of modelled reactor elements. The actual WAS tank is 150 m3 however the sludge volume is modelled based on an HRT less than 2,5 hours to avoid P-release. From the model it is concluded the WAS tank should not be used for storage of Bio-P sludge.

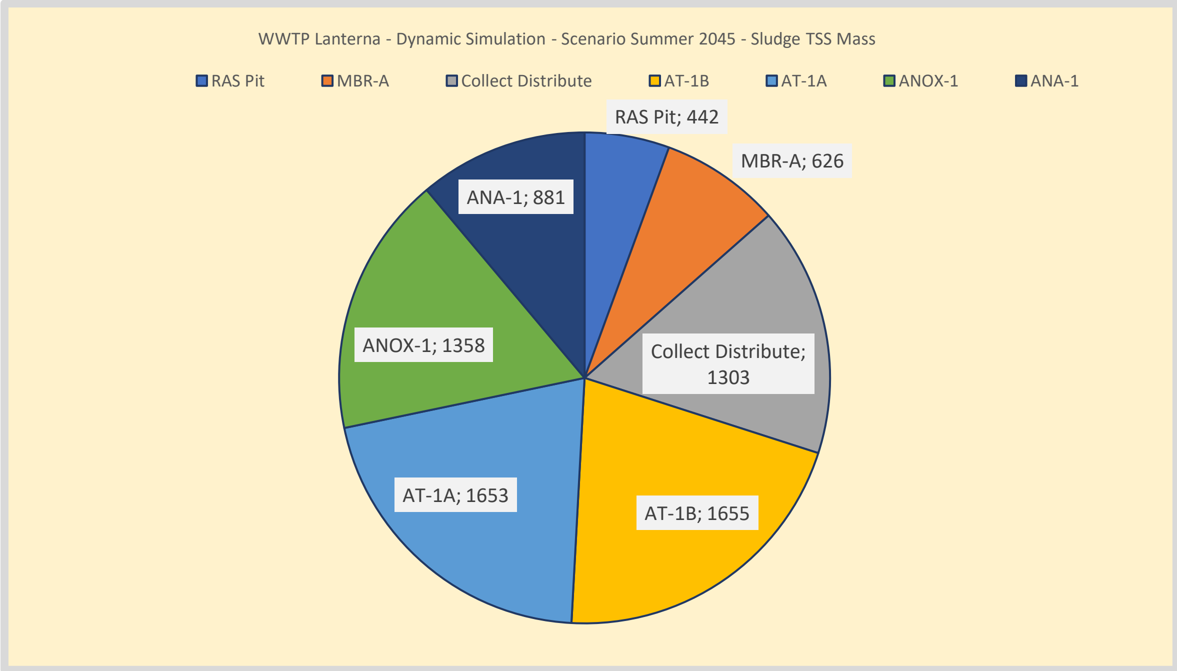


Figure 54. Simulation WWTP Lanterna - Scenario Summer 2045 - Sludge mass distribution (kgTSS) in the activated sludge reactors. This data is used to calculate the SRT of the WWTP. Idle reactors containing sludge are not included in SRT calculations.

6.3 Process controllers: Summer

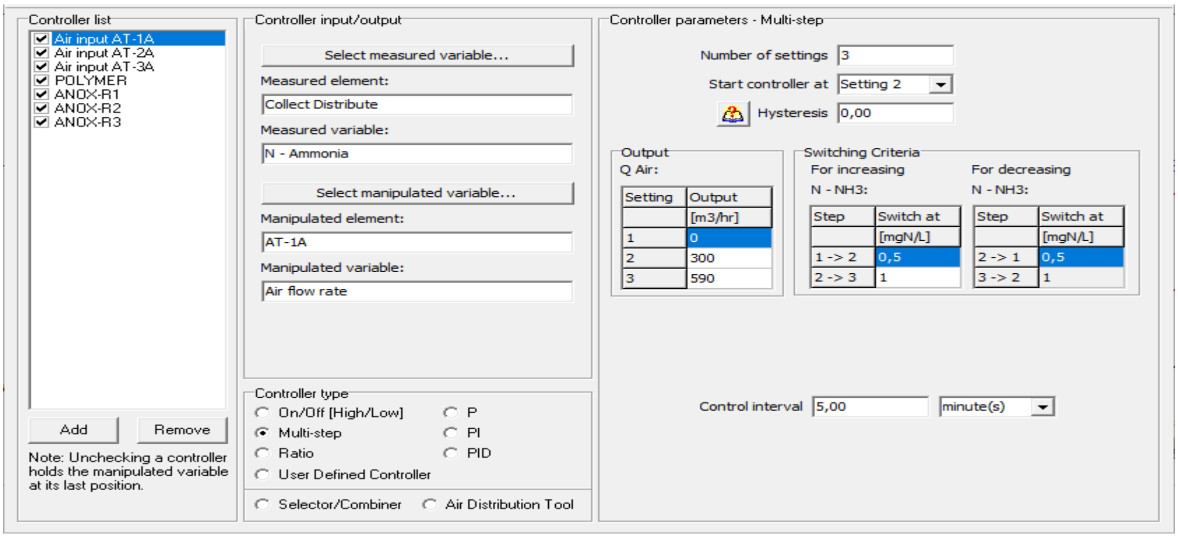


Figure 55. Simulation WWTP Lanterna - Scenario Summer 2045 - BioWin controller toolbox used for controlling the air input of AT-A. The measured variable is NH4 in the collect distribute tank. The manipulated variable the air flow in AT-A. There are 3 settings for the air flow depending on the NH4 concentration.

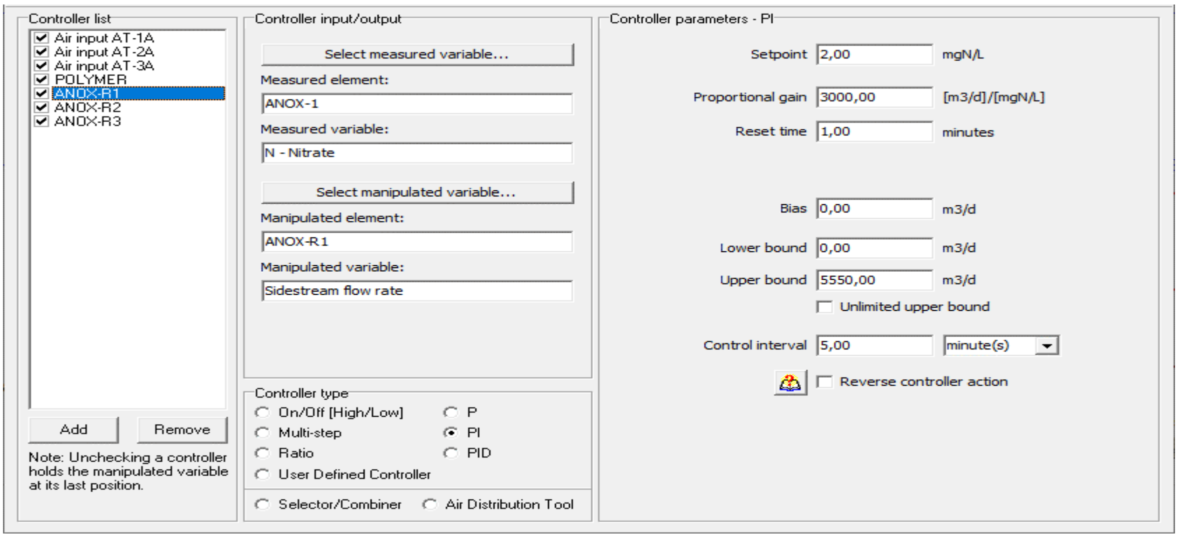


Figure 56. Simulation WWTP Lanterna - Scenario Summer 2045 - BioWin controller toolbox used for controlling the anoxic recycle ANOX-R. Indicated are the measured variable being NO3 in the anoxic tank and manipulated variable the recycle flow ANOX-R. The PI controller has an upper bound of 5.550 m3/d equal to the maximum installed pump capacity per lane.

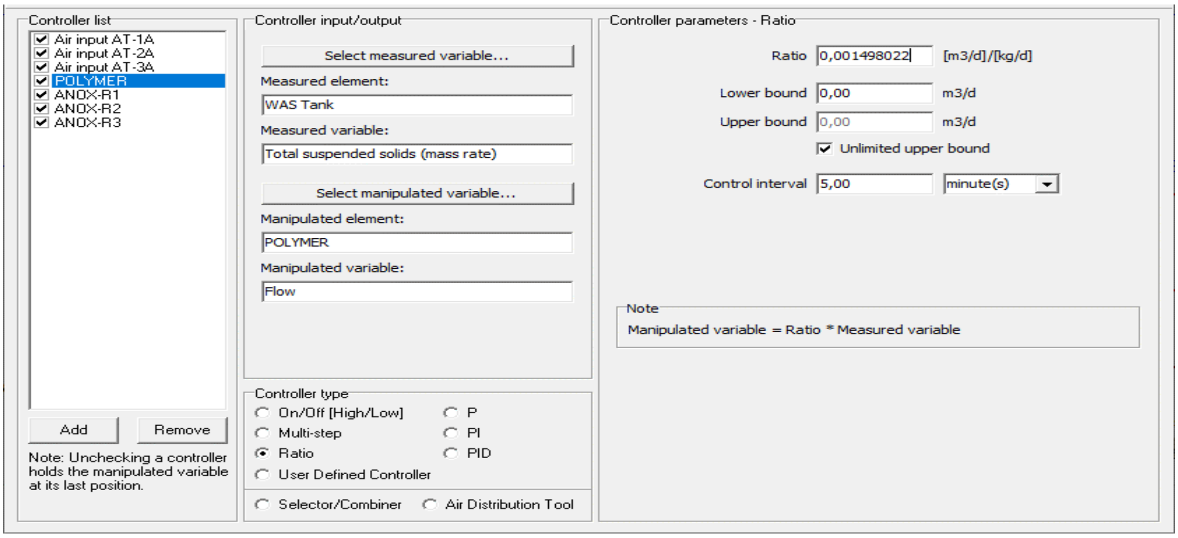


Figure 57. Simulation WWTP Lanterna - Scenario Summer 2045 - BioWin controller toolbox used for controlling the polymer dosage of the dewatering. Indicated are the measured variable being the TSS load entering the dewatering and manipulated variable the PE flow. The applied control ratio is 8 kg PE per 1000 kg TSS based on dry weight. PE is assumed to be particulate substrate with a COD/VSS ratio of 1,42.

6.4 Influent modelling results

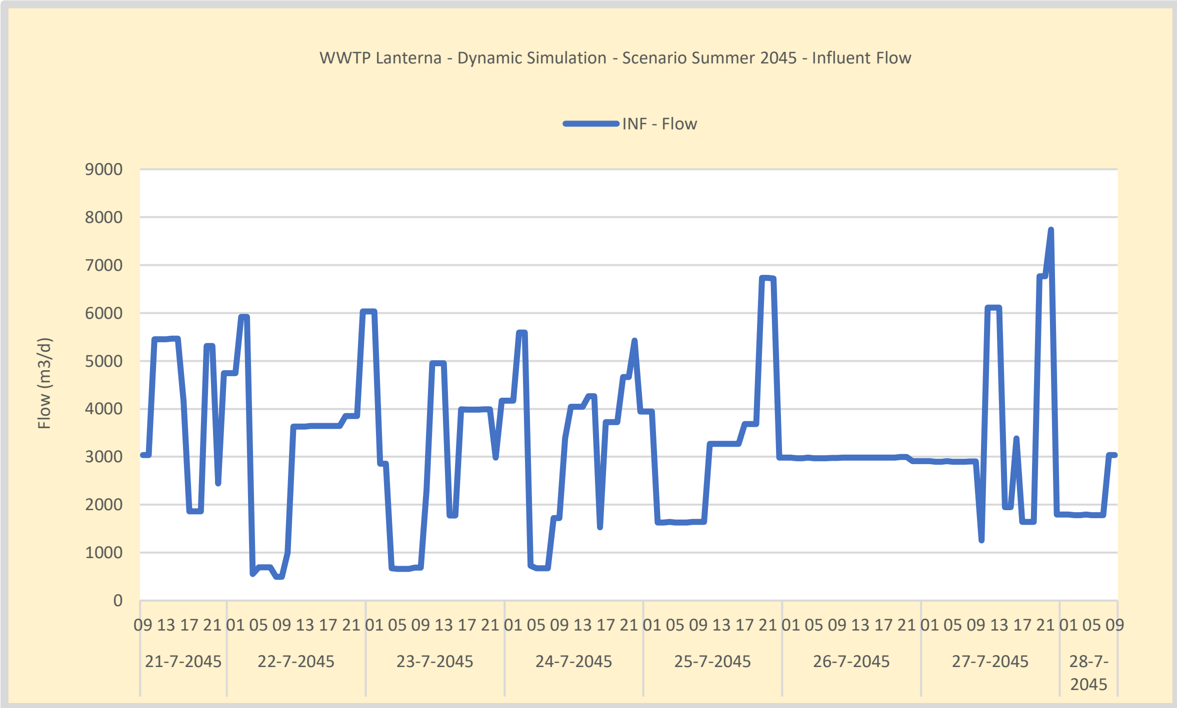


Figure 58. Simulation WWTP Lanterna - Scenario Summer 2045 - Influent flow. No rain event occurred.

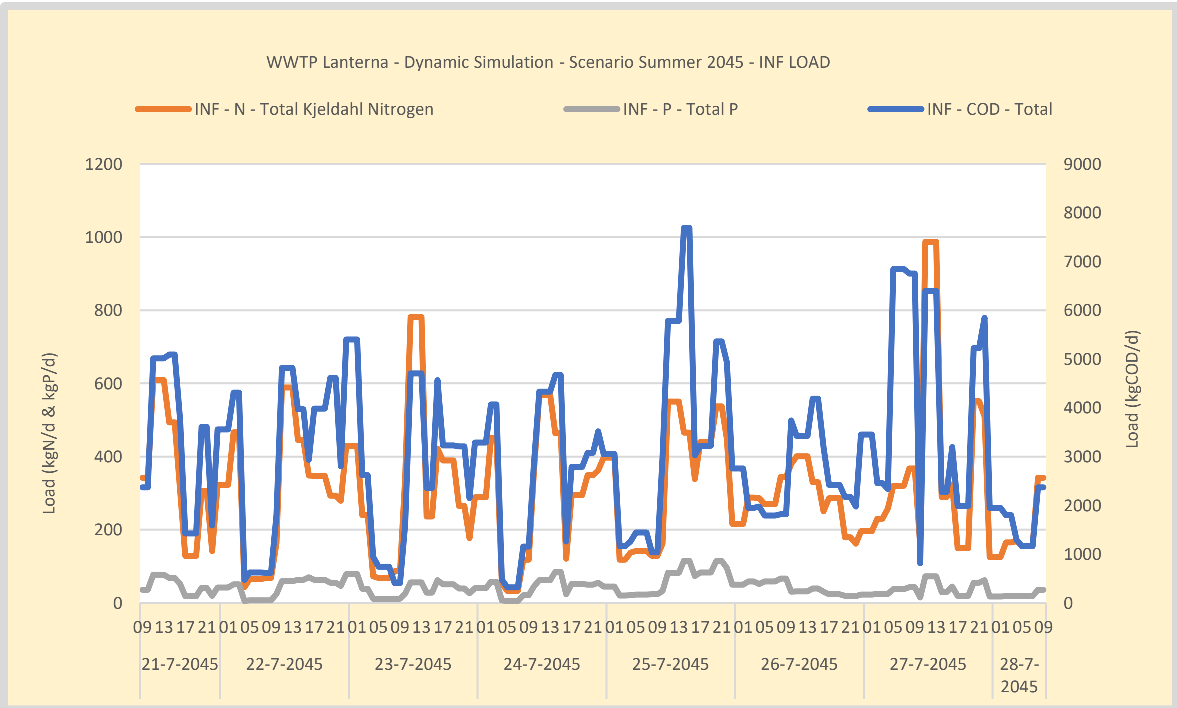


Figure 59. Simulation WWTP Lanterna - Scenario Summer 2045 - Influent loads COD, TKN and TP. No rain event occurred.

6.5 Process and recycle flows modelling results

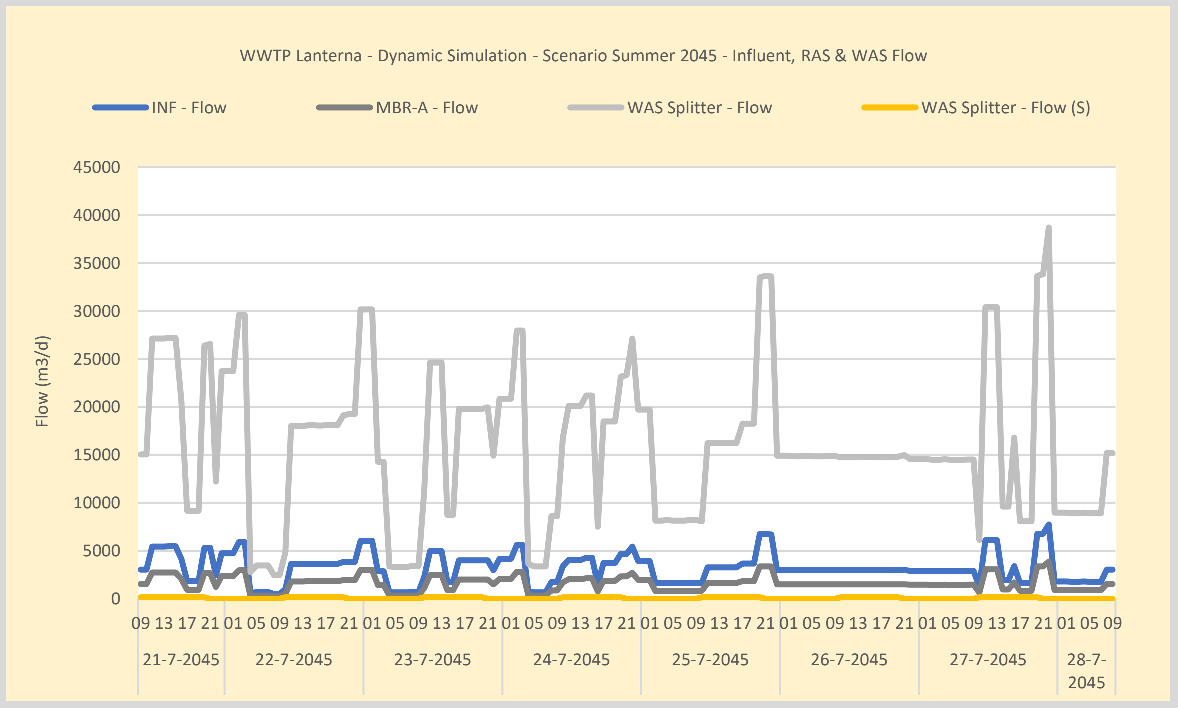


Figure 60. Simulation WWTP Lanterna - Scenario Summer 2045 - flow rate settings and control. The MLSS sludge return flow is controlled proportional to the influent. The WAS flow is time controlled and operated 10 hours a day on a constant flow.

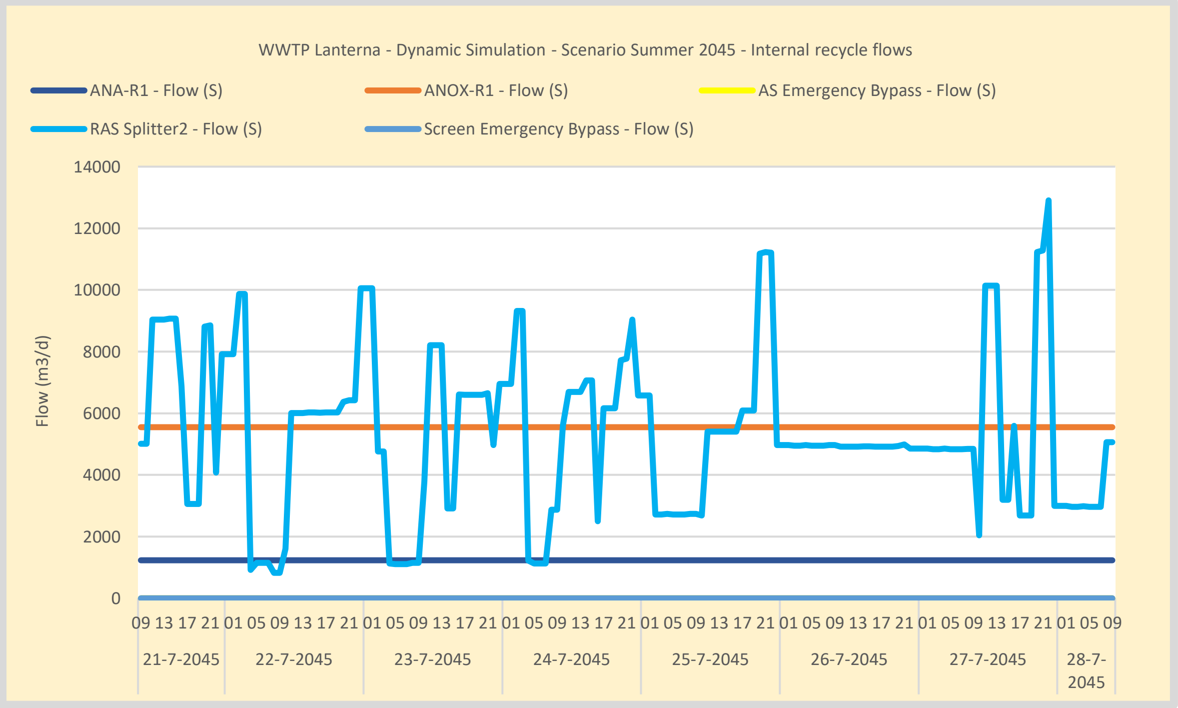


Figure 61. Simulation WWTP Lanterna - Scenario Summer 2045 - flow rate settings and control. The bypasses are not used. The anoxic recycle is controlled based on nitrate in the anoxic tank. The flow is reduced when Nitrate becomes higher than 2 mgNO3/L. The fact that this setpoint cannot be reached, indicates the recycle is limiting or that the anoxic tank is too large.

6.6 Waterline operation modelling results

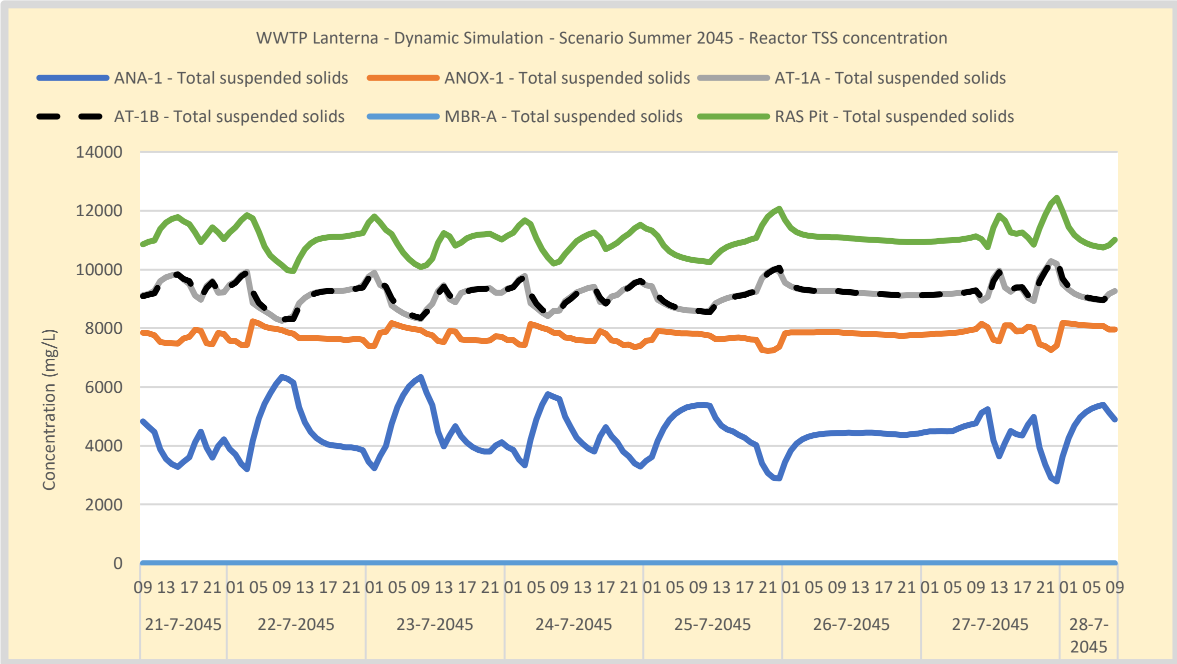


Figure 62. Simulation WWTP Lanterna - Scenario Summer 2045 - TSS profile in the waterline. TSS in the MBR is controlled on approximately 10 gTSS/L. TSS is controlled by adjusting the WAS flow and by maintaining a high MLSS recycle from the MBR. SRT is sufficient for summer operation and according to the design.

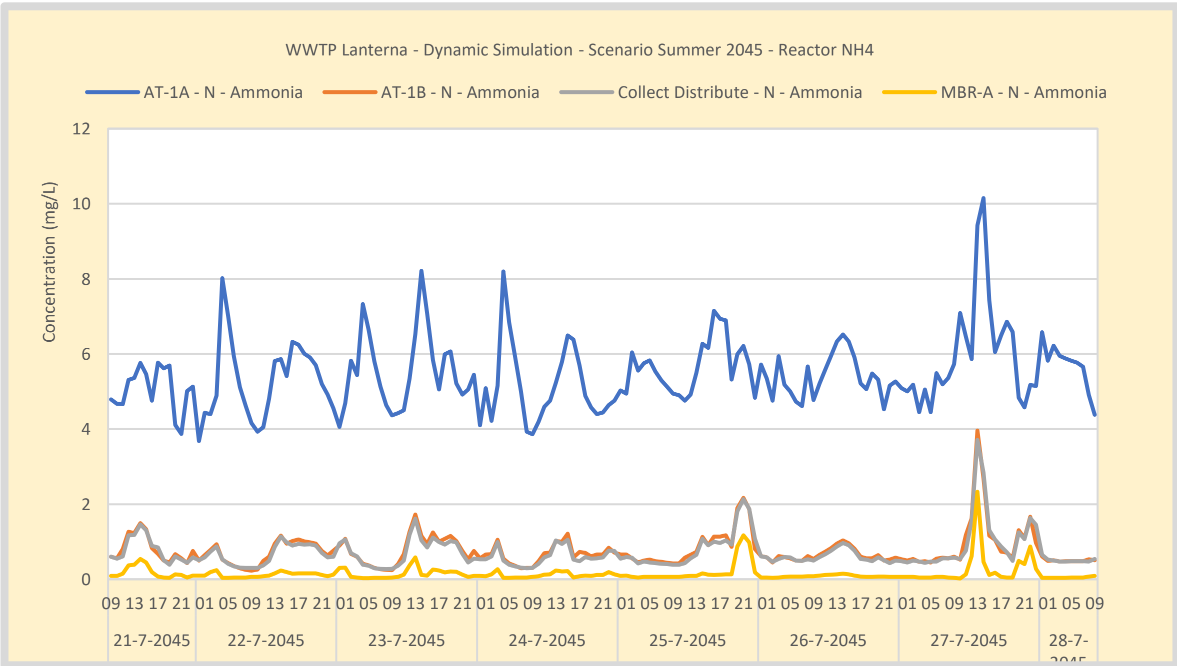


Figure 63. Simulation WWTP Lanterna - Scenario Summer 2045 - ammonium profile in the waterline. The air input of AT-A is controlled based on NH4 measured in the collect distribute tank using a 3-step controller. Above 1,0 mgNH4/L the air input goes to its maximum value. Below 0,5 air shuts off. AT-B is DO controlled on 2,0 mgO2/L.

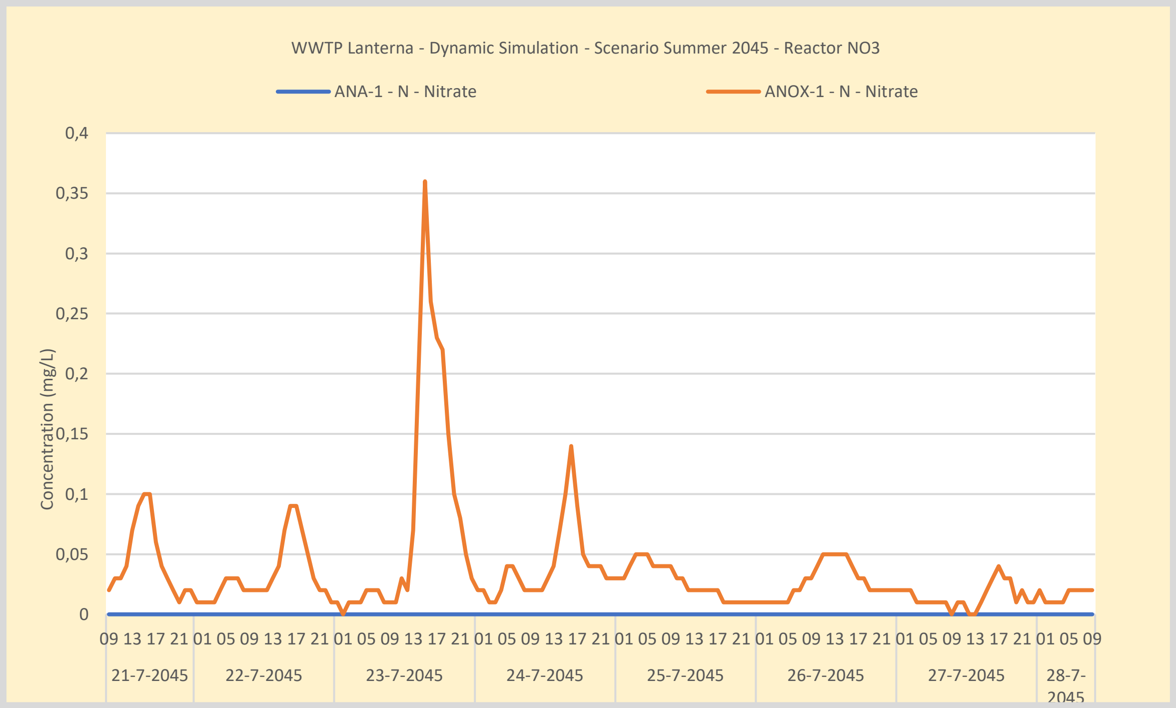


Figure 64. Simulation WWTP Lanterna - Scenario Summer 2045 - nitrate in the anoxic tank. The anoxic recycle rate is controlled on a nitrate setpoint of 2 mgNO3/L in the anoxic tank. Internal recycle capacity is not sufficient to reach this setpoint.

6.7 Waterline concentration profiles modelling results

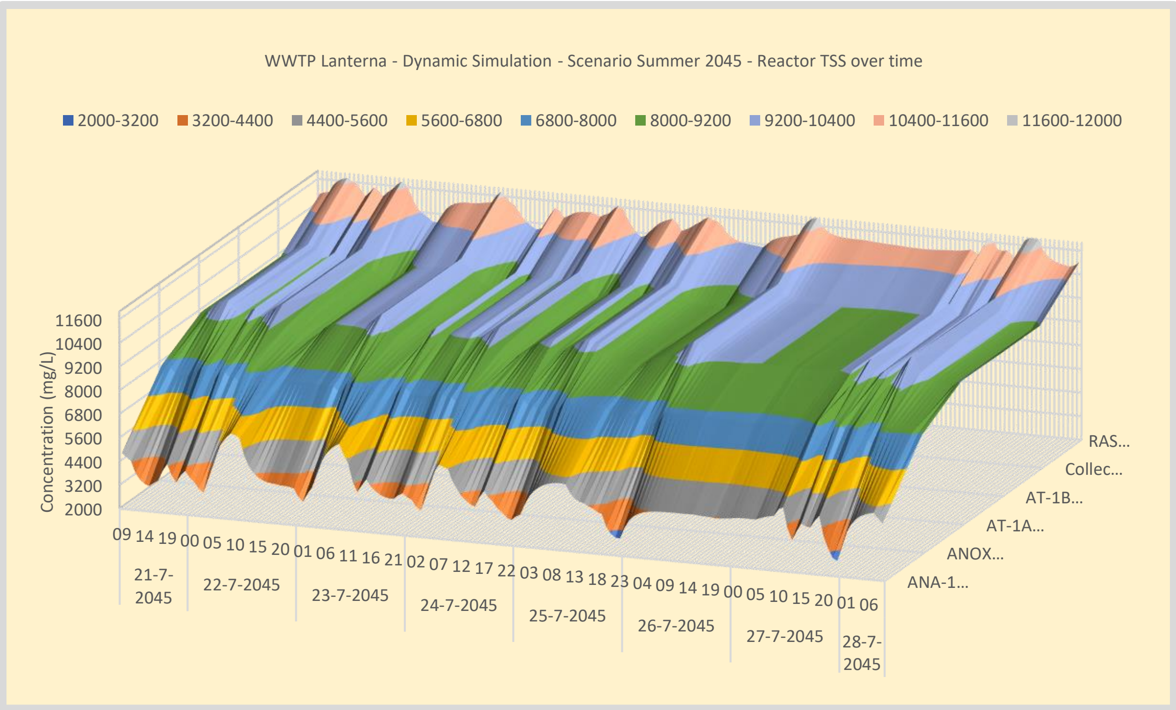


Figure 65. Simulation WWTP Lanterna - Scenario Summer 2045 - TSS concentration profile over the waterline.

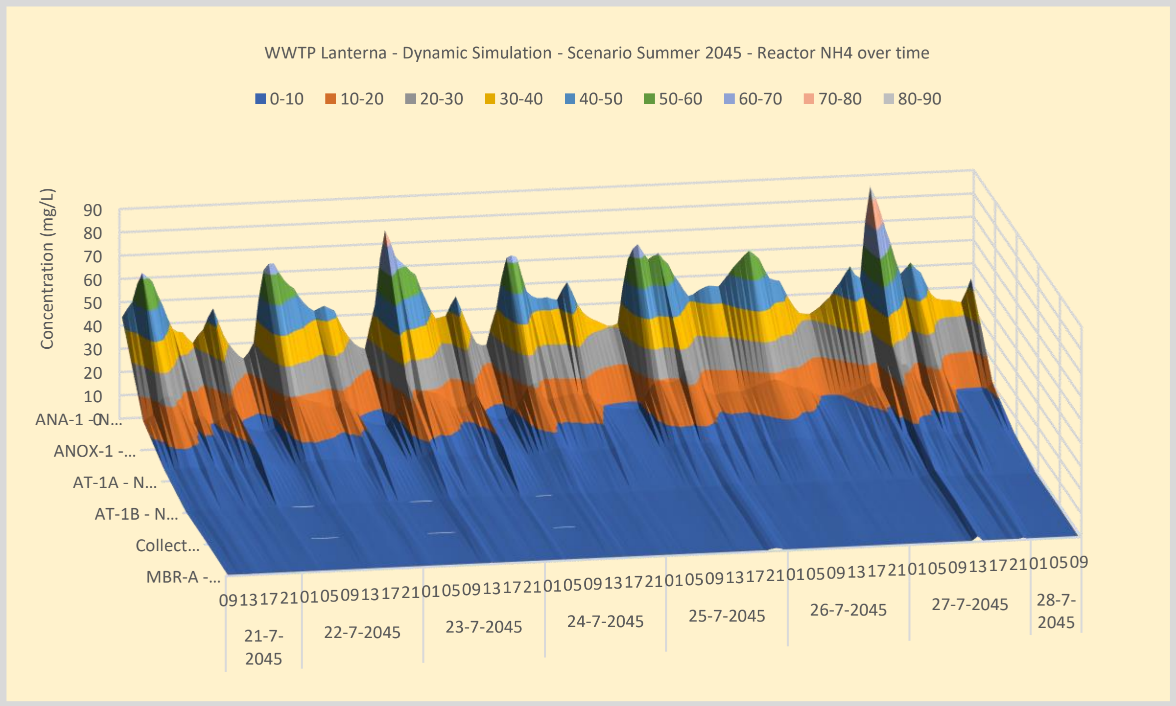


Figure 66. Simulation WWTP Lanterna - Scenario Summer 2045 - NH4 concentration profile over the waterline.

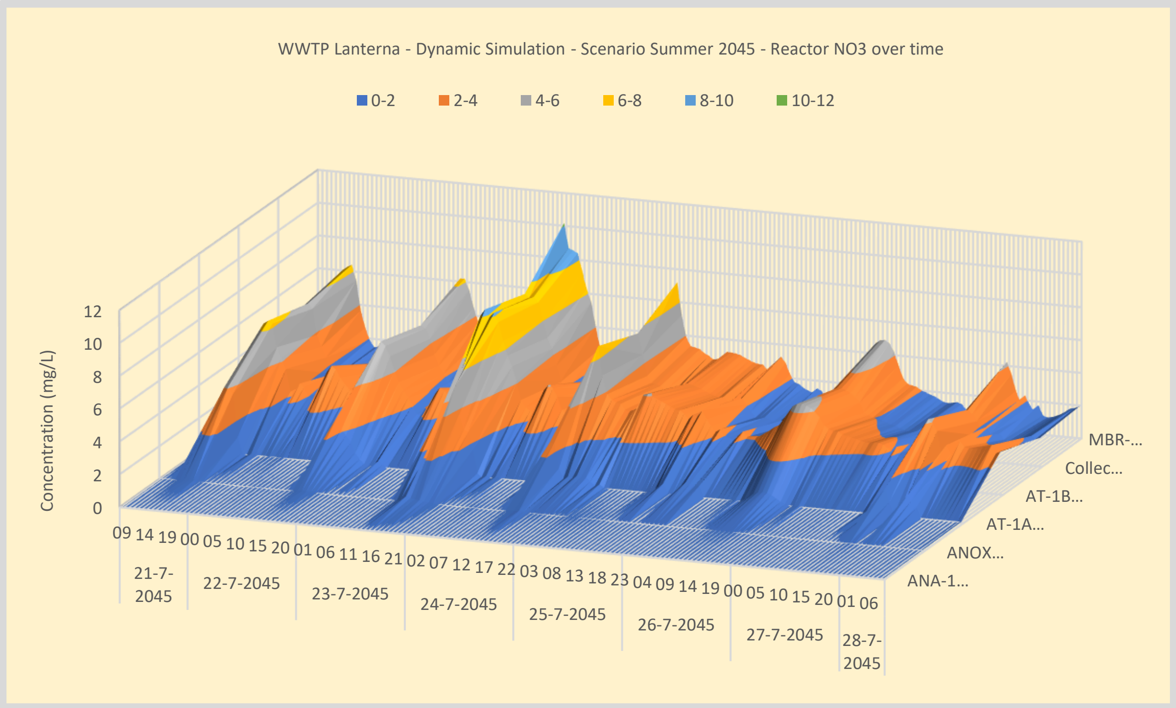


Figure 67. Simulation WWTP Lanterna - Scenario Summer 2045 - NO3 concentration profile over the waterline.

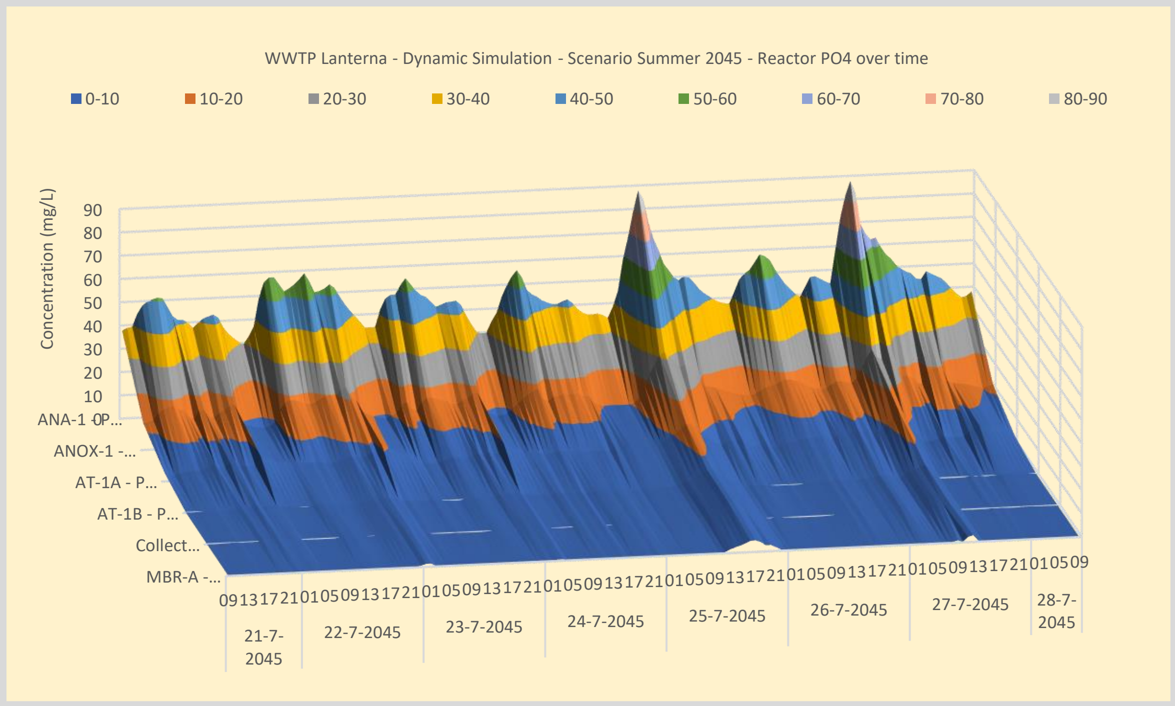


Figure 68. Simulation WWTP Lanterna - Scenario Summer 2045 - PO4 concentration profile over the waterline. Effluent PO4 increases caused by shortage of oxygen and nitrate for Bio-P uptake.

6.8 Aeration and DO concentration modelling results

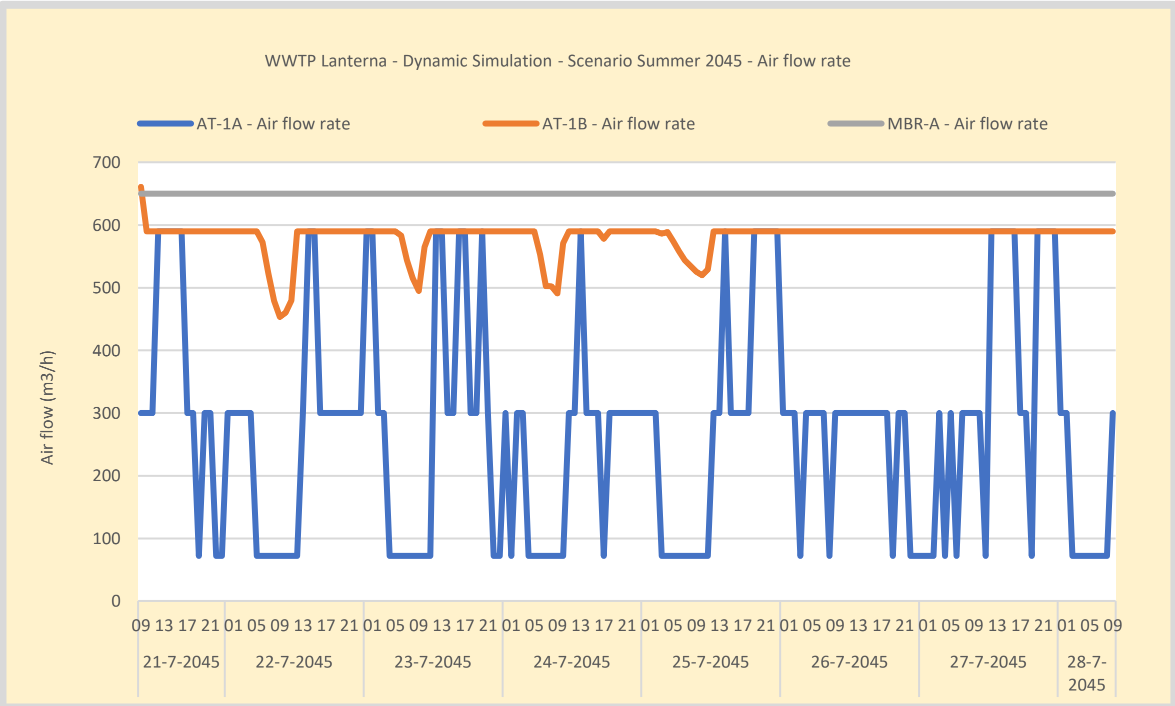


Figure 69. Simulation WWTP Lanterna - Scenario Summer 2045 - air input in the different aerated reactors. AT-A is step controlled on NH4, AT-B is setpoint controlled on the DO, the MBR is fully aerated according to the design value.

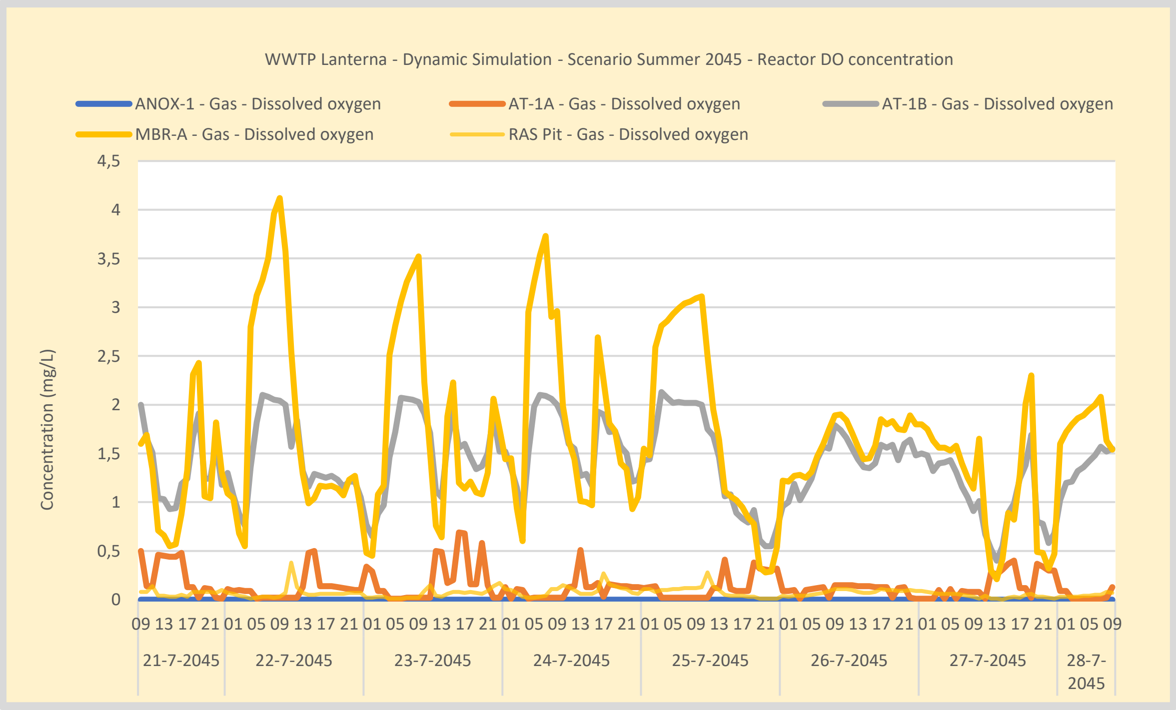


Figure 70. Simulation WWTP Lanterna - Scenario Summer 2045 - DO concentration gradients. DO is controlled in the AT-B on 2 mgO2/L and the air flow of AT-B on NH4 concentration in the outflow of the aeration. During influent TKN peak loading the air flow of AT-B is insufficient to maintain the DO setpoint. In the MBR the DO is the result of the designed maximum air input. No oxygen is measured in the anoxic zone.

6.9 pH and alkalinity modelling results

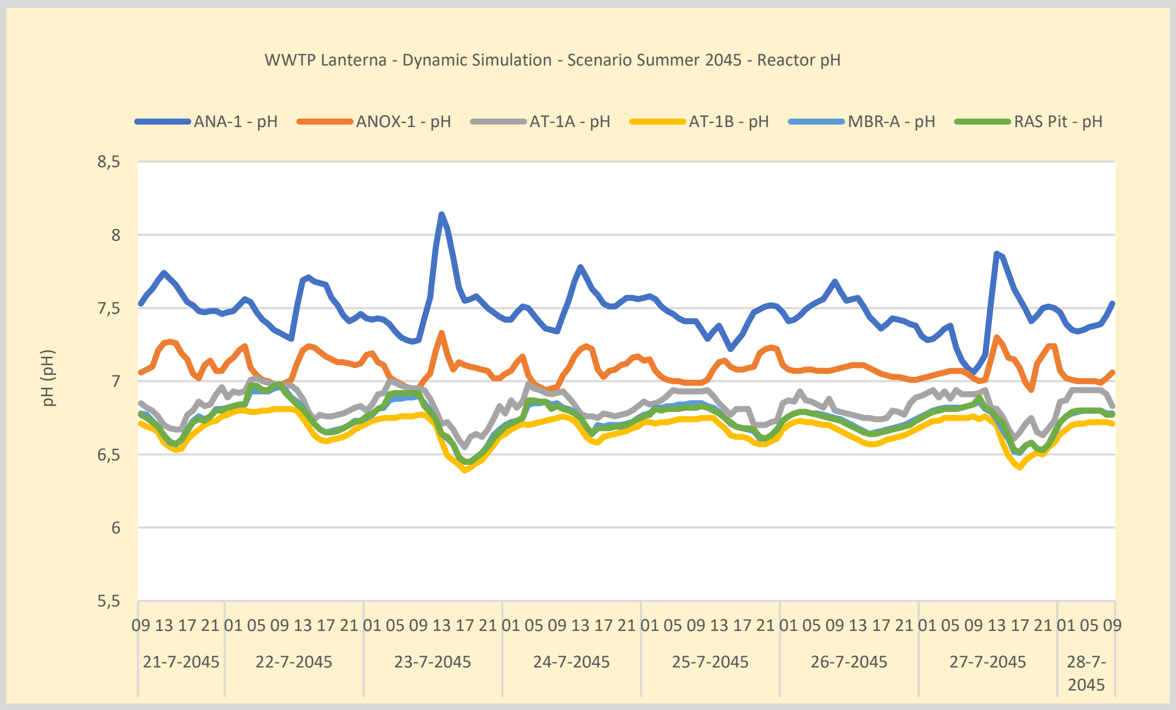


Figure 71. Simulation WWTP Lanterna - Scenario Summer 2045 - pH profile over the activated sludge reactors. Influent pH is measured continuously and is not limiting. pH is not limiting.

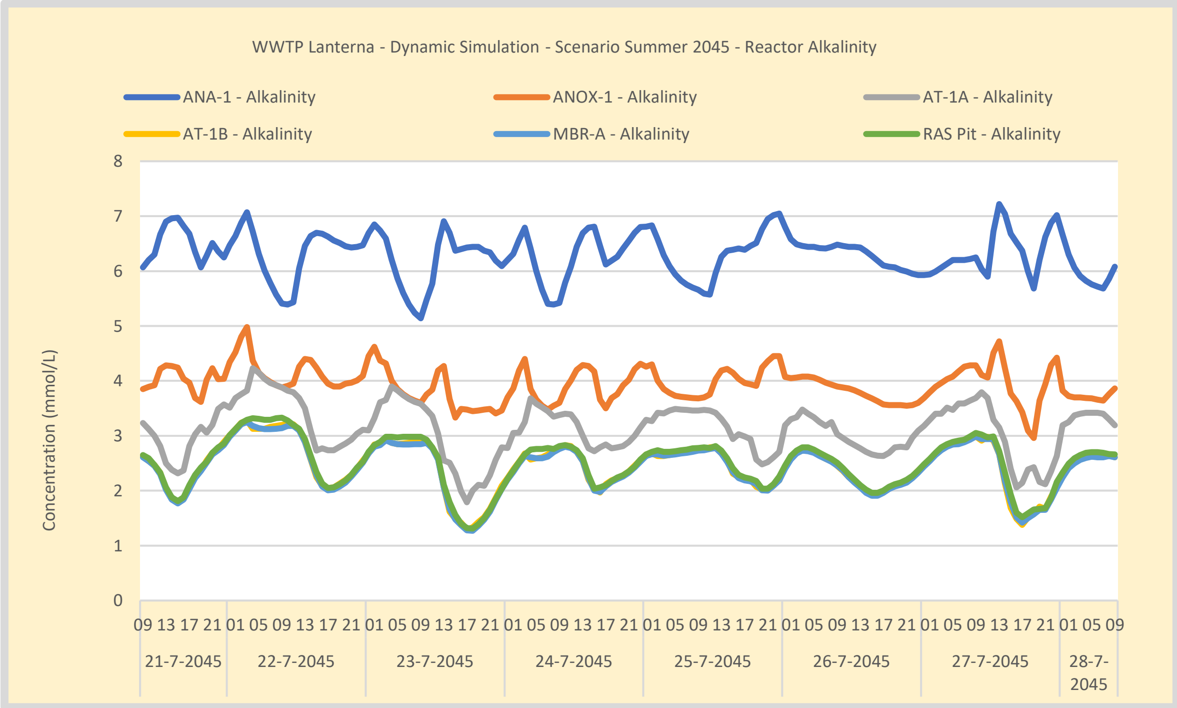


Figure 72. Simulation WWTP Lanterna - Scenario Summer 2045 - alkalinity profile over the activated sludge reactors. Influent alkalinity is estimated from local drinking water quality measurements at 7,46 mmol/L. Alkalinity is not becoming zero however potentially limiting under the operated conditions.

6.10 Chemical load and flow modelling results

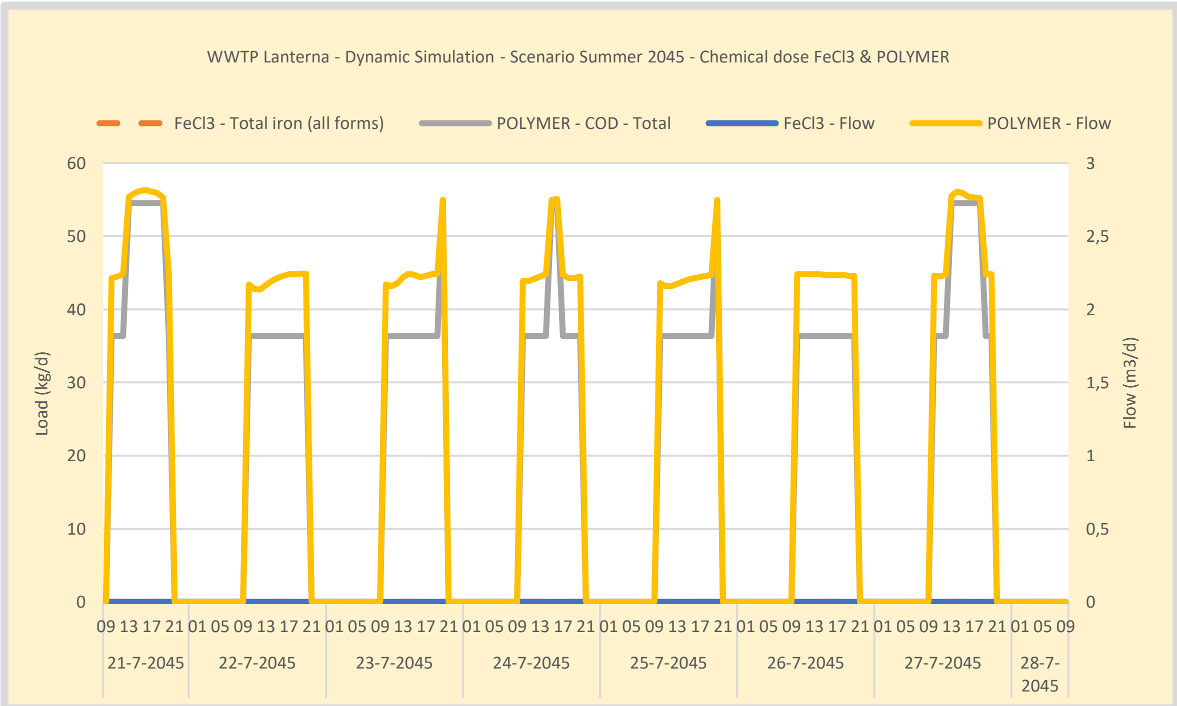


Figure 73. Simulation WWTP Lanterna - Scenario Summer 2045 - load and flow of Iron and PE. No iron is dosed. PE is assumed particulate biodegradable COD with a COD/VSS ratio of 1,42 gCOD/gTSS and dosed proportional to the WAS load based on 8 kg PE (dry weight) dosed per 1000 kg WAS (dry weight) flowing in the dewatering.

6.11 Sludge line operation modelling results

In the figures below the dynamic operation of the sludge line including dynamic WAS control and dewatering during 10 hours per day.

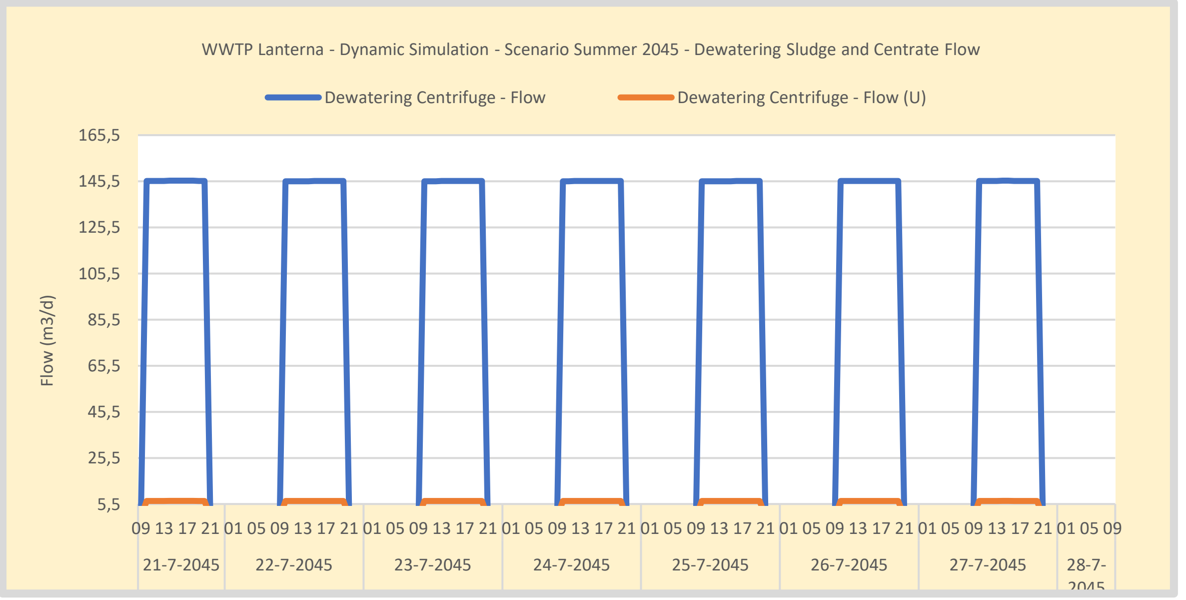


Figure 74. Simulation WWTP Lanterna - Scenario Summer 2045 - dewatered sludge and centrate flow.

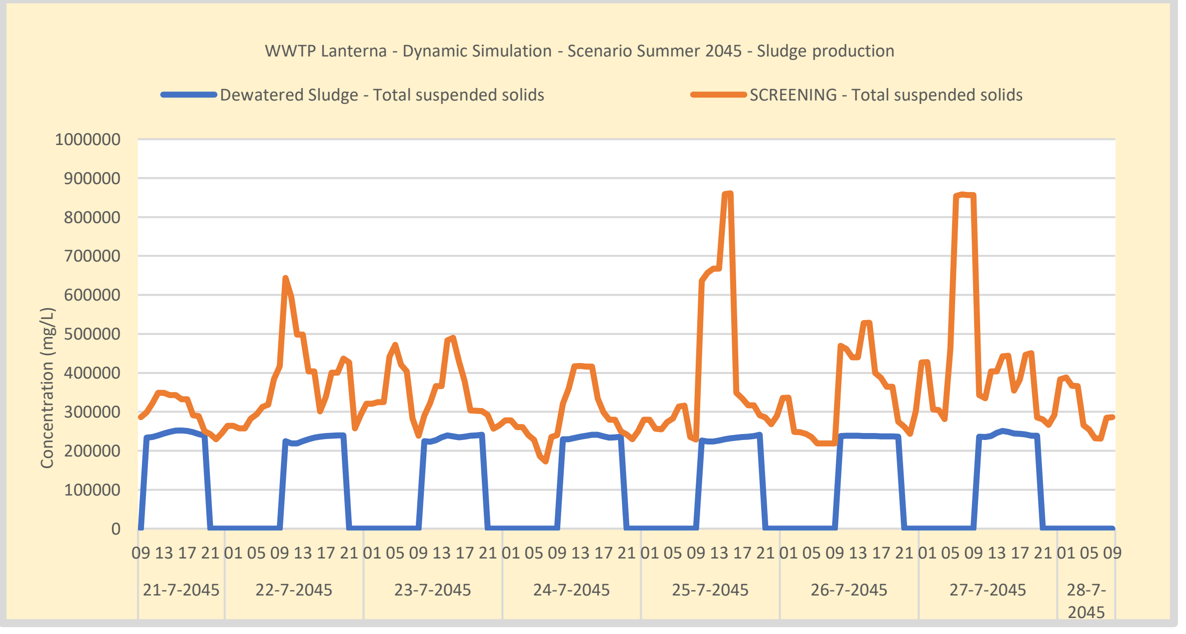


Figure 75. Simulation WWTP Lanterna - Scenario Summer 2045 - dewatered sludge and screening sludge concentration. The design assumes dewatered sludge at 23% dry matter. Screening is an estimated concentration as the result of the press operation.

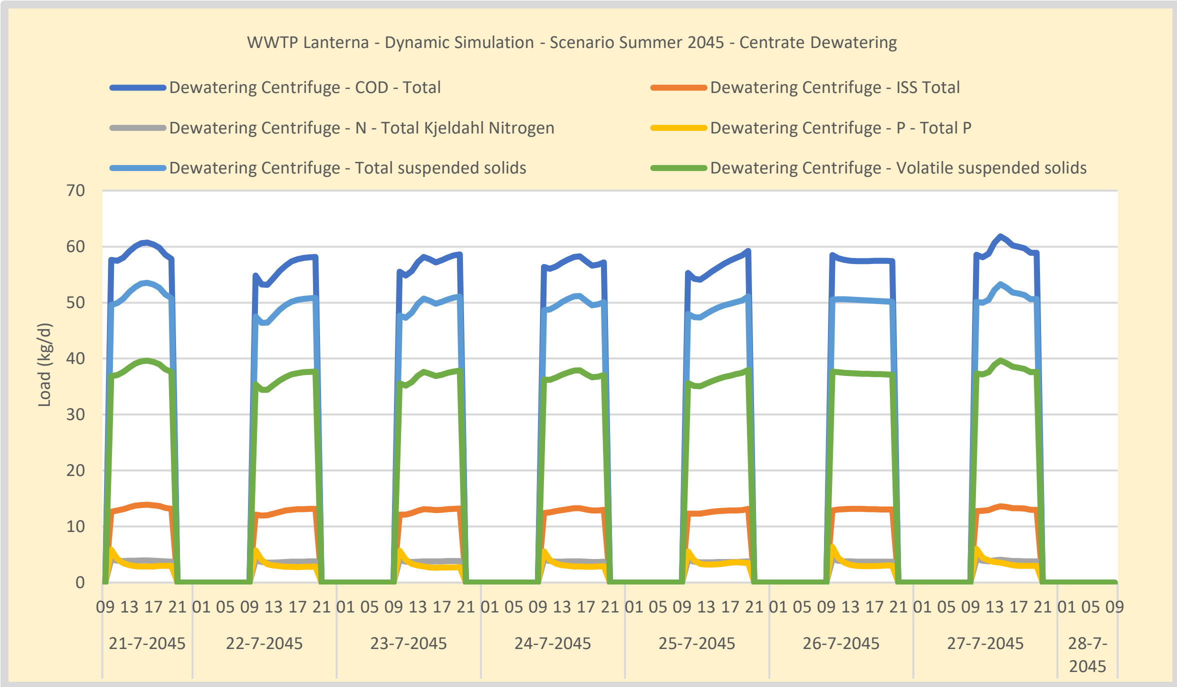


Figure 76. Simulation WWTP Lanterna - Scenario Summer 2045 - Centrate load dewatering.

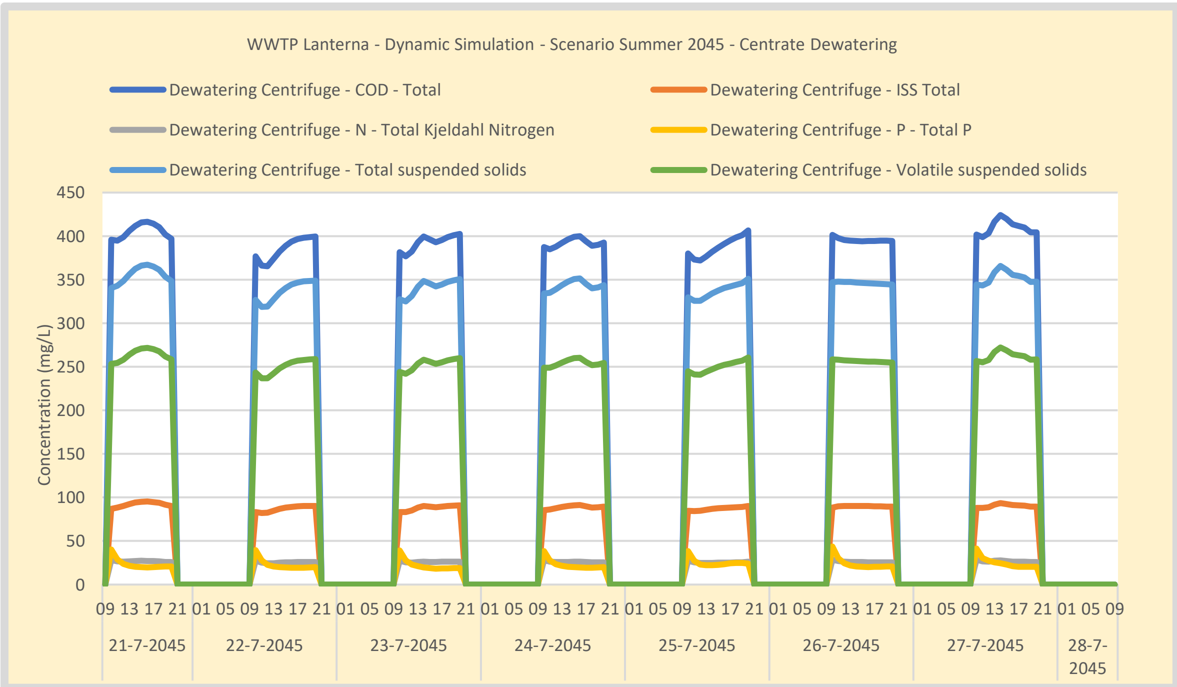


Figure 77. Simulation WWTP Lanterna - Scenario Summer 2045 - Centrate concentrations dewatering. Centrate is fed to the waterline. Phosphorus is maintained low by operating the WAS tank at low HRT.

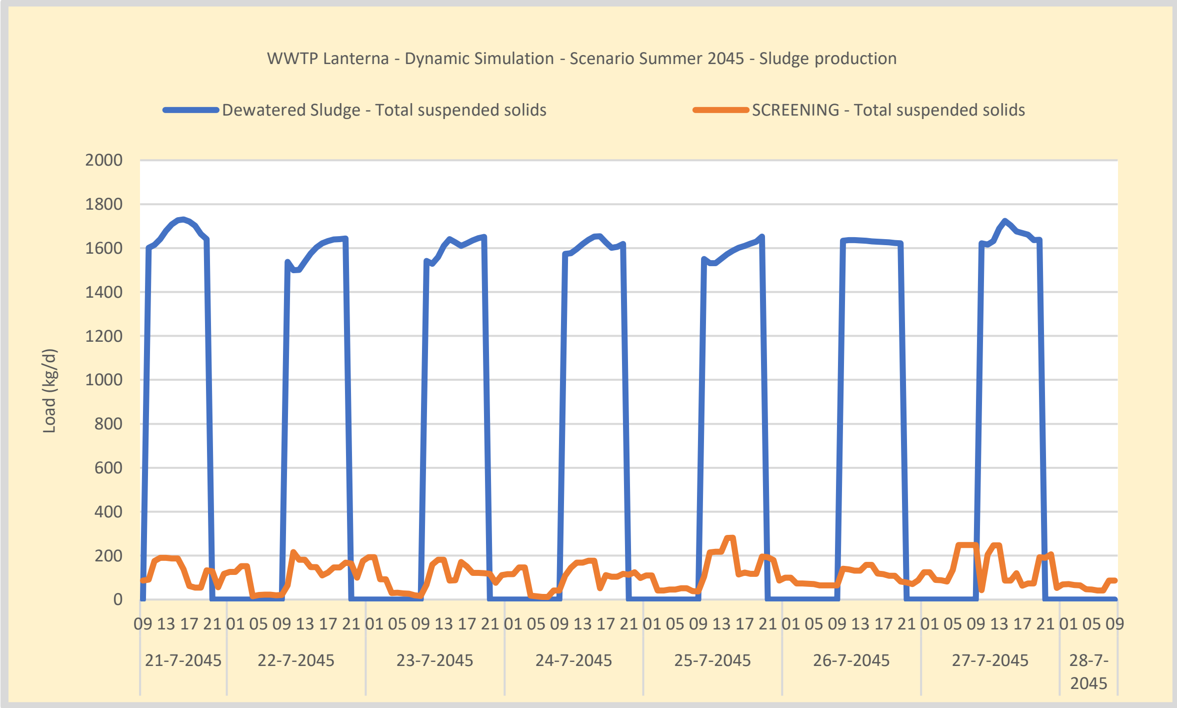


Figure 78. Simulation WWTP Lanterna - Scenario Summer 2045 - dewatered sludge load and compacted screening load. Dewatered sludge is operated 10 hours a day at 23%. Screening is produces continuously as a factor of the influent.

6.12 Effluent modelling results

In the figures below the dynamic effluent quality of the plant is presented under summer conditions. No rain events occurred however several peak loadings did take place affecting the simulation results. The measurement is coming from the effluent buffer and has a reduced dynamic profile.

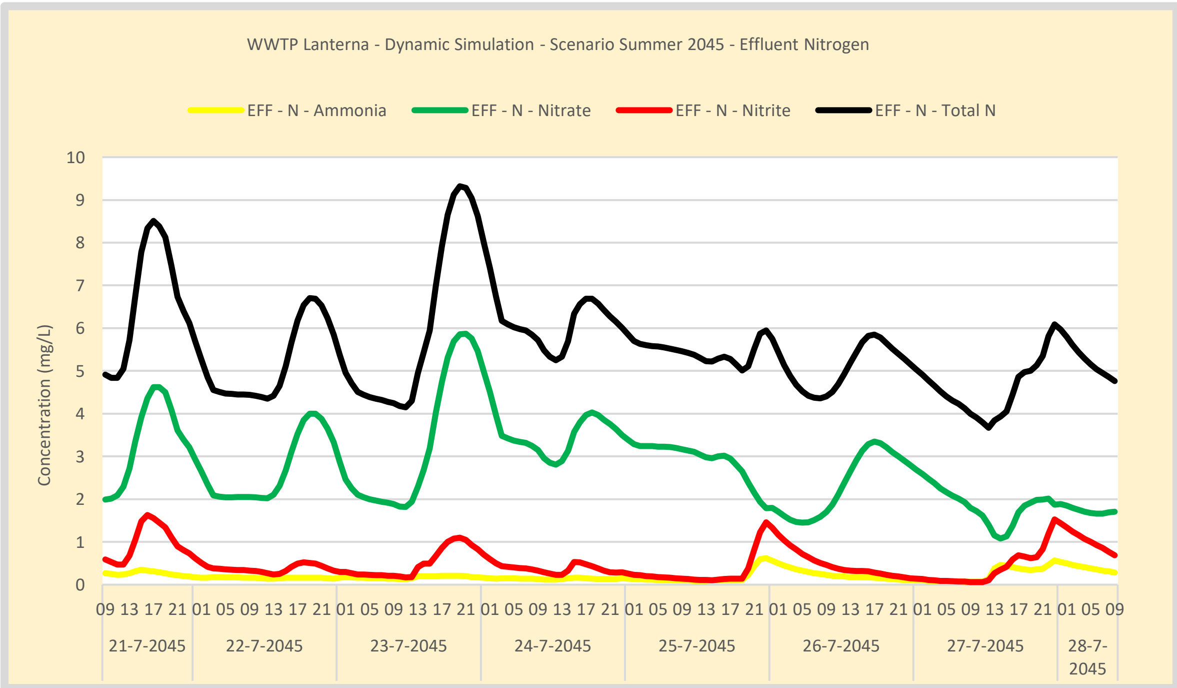


Figure 79. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent nitrogen concentration. Effluent is measured in the outflow of the large effluent buffer. Nitrite production is low and aeration capacity sufficient.

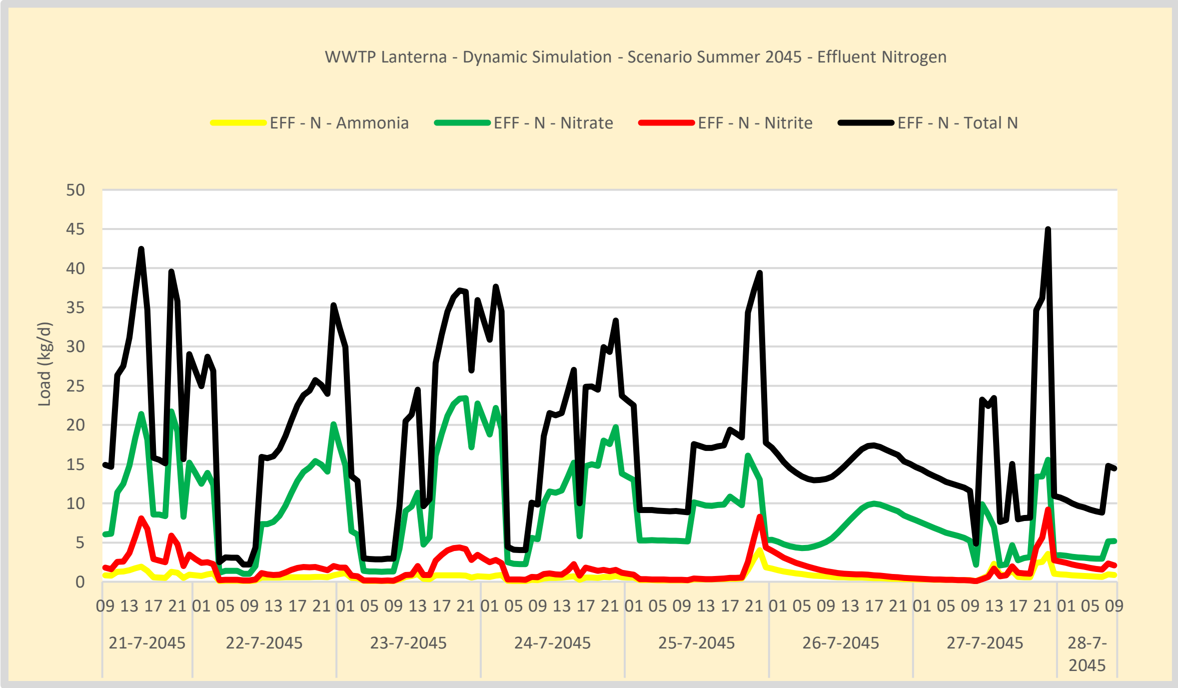


Figure 80. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent nitrogen load. Effluent is measured in the outflow of the large effluent buffer. Fluctuations are mainly the result of flow variation.

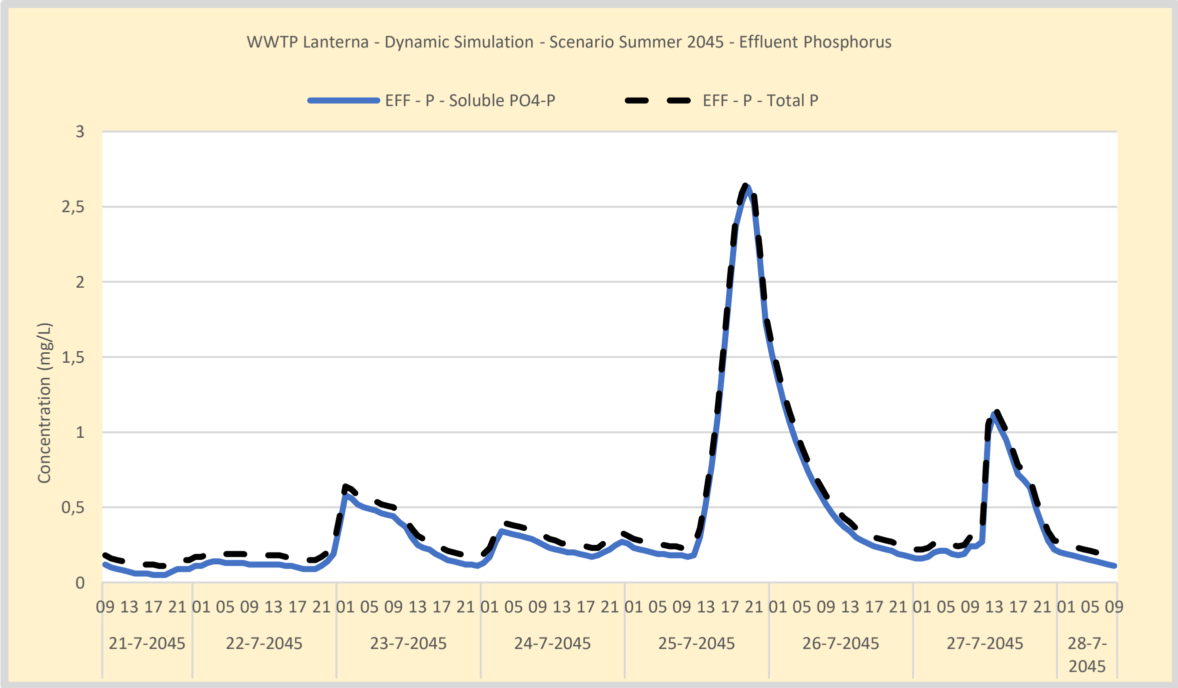


Figure 81. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent phosphorus concentration. No Iron is dosed. Effluent is measured in the outflow of the large effluent buffer. Effluent PO4 increases caused by shortage of oxygen and nitrate for Bio-P uptake.

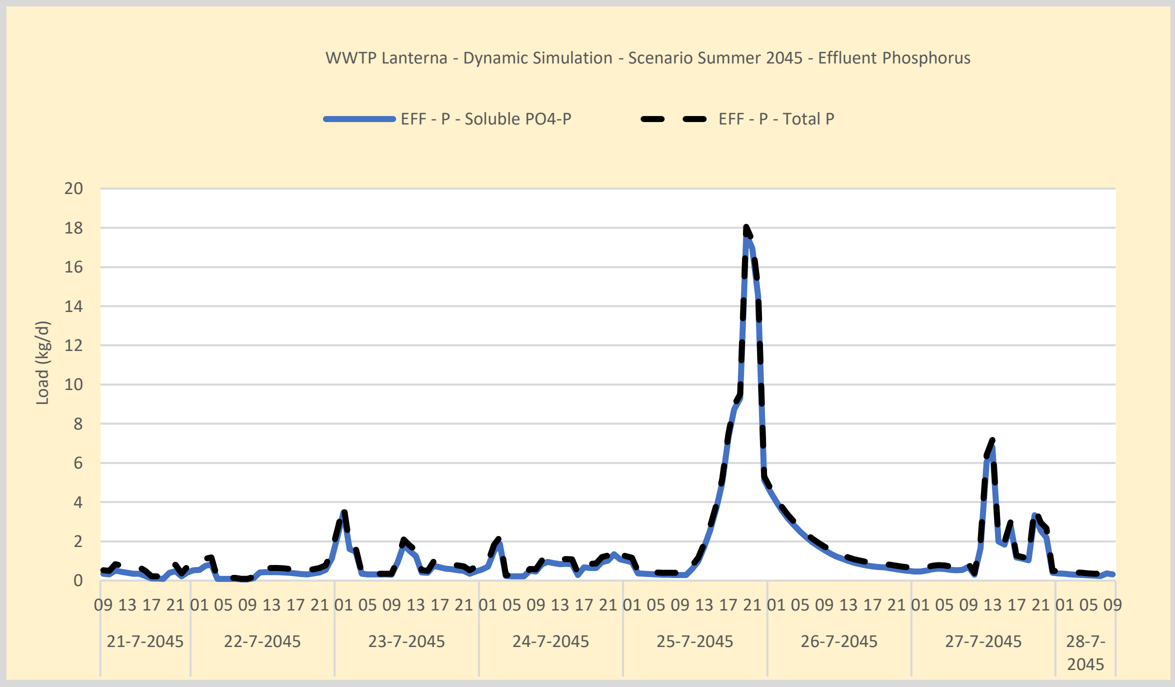


Figure 82. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent phosphorus load. No Iron is dosed. Effluent is measured in the outflow of the large effluent buffer. Effluent PO4 increases caused by shortage of oxygen and nitrate for Bio-P uptake.

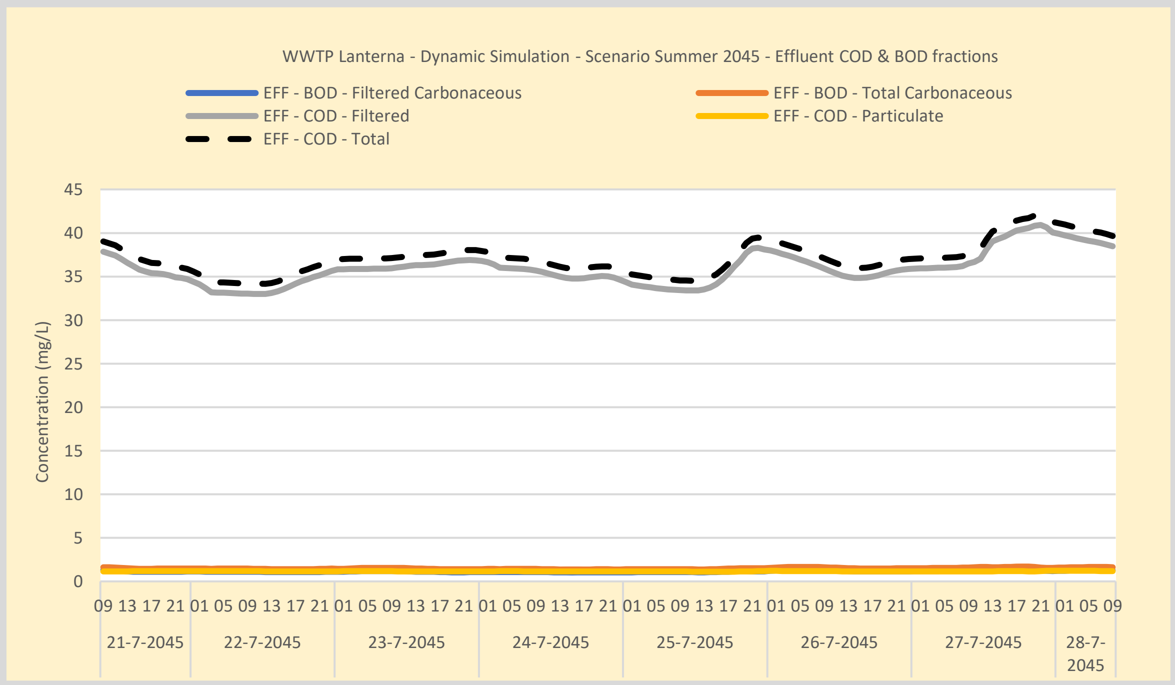


Figure 83. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent COD and BOD concentration. Effluent is measured in the outflow of the large effluent buffer. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Effluent is measured in the outflow of the large effluent buffer.

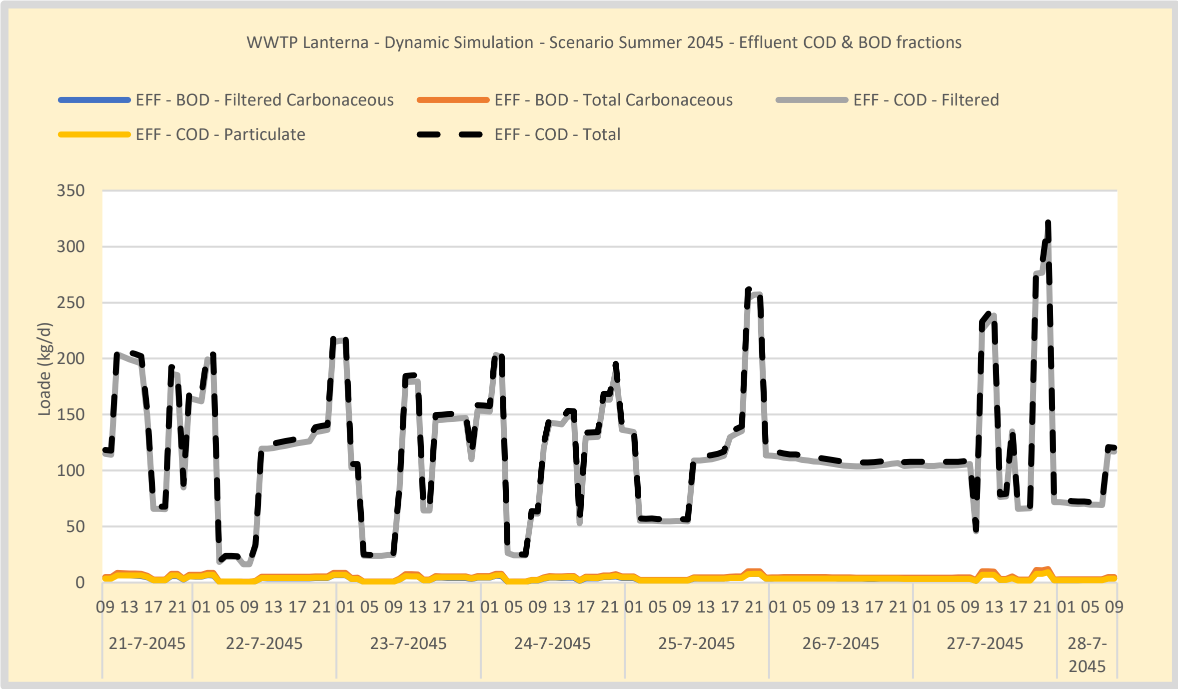


Figure 84. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent COD and BOD load. Effluent is measured in the outflow of the large effluent buffer. Variations in the load are largely the result of flow variations. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material.

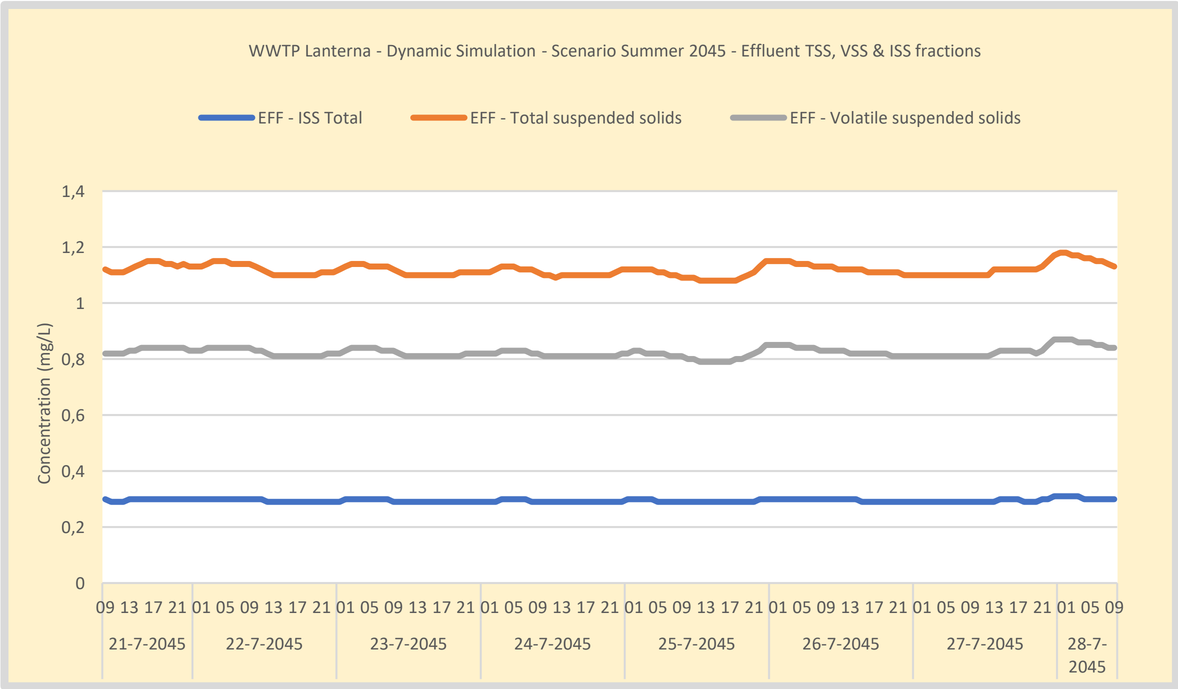


Figure 85. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent TSS, VSS and ISS concentration. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Load variations are mainly due to the flow. Effluent is measured in the outflow of the large effluent buffer reducing concentration variations.

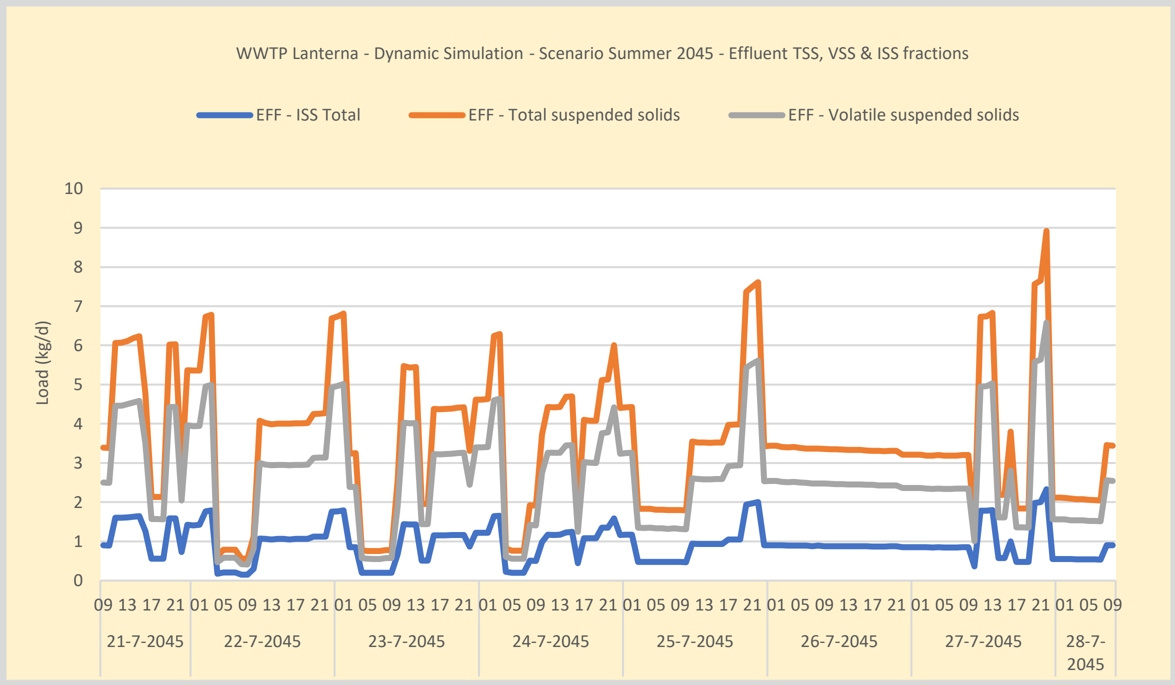


Figure 86. Simulation WWTP Lanterna - Scenario Summer 2045 - Effluent TSS, VSS and ISS load. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Load variations are mainly due to flow variations. Effluent VSS is related to the fecal load for sea water quality modelling.

6.13 Conclusion dynamic simulations summer period 2019

The WWTP operates according to the detailed design based on the influent loading extrapolated towards 2045. The effluent requirement for all parameters is within the required design limits. The model is simulated based on typical default settings and no biological parameter adjustments are required to obtain these results.

During summer the SRT of the plant is never limiting for nitrification. However during influent TKN peak loading the airflow of AT-B is limiting to reach the DO setpoint.

The anoxic recycle rate is limiting for the size of the anoxic tank. The optimal NO3 concentration of 2 mgNO3/L I the anoxic zone cannot be reached with the installed pump capacity. However, the anoxic tanks are large enough to obtain sufficient denitrification. It is advised to use maximum internal recycle rates, also during summer low loading conditions to ovoid anaerobic conditions in the anoxic tanks.

Phosphorus is removed from the wastewater by Bio-P and without dosage of iron. Effluent PO4 increases caused by shortage of oxygen and nitrate for Bio-P uptake.

The choice of operation largely determines the effluent results. A simple however realistic control strategy is modelled which shows to be effective controlling the system under both summer and winter conditions.

The large effluent buffer reduces effluent concentration fluctuations.

A trace of solids (0,01%) and colloidal material (0,1%) in the effluent is modelled to be used for sea water quality modeling. This fraction is related to the presence of fecal bacteria and viruses in the effluent.

Summer operation is compared to winter operation a classical type of operation within the typical range. Limiting factors during peak loading are the aeration capacity and aerobic SRT which are, according to the dynamic simulations, within the designed range.

The alkalinity of the wastewater potentially can become limiting as the result of low influent alkalinity and stripping of CO_2. Influent alkalinity is an estimated value in the model based on the local drinking water quality. During summer no shortage of alkalinity is simulated.

7 Conclusions and recommendations

7.1 General conclusions

- Model simulation shows that the effluent requirements can be met for both summer and winter loading conditions up to the year 2045.
- The model is simulated under dynamic conditions. Dynamic flow profiles are calculated representing summer and winter conditions in the year 2045. For realistic scenario modelling, 2019 measured dynamic flow data is extrapolated towards 2045. The 2045 winter and summer flow profiles are obtained by linear extrapolation based on an estimated growth of households and tourist economic activity. Growth numbers are adapted from the detailed design. Extrapolation of flow profiles is done on an hourly basis. It is thereby assumed that the wastewater concentration, frequency of peak discharges and rain events do not change towards 2045.
- Simulations indicate that the design is capable of treating wastewater to the desired effluent level and that there is sufficient operational flexibility to cope with different seasonal loading conditions.
- The effluent requirement can be met under all modelled conditions including winter rain events and summer and winter peak loading.
- Simulations show that effluent results strongly depend on the method of operation and control. This study shows that the plant can be controlled effectively using simple however realistic process controls.
- During summer, the WWTP removes phosphorus biologically, based on the Bio-P process. During the winter, a limited amount of Iron may be dosed for chemical P-removal. Effluent PO_4 increases may be caused by shortage of oxygen and nitrate for Bio-P uptake.
- Winter operation meets the design requirements however, operation is not typical in respect to a high SRT, long anaerobic and anoxic HRT, high internal recycle rates proportional to the influent and high DO in the activated sludge system.
- Points of attention for (winter) operation are:
    - Long hydraulic and sludge residence times.
    - Over aeration and CO_2 stripping in the MBR, possible drop in alkalinity and potentially pH limitation.
    - Too little flow recycle capacity resulting in long anaerobic residence time, anaerobic biomass decay and reduction of nitrification and Bio-P capacity.
    - P-release in the WAS storage tank with operational HRT > 2-3 hours.
    - Too little WAS sludge production (long SRT) to meet the Bio-P requirement.
- Summer operation is a classical type of operation within typical operational range. Dynamic simulations indicate that under summer peak loading the aeration capacity

and aerobic SRT can become limiting. On average however, all is within the designed range.

7.2 Main recommendation

It is recommended to proceed with further development of the scenario analysis and sea water modelling taking in account the presented conclusions.