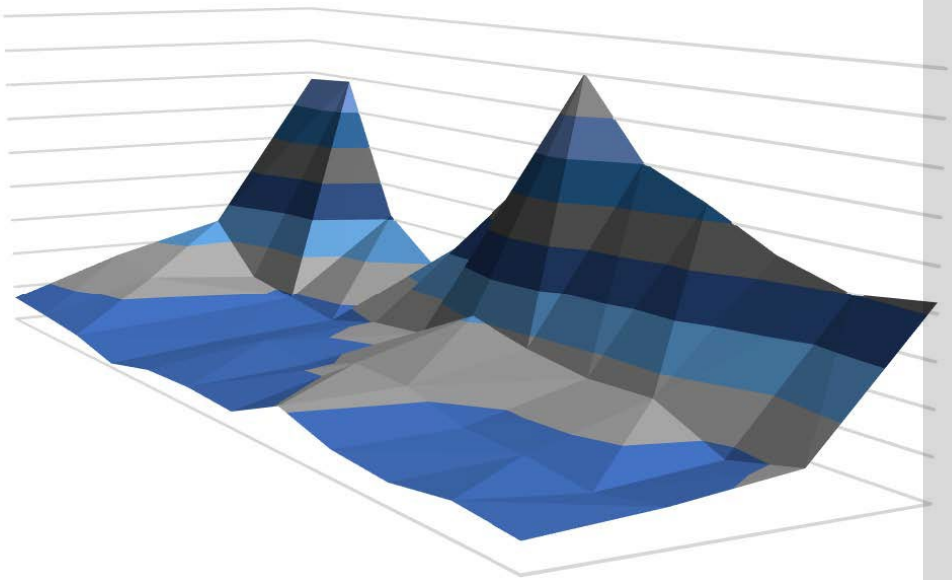
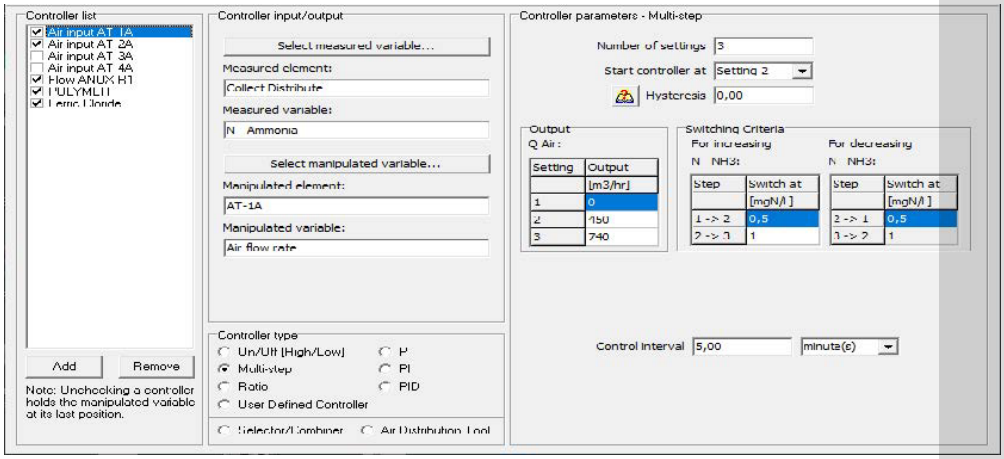
Zajednica izvršitelja

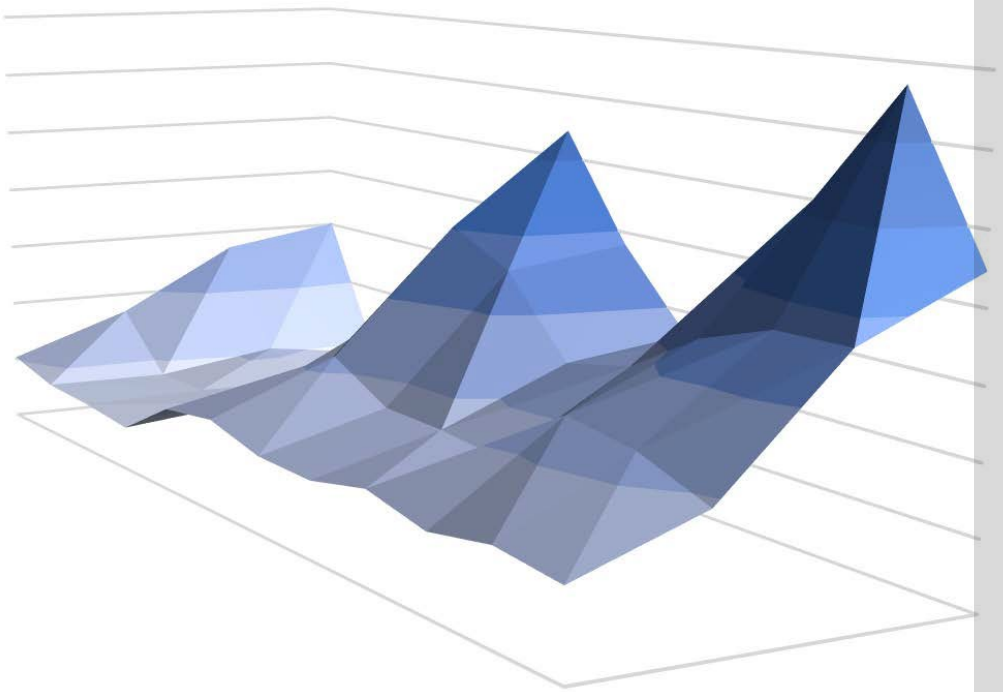
Naručitelj

Krajnji korisnik

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 7b Modeliranje UPOV-a – Analiza scenarija :UPOV Poreč Sjever

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**

IZVJEŠĆE 7 dio 2/ 4

MODELIRANJE UPOVa:

ANALIZA SCENARIJA - UPOV POREC SJEVER

Studeni 2021

Zajednica izvršitelja

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IZVJEŠĆE 7 dio 2/ 4

MODELIRANJE UPOVa:

ANALIZA SCENARIJA - UPOV POREC SJEVER

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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 prečišćavanje 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. Zahtjevi efluenta po svim parametrima su unutar postavljenih projektnih granica.

• Model je simuliran u dinamičkim uvjetima. Dinamički profili protoka su izračunati predstavljajući 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 SUEZ-a. 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.

• Zahtjevi na efluent mogu se zadovoljiti u svim modeliranim uvjetima uključujući zimske kišne događaje te ljetno i zimsko vršno opterećenje.

• 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, PPOV uklanja fosfor biološki, na temelju Bio-P postupak. Tijekom zime, željezo se može dozirati za kemijsko uklanjanje P, posebno tijekom kiše.

• Tijekom ljeta kapacitet prozračivanja može postati ograničen u uvjetima vršnog opterećenja

što rezultira proizvodnjom nitrita. U prosjeku je amonij potpuno oksidiran.

• Međutim, alkalnost nije ograničavajuća, može pasti pod određenim uvjetima rada, na primjer preko prozračivanja tijekom zimskih uvjeta niskog opterećenja.

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

• Točke pažnje za (zimski) rad su:

  o mogući pad alkalnosti i potencijalno ograničenje pH vrijednosti zbog prekomjernog prozračivanja zimi.

  o Premali kapacitet recikliranja protoka što rezultira predugim anaerobnim HTR i propadanjem kapaciteta nitrifikacije.

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

  o Previše kisika i nitrata da bi zadovoljili zahtjeve Bio-P.

• Trag krutih tvari (0,01%) i koloidnog materijala (0,1%) u efluentu modeliran je za korištenje za modeliranje kvalitete morske vode. Ova frakcija je povezana s prisutnošću fekalnih bakterija i virusa u efluentu.

• Veliki spremnik za otpadne vode smanjuje fluktuacije efluenta.

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

WWTP Poreč-North

2021 08 15

Definitive Concept

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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 Poreč-North based on 2019 influent flow and concentration measurements projected towards the year 2045.
Working Title	:	Report 7.2 – WWTP Poreč-North – 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.
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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 effluent requirement for all parameters is within the required design limits. In the winter the capacity of the plant is however at its maximum limit for Bio-P and nitrification.
- The model is simulated based on typical default settings and no biological parameter adjustments are required to obtain these results.
- The model is simulated under dynamic conditions. For realistic scenario modelling, 2019 measured dynamic flow data is extrapolated towards loading conditions expected in the year 2045.
- Based on the 2019 dynamic flow profile on an hourly basis the flow is extrapolated towards 2045 by adding the estimated growth of households and tourist activity. This is adapted from the detailed design. It is assumed that the wastewater concentration, frequency of peak discharges and rain events do not change towards 2045.
- Simulations show that the design can treat wastewater to the desired level and that there is sufficient operational flexibility to cope with seasonal and peak loading conditions.
- Winter and summer operation are similar in respect to the operated SRT, and no lines are taken out of operation during the winter.
- 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.
- In the summer alkalinity is not likely to become limiting. In the winter over-aeration may result in a drop of alkalinity and pH limitation. Influent alkalinity is an estimated value in the model based on the local drinking water quality.
- During the winter the plant may require dosage of Iron to remove phosphate chemically, especially with rain conditions. During summer, TKN peak loading may result in temporary low oxygen and nitrate in the tanks which can result in increased effluent PO4.
- The anoxic recycle flow is limiting for the size of the anoxic tank resulting in anoxic tanks becoming anaerobic for large part of the operation. It is advised to use the maximum internal recycle flow the whole year round to reduce the effect of too long anaerobic HRT thereby reducing the effect of decay of nitrification.
- In summer, during daily TKN peak loadings, nitrification is limiting resulting in accumulation of ammonium and nitrite (NO2).
- During summer aeration capacity may become limiting under peak loading conditions resulting in the production of nitrite. In average ammonium is fully oxidized.

- 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:
    - possible drop in alkalinity and potentially pH limitation due to over-aeration in the winter.
    - Too little flow recycle capacity resulting in too long anaerobic HTR and decay of nitrification capacity.
    - P-release in the WAS storage tank with operational HRT > 2-3 hours.
    - Too oxygen and nitrate to meet the Bio-P requirement.
- 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.
- The large effluent buffer reduces effluent fluctuations.

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.

2.1 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.

3 Dynamic modelling of WWTP Poreč-North

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 quality 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.

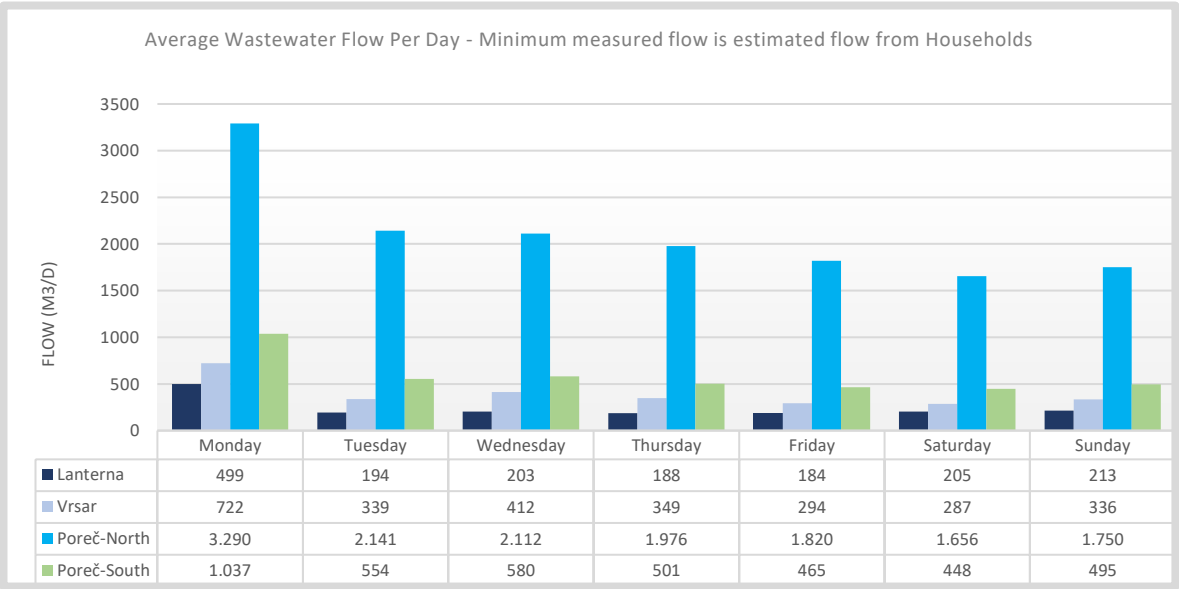
- It is assumed that during the summer the MBR is fully aerated, and the airflow is not controlled. During the winter, the total aerated volume can become too high, resulting in stripping of CO2 and drop in alkalinity and possibly pH. Therefore during winter, parallel MBR reactors may be taken out of operation, or limited in the aeration by setting a maximum DO to 6 mgO2/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 Poreč-North – Wastewater Flow prognosis.

WWTP Poreč-North - Data for Poreč-North WWTP sizing				
	Population (PE)	Tourist Overnights Average	Households	Non-Households
Months	2011	2009-2011	2009-2011 (m3/month)	2009-2011 (m3/month)2
1	15590	600	54700	11900
2	15590	0	50600	12600
3	15590	2600	49100	13500
4	15590	33000	60600	25800
5	15590	88000	82700	42600
6	15590	168900	94800	58700
7	15590	256300	120500	78400
8	15590	278200	136000	82700
9	15590	157100	111500	67400
10	15590	17200	60300	30900
11	15590	0	50700	13200
12	15590	2000	43400	9400
Estimated growth of tourist overnights from 2011 to 2045				0,15
Permanent population 2045				18973

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

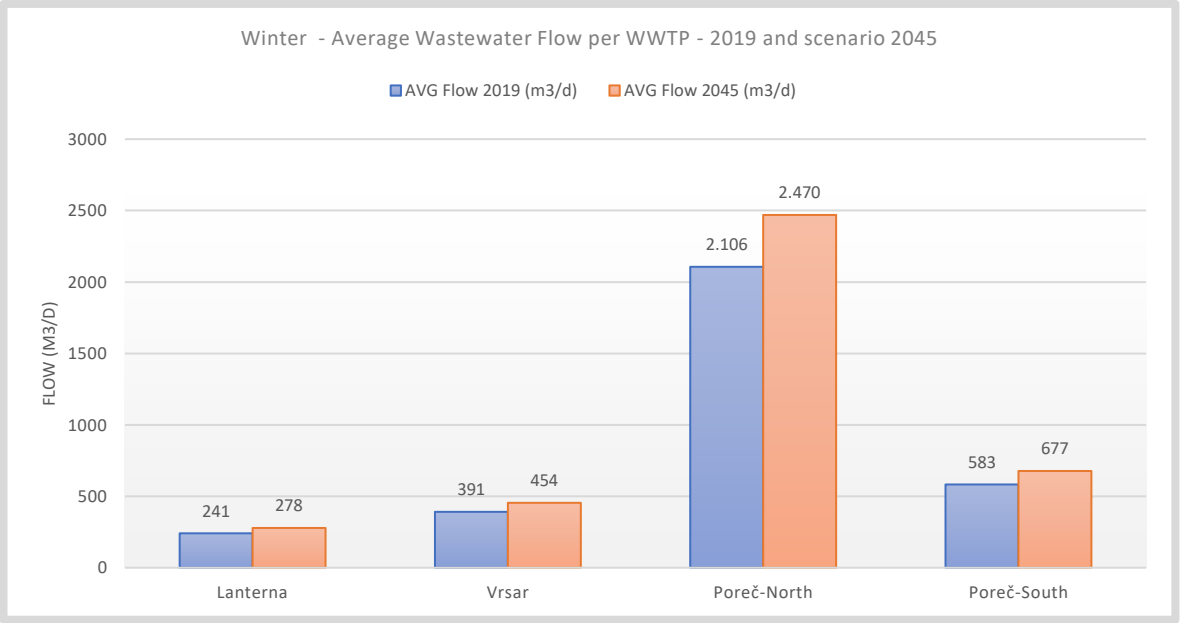


Figure 2. Winter – Average Wastewater Flow per WWTP – 2019 and scenario 2045. Average of measured 2019 dynamic influent flow data extrapolated towards 2045. The flow difference is the combination of growth of households by approximately 21% per community and assumed 15% growth of touristic activity during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

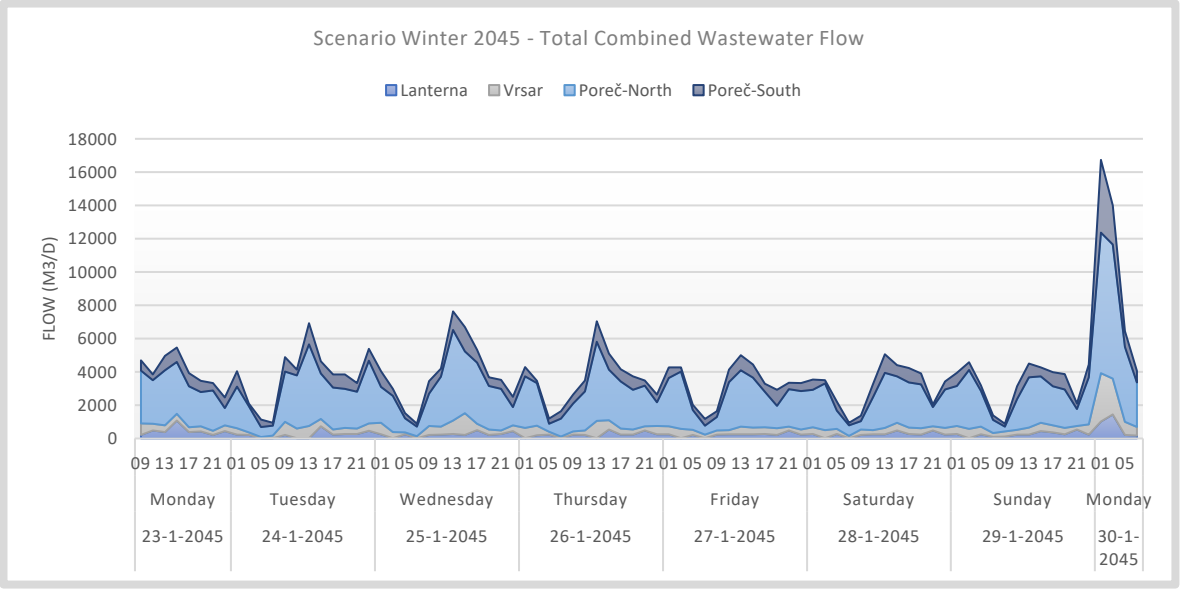


Figure 3. Scenario Winter 2045 – Total Combined Wastewater Flow of all WWTP's. The 2045 prognosis includes the same rain event measured in 2019. The 2019 and 2045 flow dynamics are largely identical however, the 2045 flow is larger resulting from increasing households and touristic activity.

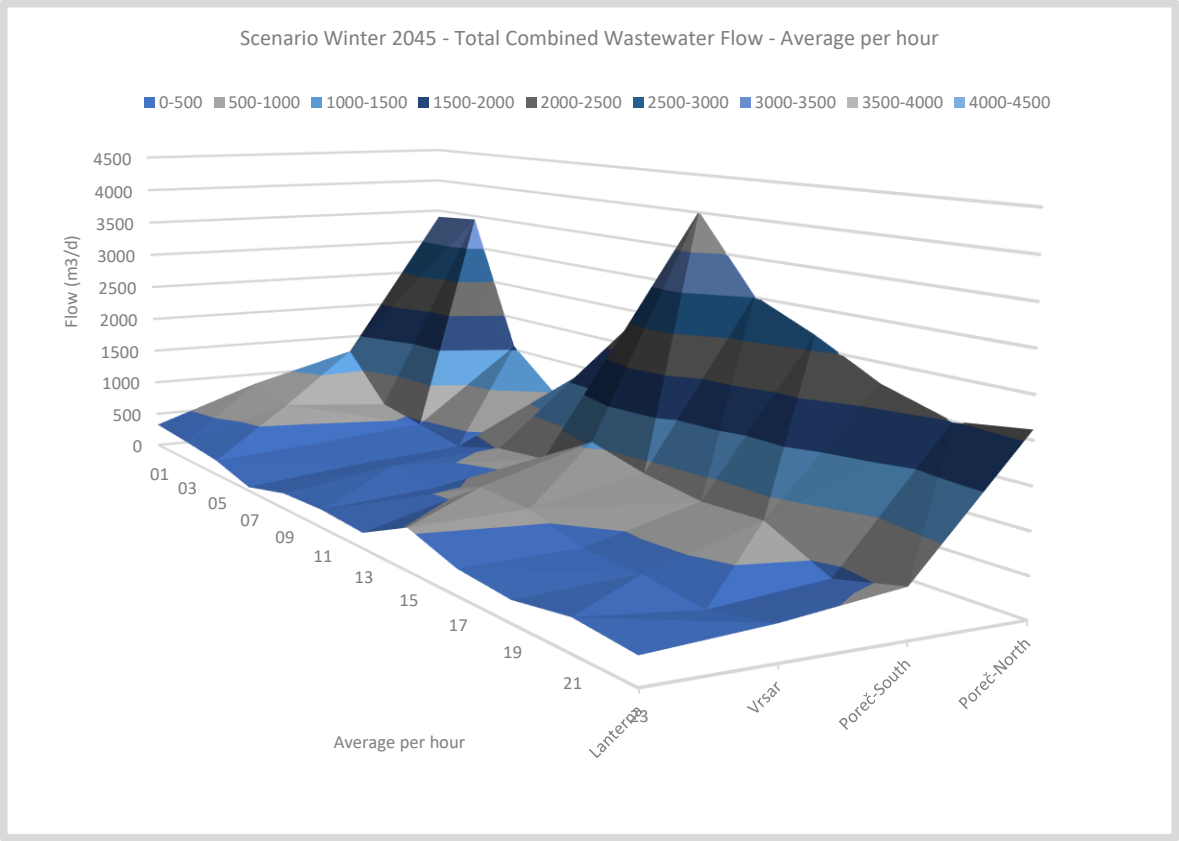
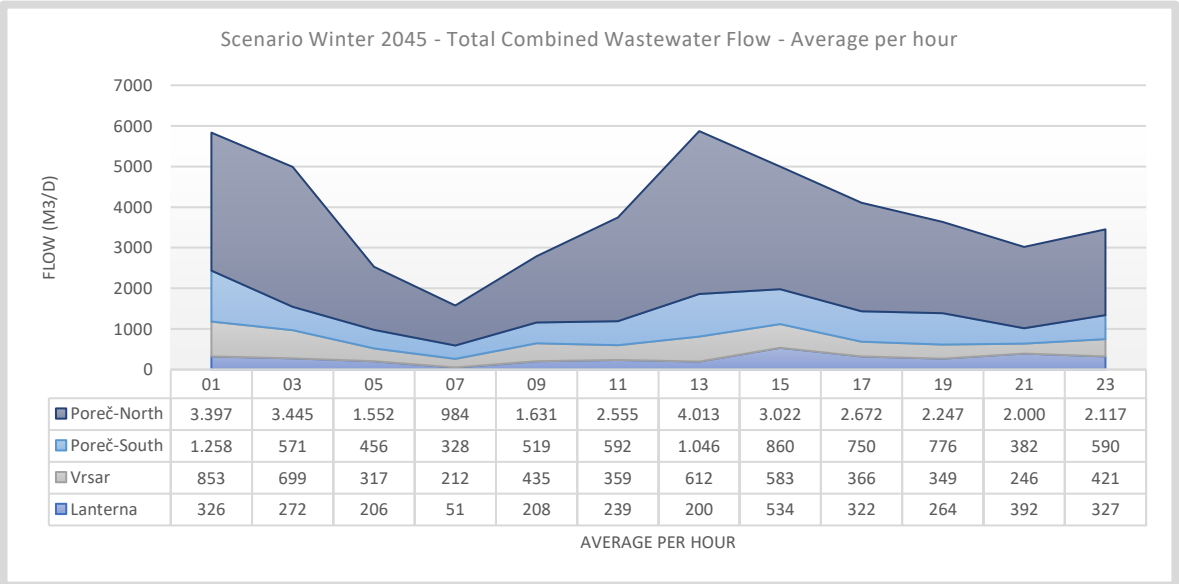
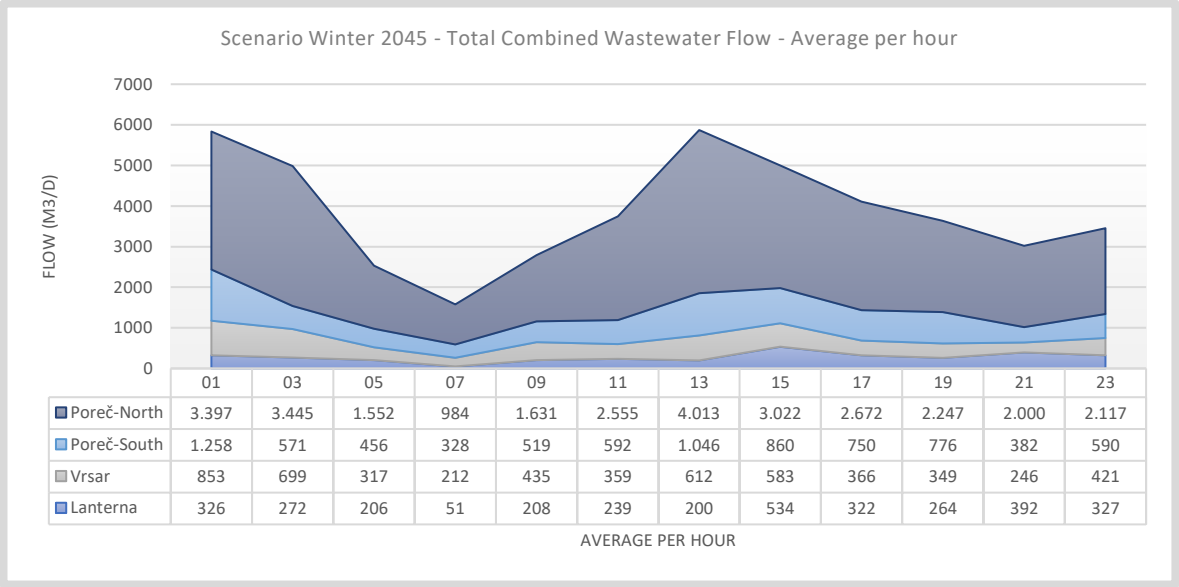


Figure 4. Scenario Winter 2045 – Surface plot Dry weather Total Combined Wastewater Flow 24-hour average hourly measurements. The data excludes the rain event at day 7. The plot order is from lowest to highest wastewater producing community.



	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.

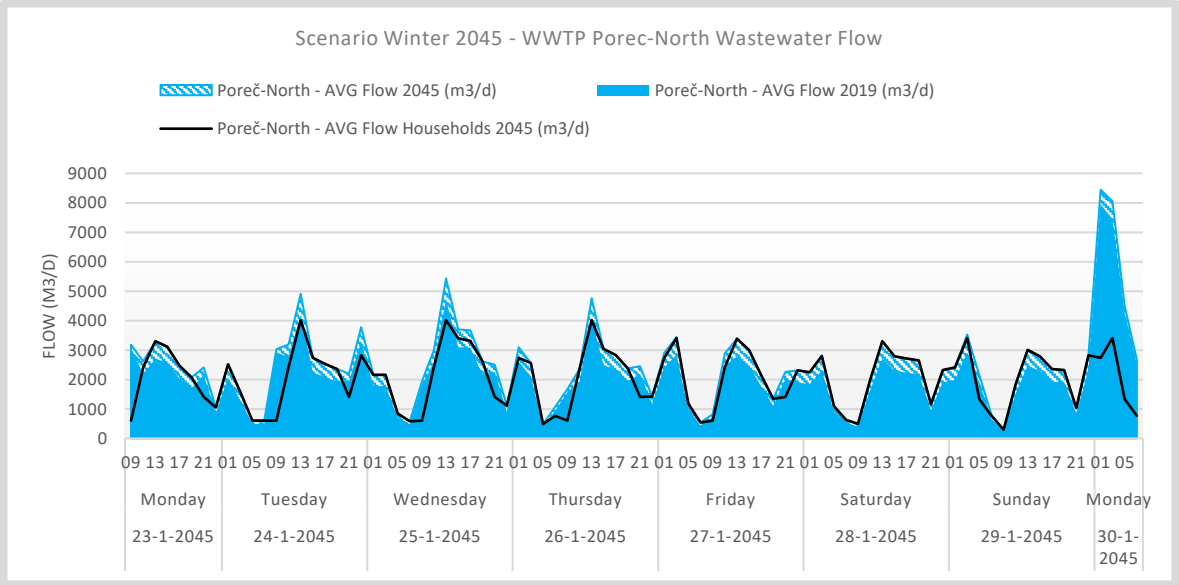
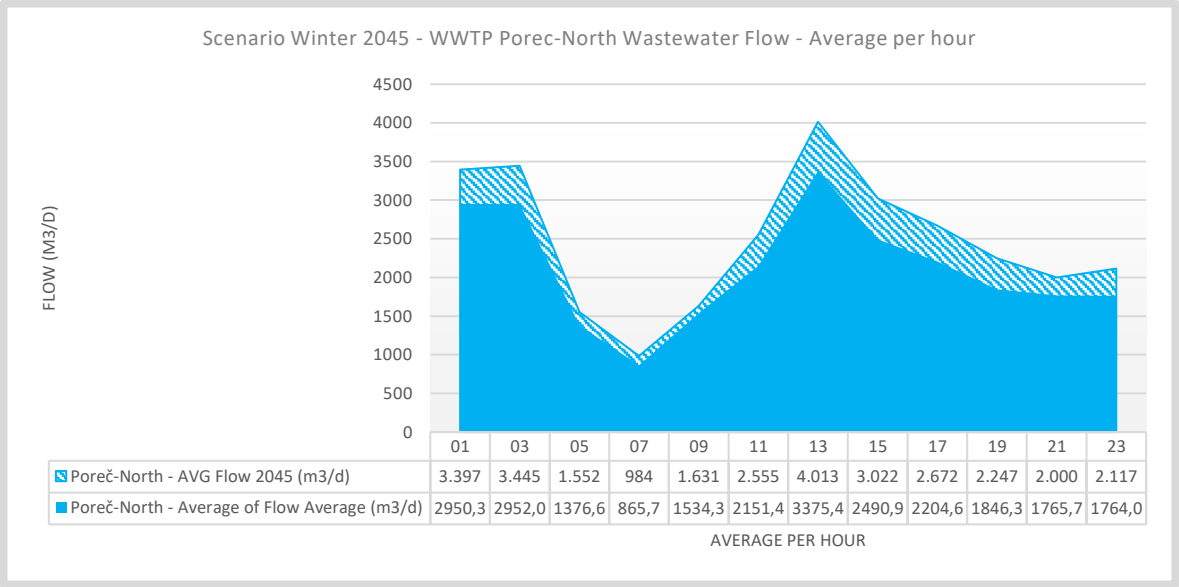


Figure 7. Scenario Winter 2045 – WWTP Poreč-North Wastewater Flow 24-hour 7-day dynamic 2019 measurements and 2045 prognosis. Both the 2019 and 2045 flow data are modelled and included in the scenario study. The 2045 data includes the growth of households and touristic activity.



	01	03	05	07	09	11	13	15	17	19	21	23
Poreč-North - AVG Flow 2045 (m3/d)	3.397	3.445	1.552	984	1.631	2.555	4.013	3.022	2.672	2.247	2.000	2.117
Poreč-North - Average of Flow Average (m3/d)	2950,3	2952,0	1376,6	865,7	1534,3	2151,4	3375,4	2490,9	2204,6	1846,3	1765,7	1764,0

Figure 8. Scenario Winter 2045 – WWTP Poreč-North 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.

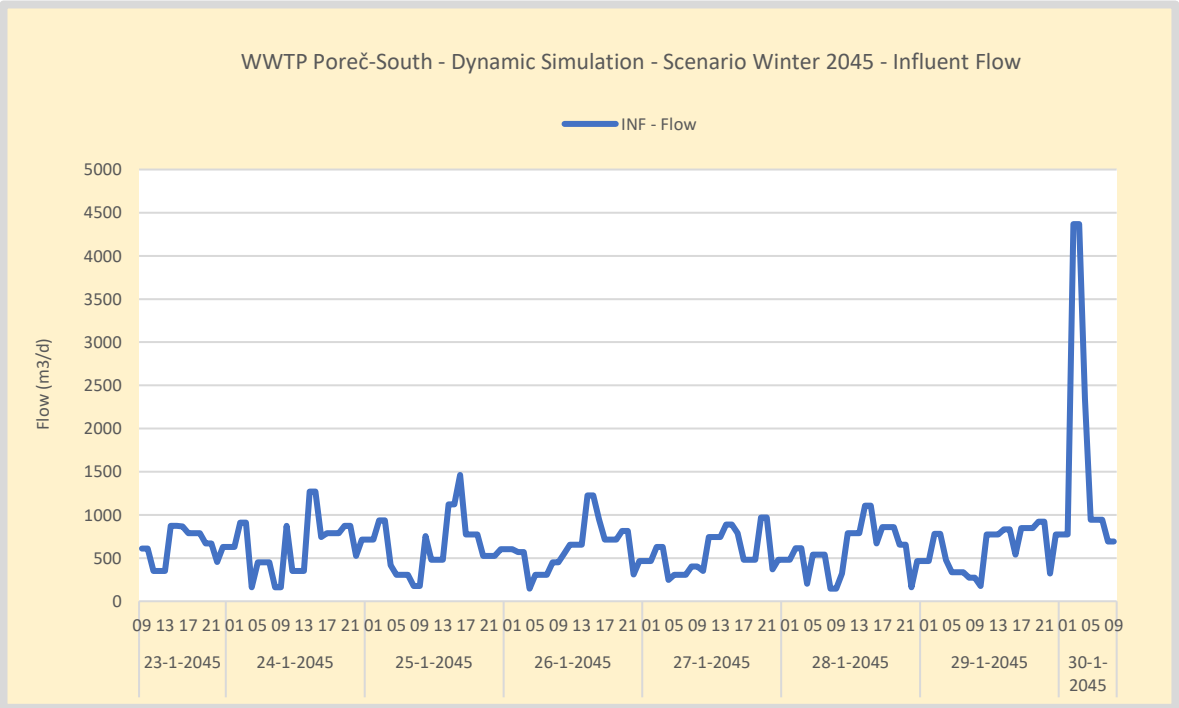


Figure 9. Scenario Winter 2045 – BioWin modelling WWTP Poreč-North: Wastewater Influent Flow 24-hour 7-day dynamic model input data. Some datapoint are reconstructed form 24-hour average hourly measurements. The data is interpolated in the model from measurements every 2 hours to an hourly basis. The 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

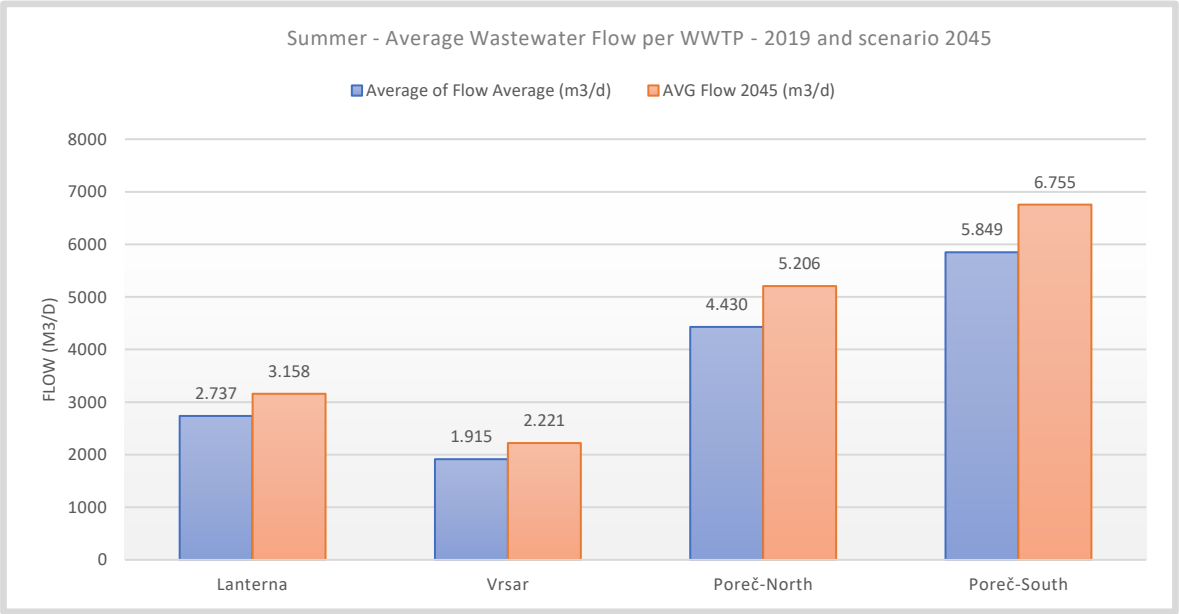


Figure 10. Summer - Average Wastewater Flow per WWTP – 2019 and scenario 2045. Average of measured 2019 dynamic influent flow data extrapolated towards 2045.

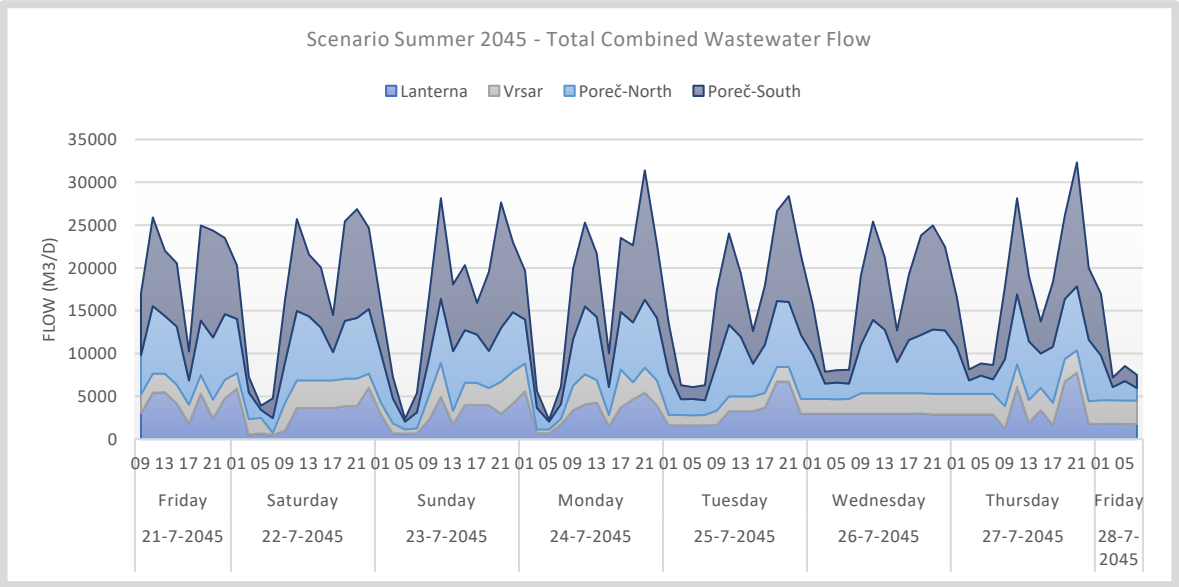
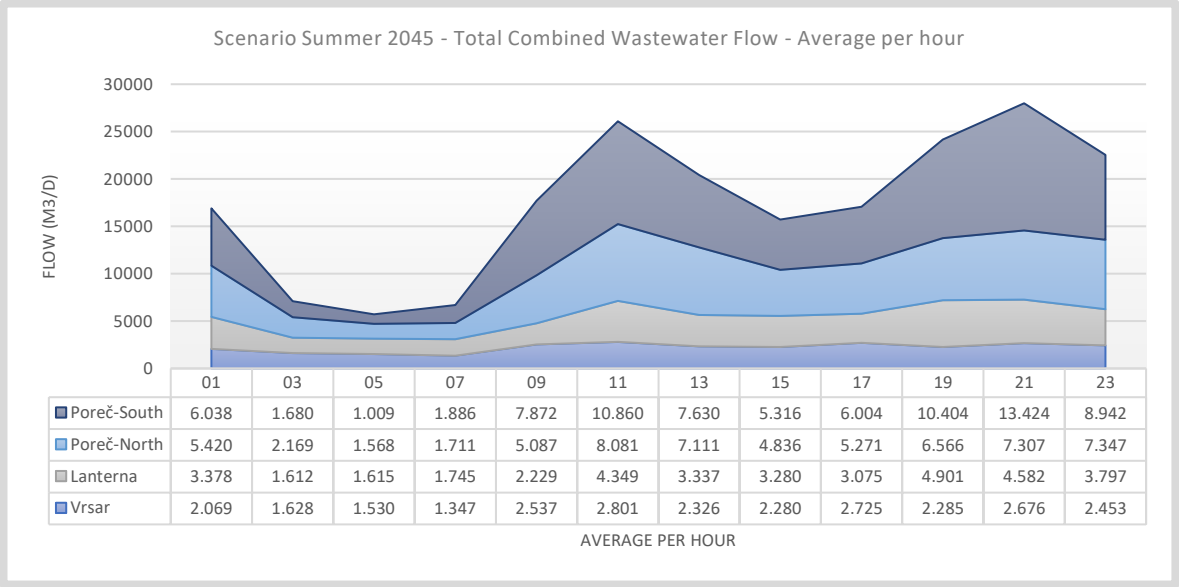


Figure 11. Scenario Summer 2045 – Total Combined Wastewater Flow 24-hour 7-day dynamic measurements. No rain event occurred during the measurement period.



	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.

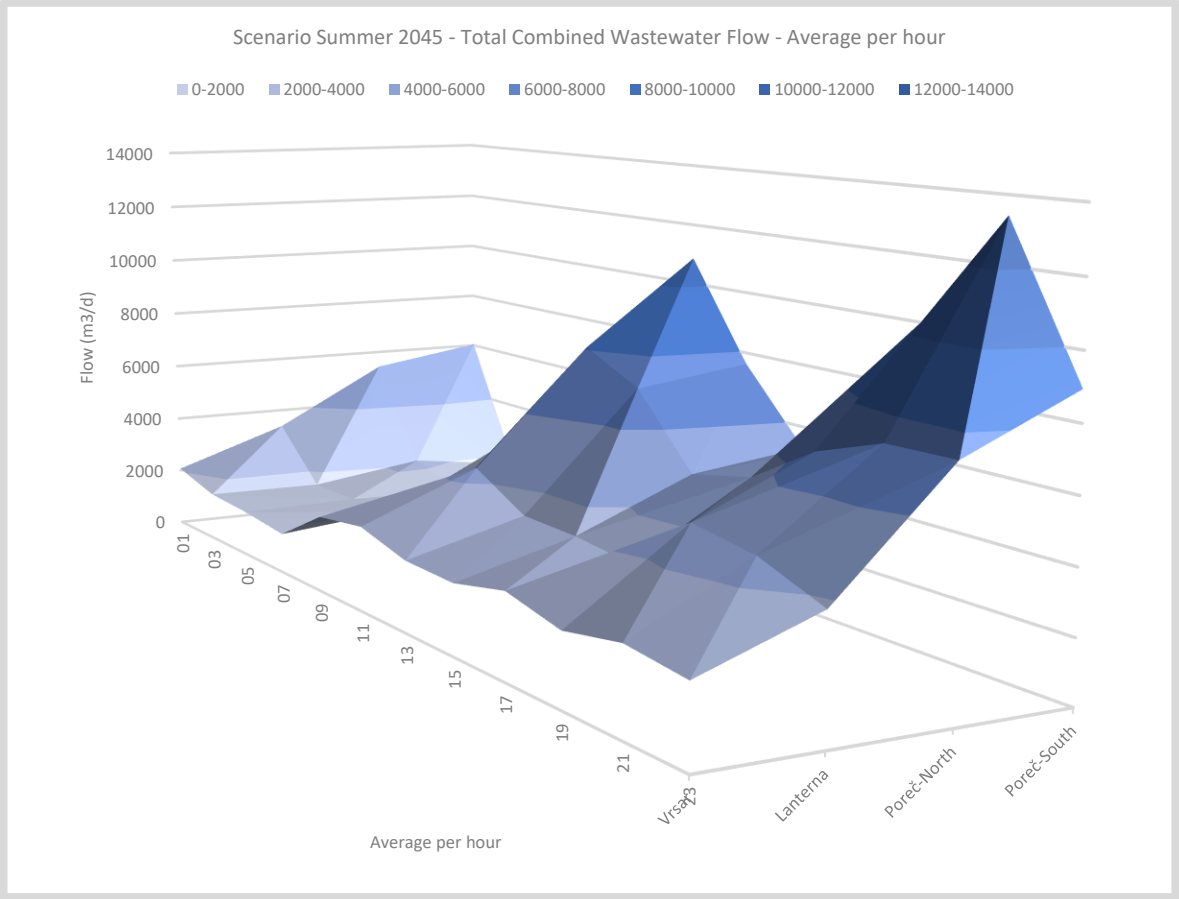


Figure 13. Scenario Summer 2045 – Surface plot Total Combined Wastewater Flow 24-hour average hourly measurements. No rain event occurred during the measurements. The plot order is from lowest to highest wastewater producing community.

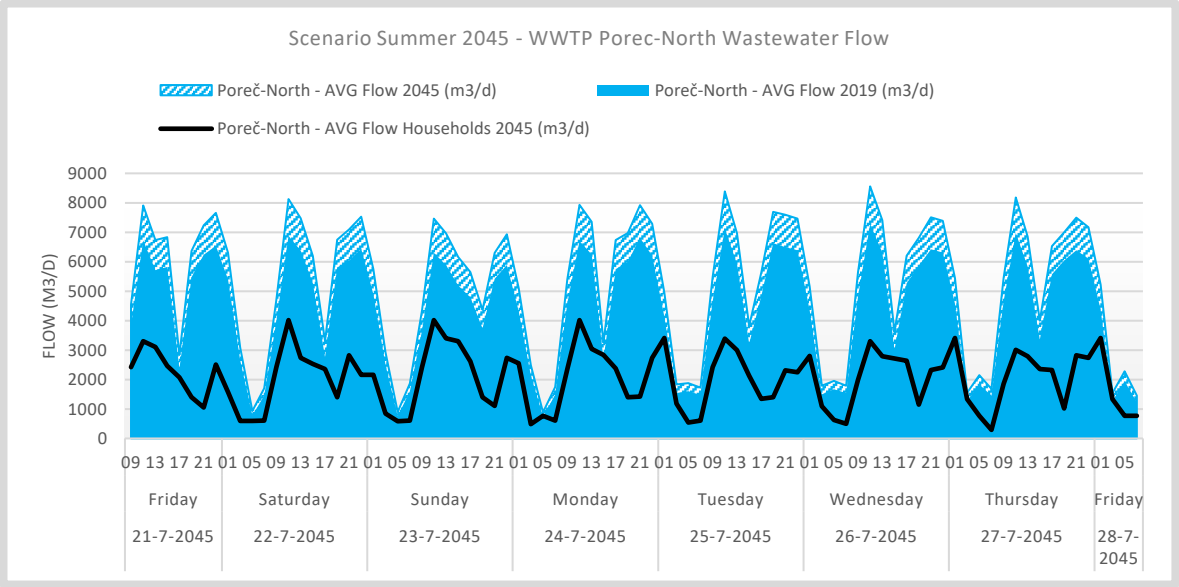
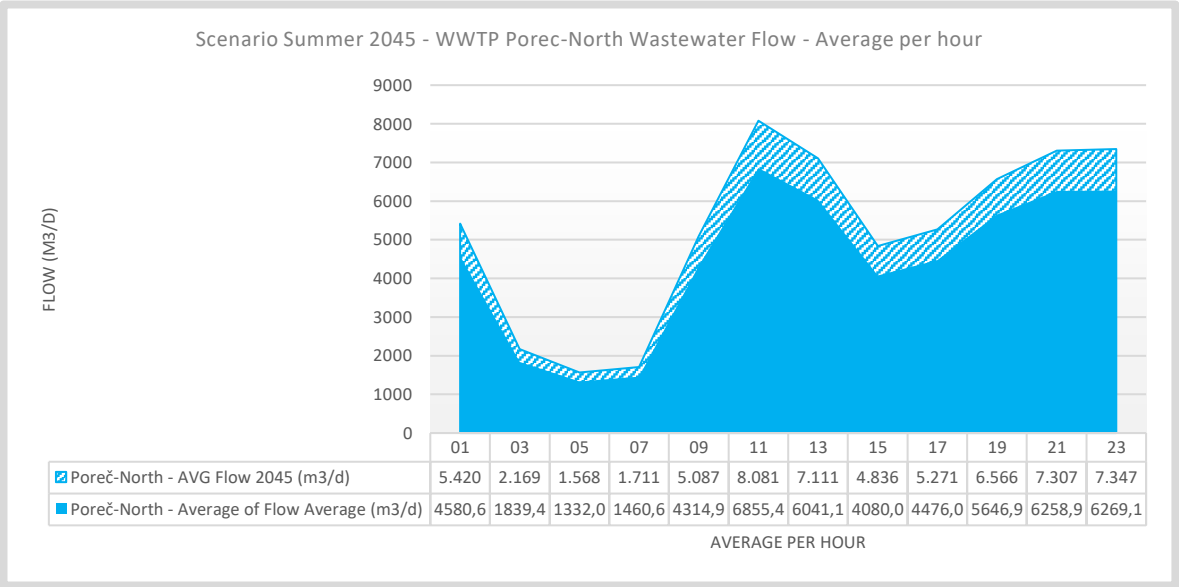


Figure 14. Scenario Summer 2045 – WWTP Poreč-North Wastewater Flow 24-hour 7-day dynamic 2019 measurements and 2045 prognosis. Both the 2019 and 2045 flow data are used for dynamic modelling. The 2045 data includes the growth of households and touristic activity.



	01	03	05	07	09	11	13	15	17	19	21	23
Poreč-North - AVG Flow 2045 (m3/d)	5.420	2.169	1.568	1.711	5.087	8.081	7.111	4.836	5.271	6.566	7.307	7.347
Poreč-North - Average of Flow Average (m3/d)	4580,6	1839,4	1332,0	1460,6	4314,9	6855,4	6041,1	4080,0	4476,0	5646,9	6258,9	6269,1

Figure 15. Scenario Summer 2045 – WWTP Poreč-North 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.

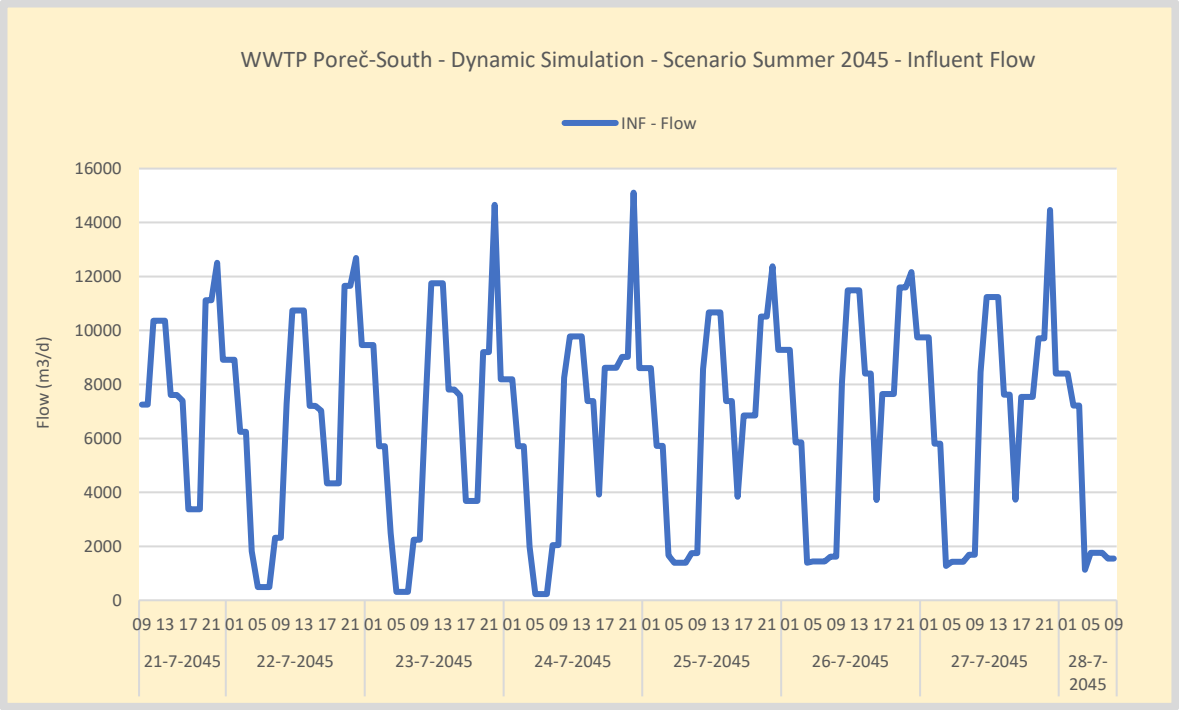


Figure 16. Scenario Summer 2045 – BioWin modelling WWTP Poreč-North: Wastewater Flow 24-hour 7-day dynamic model input data. In the model 2 hourly measurements are interpolated to an hourly basis. The flow dynamics are adapted from the 2019 measurements extrapolated towards 2045.

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

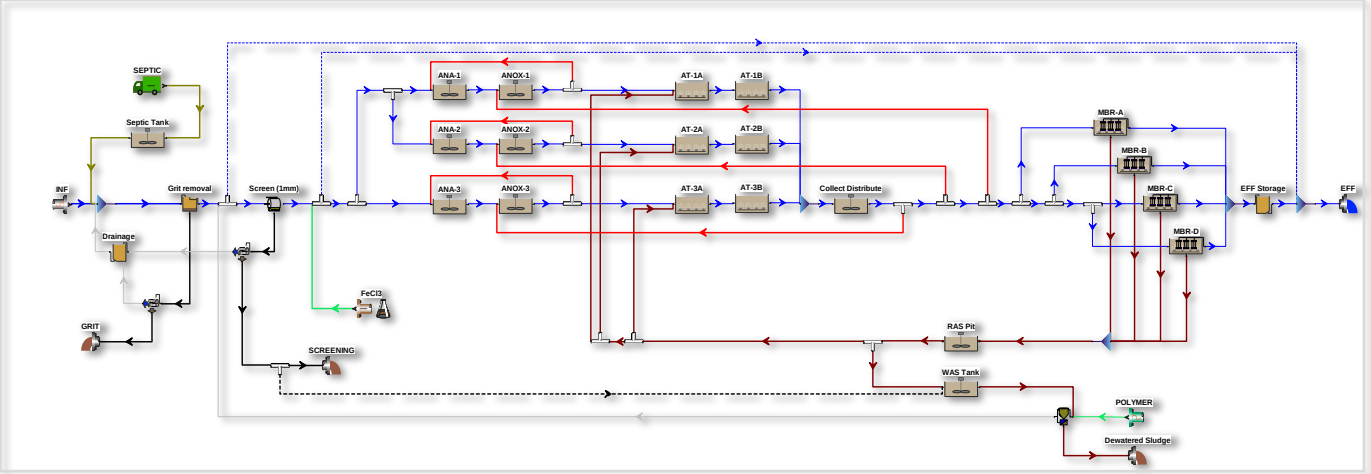


Figure 17. Simulation WWTP Poreč-North - BioWin model winter operation. All lines and MBRs are operated the whole year round. Dashed lines are bypasses not used/operated. Iron is required for P-removal. Screening is assumed to be stored separately from the dewatered sludge.

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 Poreč-South - Scenario Winter 2045 - Dynamic average effluent concentration (mg/L)			
EFF	Temperature	Concentration	12,0
EFF	COD - Total	Concentration	32,4
EFF	N - Total N	Concentration	8,0
EFF	P - Total P	Concentration	0,3
EFF	Total suspended solids	Concentration	0,5

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

WWTP Poreč-South - Scenario Winter 2045 - Dynamic average Air flow rate (m3/h)			
AT-1A	Air flow rate	Flow	225,8
AT-1B	Air flow rate	Flow	72,4
AT-2A	Air flow rate	Flow	225,8
AT-2B	Air flow rate	Flow	72,4
AT-3A	Air flow rate	Flow	0,0
AT-3B	Air flow rate	Flow	0,0
AT-4A	Air flow rate	Flow	0,0
AT-4B	Air flow rate	Flow	0,0
MBR-A	Air flow rate	Flow	273,8
MBR-B	Air flow rate	Flow	280,6

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

WWTP Poreč-South - Scenario Winter 2045 - Dynamic average Flows (m3/d)			
ANA-R1	Flow (S)	Flow	2.050,0
ANA-R2	Flow (S)	Flow	2.050,0
ANA-R3	Flow (S)	Flow	0,0
ANA-R4	Flow (S)	Flow	0,0
ANOX-R1	Flow (S)	Flow	10.411,9
ANOX-R2	Flow (S)	Flow	10.411,9
ANOX-R3	Flow (S)	Flow	5.205,9
ANOX-R4	Flow (S)	Flow	0,0
AS Emergency Bypass	Flow (S)	Flow	0,0
Dewatering Centrifuge	Flow (U)	Flow	0,6
Grit removal	Flow (U)	Flow	0,1
MBR-A	Flow (U)	Flow	1.131,9
MBR-B	Flow (U)	Flow	1.131,9
MBR-C	Flow (U)	Flow	0,0
Screen (1mm)	Flow (U)	Flow	0,1
Screen Emergency Bypass	Flow (S)	Flow	0,0

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

WWTP Poreč-South - Scenario Winter 2045 - Dynamic average SRT and HRT		
Temperature	12	°C
Average waste sludge production	145,5	kgTSS/d
SRT Total	53,9	d
SRT Aerobic	20,8	d
SRT AT+ANOX	30,4	d
WAS Tank HRT	0,9	hour
ANA HRT to influent	14,1	hour

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

WWTP Poreč-South - Scenario Winter 2045 - Dynamic average Iron and Polymer (mg/L & kg/d)			
FeCl3	Flow	Flow	0,099
FeCl3	Total iron (all forms)	Concentration	150.000
FeCl3	Total iron (all forms)	Load	14,867
POLYMER	COD - Total	Concentration	18.180
POLYMER	COD - Total	Load	1,689
POLYMER	Flow	Flow	0,093

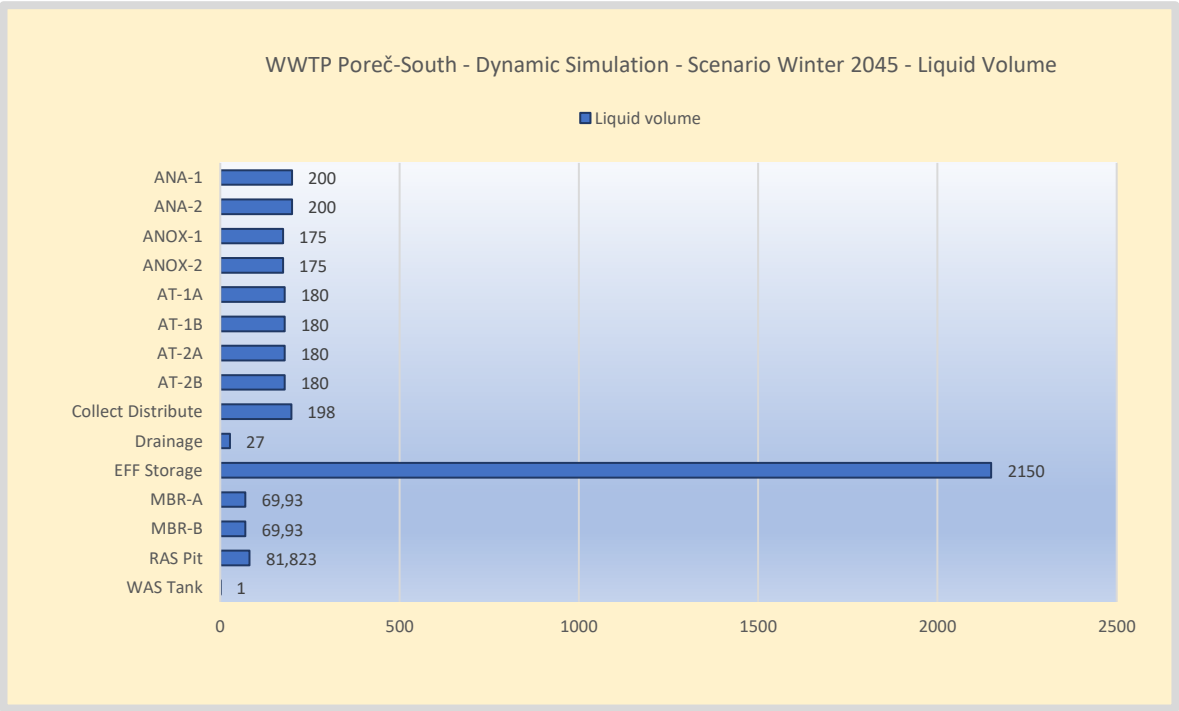


Figure 18. Simulation WWTP Poreč-North - Scenario Winter 2045 - Volume distribution of modelled reactor elements. The actual WAS tank is 150 m3 however, the sludge volume is modelled based on an HRT < 2,5 hours to avoid P-release. From the model it is concluded the WAS tank should not be used for longer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

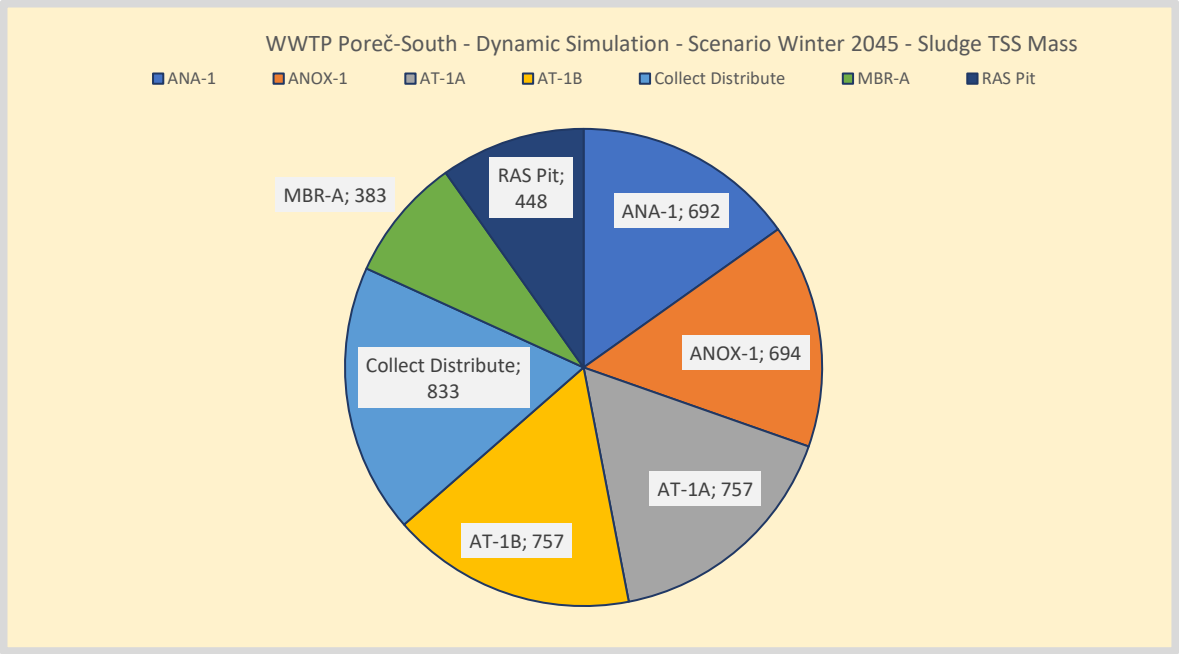


Figure 19. Simulation WWTP Poreč-North - Scenario Winter 2045 - Sludge mass distribution (kgTSS) in the activated sludge reactors. This data is used to calculate the SRT of the WWTP. Idle reactors are not included in SRT calculations.

5.3 Process controllers: Winter

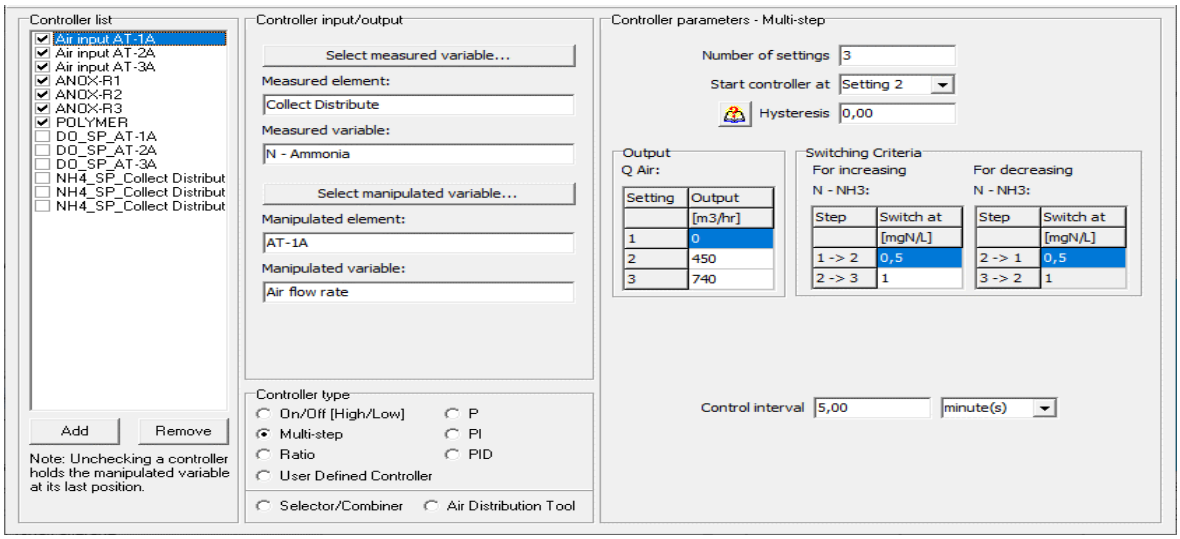


Figure 20. Simulation WWTP Poreč-North - Scenario Winter 2045 - Controlling the air input of AT-A. The measured variable is NH4 in the collect distribute tank. The manipulated variable the air flow in AT-A. There are 3 settings for the air flow depending on the NH4 concentration. Parallel lines are operated similar.

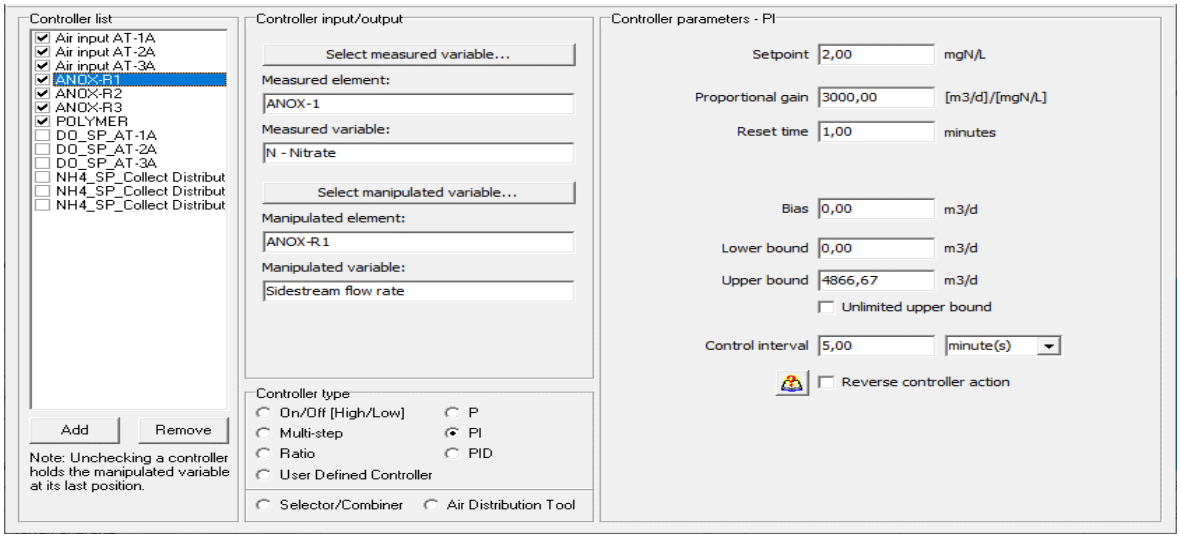


Figure 21. Simulation WWTP Poreč-North - Scenario Winter 2045 - Controlling the anoxic recycle ANOX-R. Indicated are the measured variable being NO3 in the anoxic tank and manipulated variable the recycle flow ANOX-R. The PI controller has an upper bound per operated lane of 66,6% proportional to influent flow according to the maximum installed pump capacity per lane.

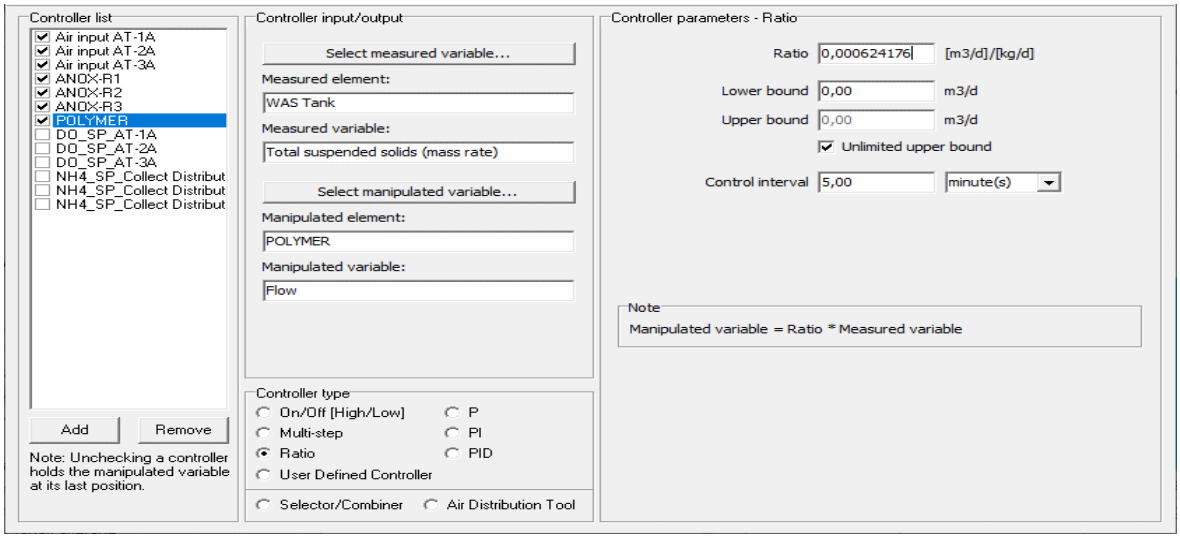


Figure 22. Simulation WWTP Poreč-North - Scenario Winter 2045 - Controlling the polymer dosage of the dewatering. Indicated are the measured variable being the TSS load entering the dewatering and manipulated variable the PE flow. The applied control ratio is 8 kg PE per 1000 kg TSS based on dry weight. PE is assumed to be particulate substrate with a COD/VSS ratio of 1,42.

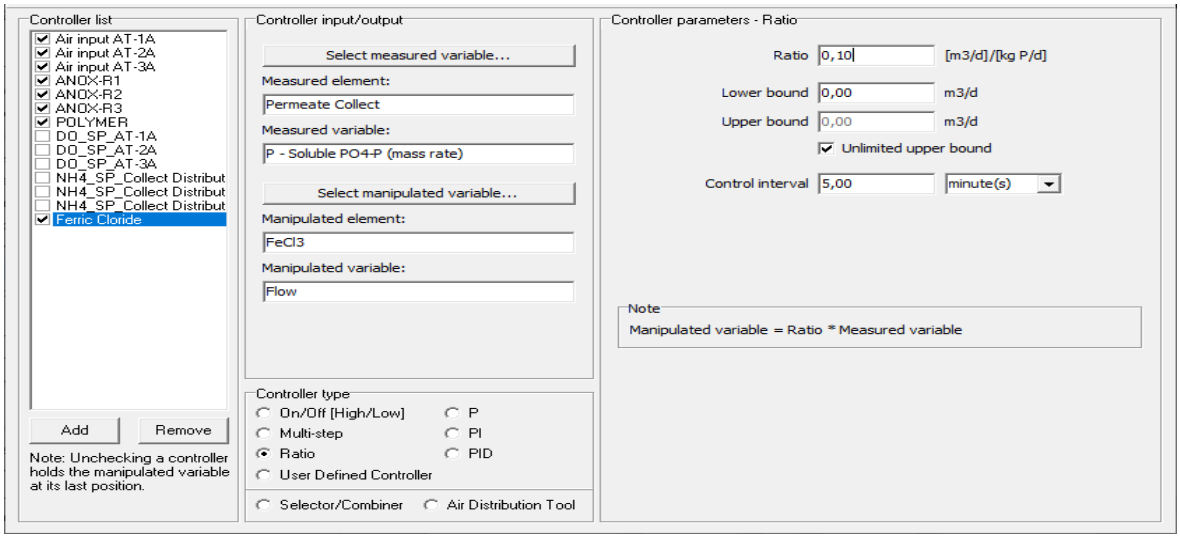


Figure 23. Simulation WWTP Poreč-North - Scenario Winter 2045 - Controlling the Iron dosage. Dosage is proportional to the measured effluent PO4 mass.

5.4 Influent modelling results

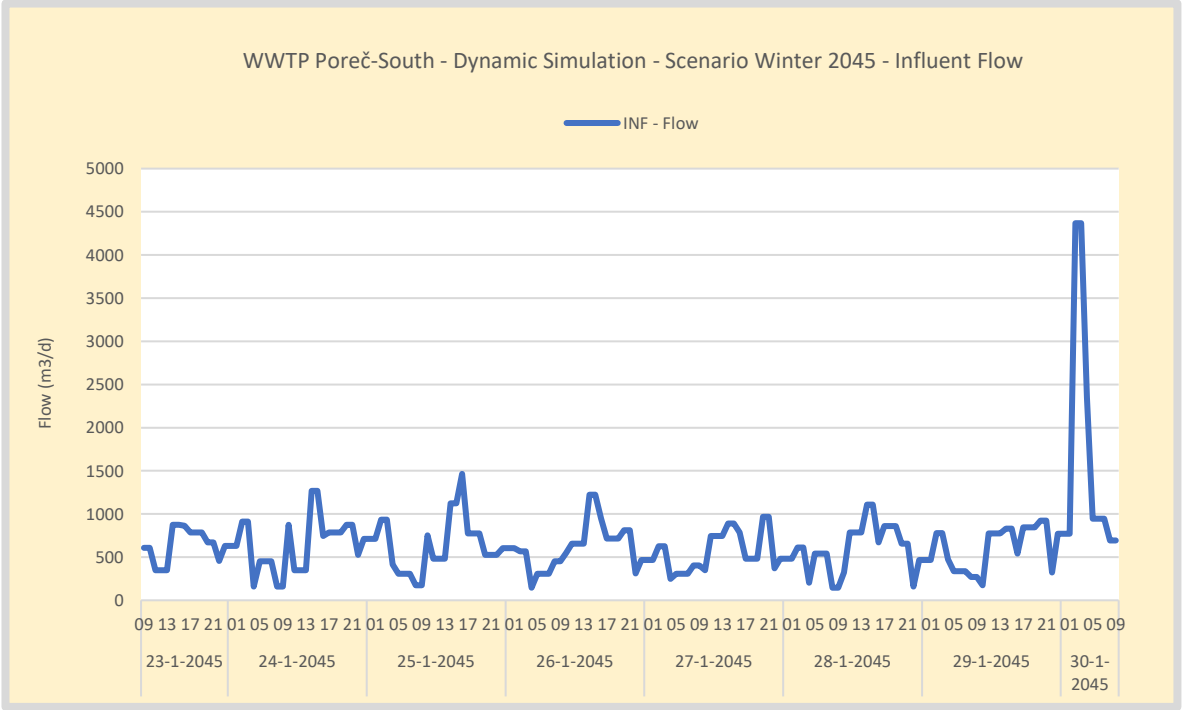


Figure 24. Simulation WWTP Poreč-North - Scenario Winter 2045 - Influent flow. The profile is based on data measured in 2019 extrapolated towards 2045. Day 7 has a rain event.

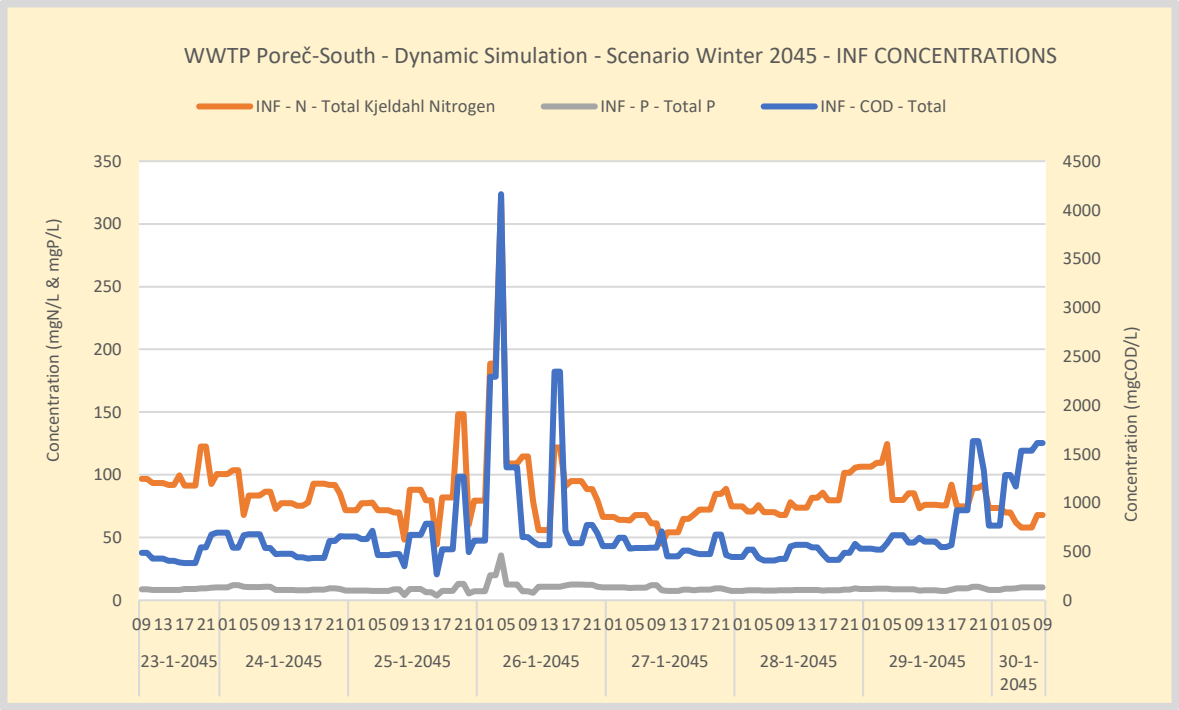


Figure 25. Simulation WWTP Poreč-North - Scenario Winter 2045 - Influent loads COD, TKN and TP. The profile is based on data measured in 2019 extrapolated towards 2045. In the data a large TKN concentration peak is simulated. This peak is measured in 2019 at low flow conditions and has a minor effect on the WWTP loading.

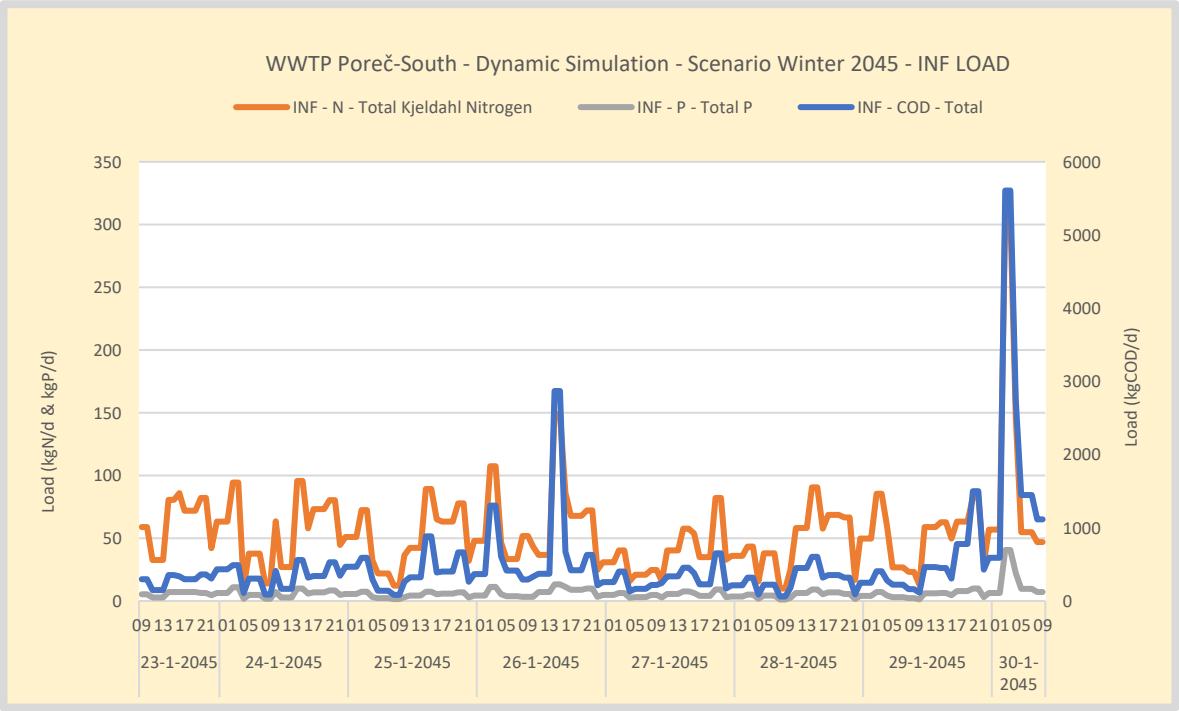


Figure 26. Simulation WWTP Poreč-North - Scenario Winter 2045 - Influent loads COD, TKN and TP. The profile is based on data measured in 2019 extrapolated towards 2045. The influent has reoccurring TKN peaks during the day and the WWTP may be limited in aeration capacity during peak loading.

5.5 Process and recycle flows modelling results

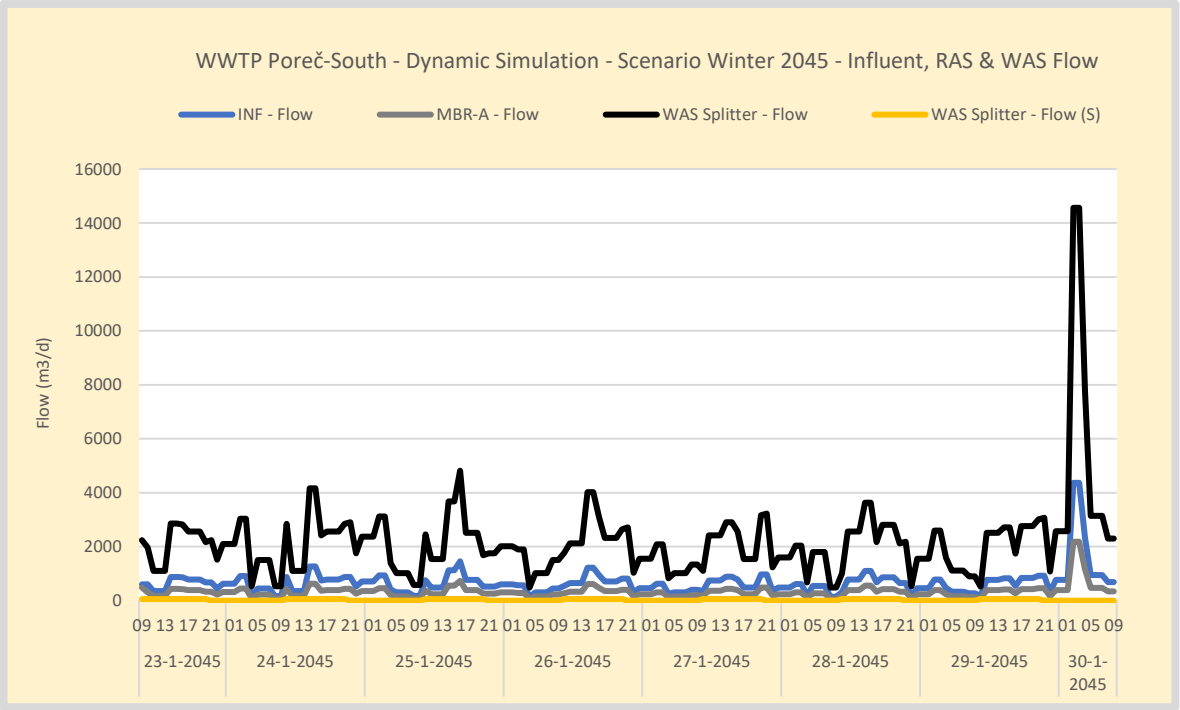


Figure 27. Simulation WWTP Poreč-North - Scenario Winter 2045 - flow rate settings and control. The MLSS sludge return flow is controlled proportional to the influent (500% proportional to the influent). This results in a more stable TSS concentration in the reactors. The WAS flow is operated 10 hours a day on a constant flow to the dewatering.

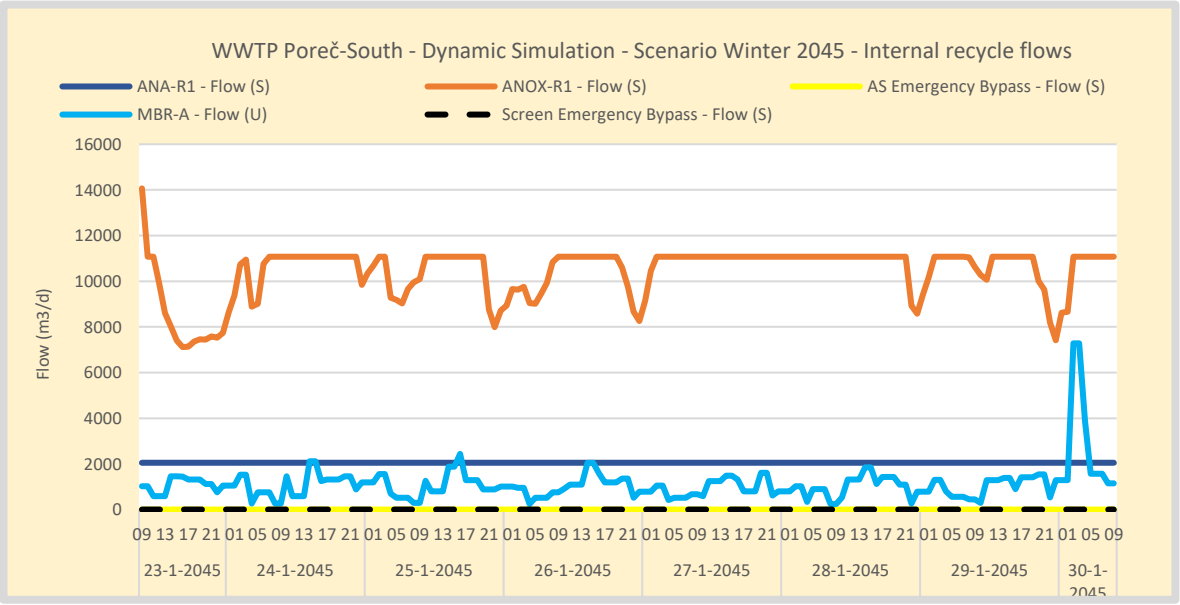


Figure 28. Simulation WWTP Poreč-North - Scenario Winter 2045 - flow rate settings and control. The bypasses are not used. The anaerobic recycle is set to the maximum flow to reduce anaerobic decay conditions. The sludge return is controlled proportionally with the influent. The anoxic recycle is controlled on 2 mgNO/L in the anoxic tank and most time the recycle flow capacity is limiting to obtain the NO3 setpoint and is at its maximum value.

5.6 Waterline operation modelling results

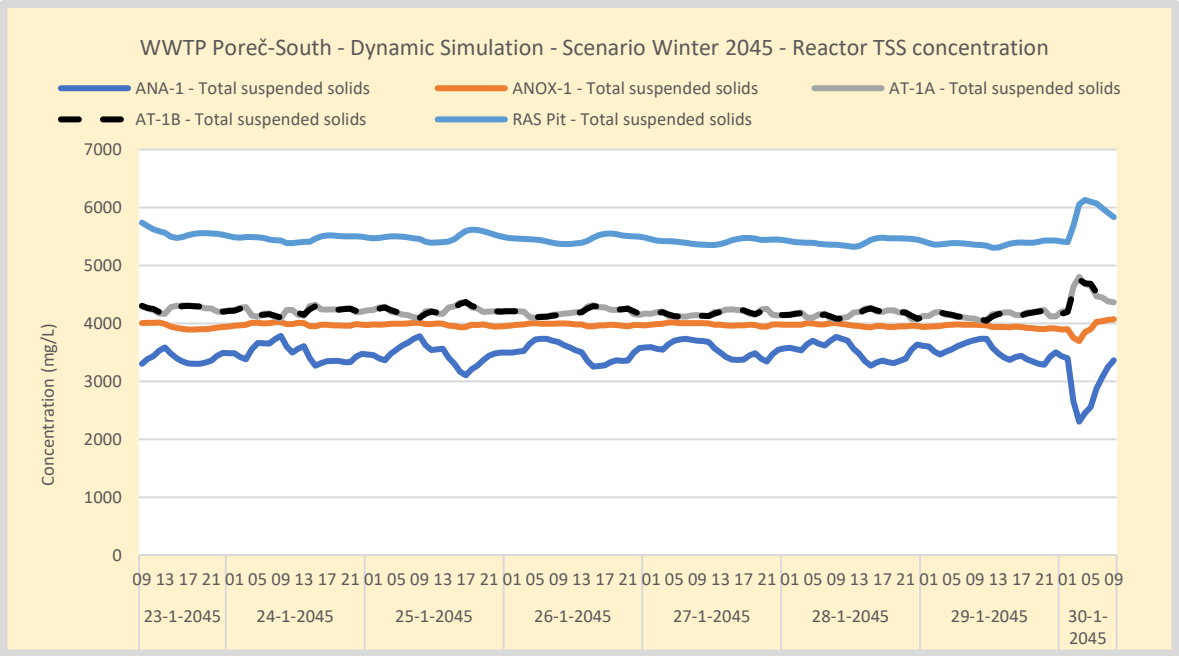


Figure 29. Simulation WWTP Poreč-North - Scenario Winter 2045 - TSS profile in the waterline. TSS in the MBR is controlled on approximately 11 gTSS/L by adjusting the WAS flow and SRT. The winter and summer operation are similar.

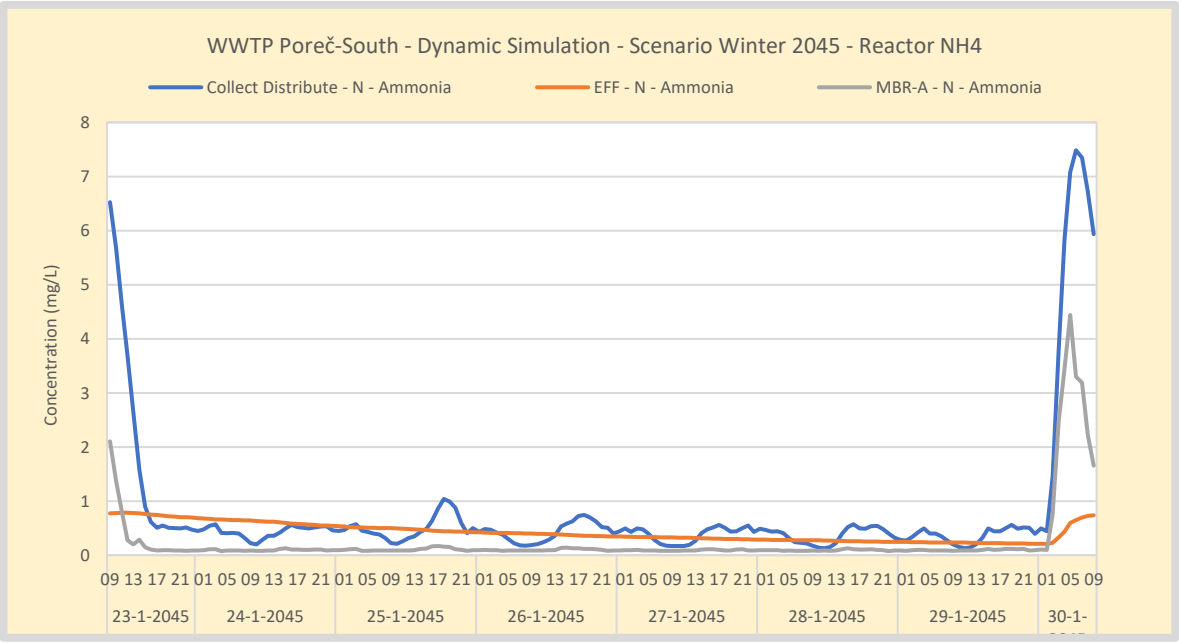


Figure 30. Simulation WWTP Poreč-North - Scenario Winter 2045 - ammonium profile in the waterline. The air input of AT-A is controlled based on NH4 in the Collect Distribute tank. During daily peak loading the nitrification is limiting and ammonium accumulates in the reactors. In average total nitrogen is below the maximum required design value.

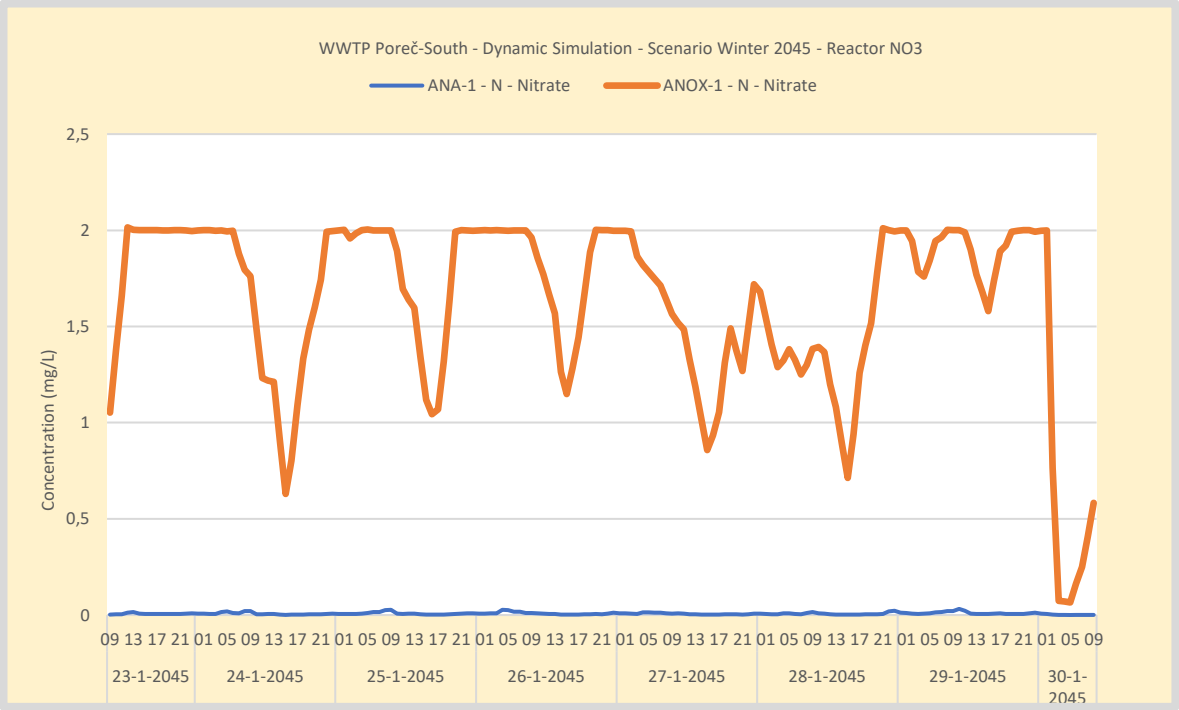


Figure 31. Simulation WWTP Poreč-North - Scenario Winter 2045 - nitrate in the anoxic tank. The anaerobic recycle rate is set to a maximum flow to reduce the effective anaerobic volume. The anoxic recycle is controlling nitrate in the anoxic tank on 2 mgNO3/L. The recycle flow is insufficient to maintain this setpoint. This results in too long effective anaerobic conditions and decay of nitrification capacity.

5.7 Waterline concentration profiles modelling results

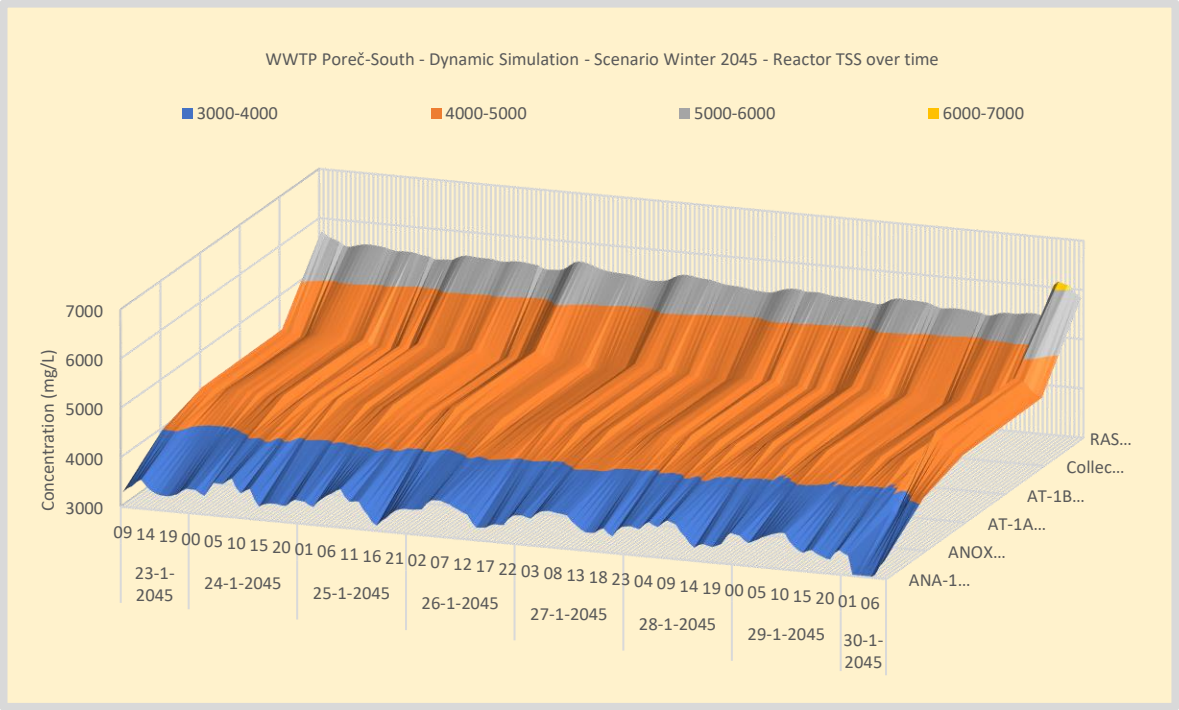


Figure 32. WWTP Poreč-North - Scenario Winter 2045 - TSS concentration profile over the waterline.

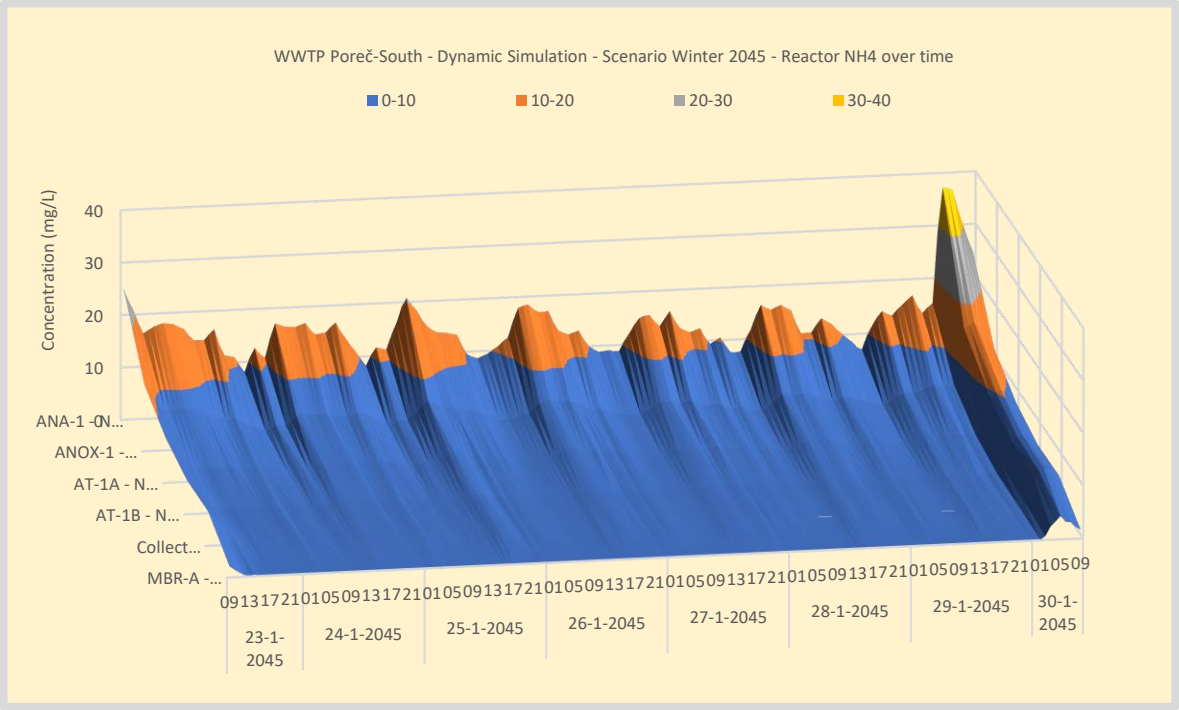


Figure 33. Simulation WWTP Poreč-North - Scenario Winter 2045 - NH4 concentration profile over the waterline.

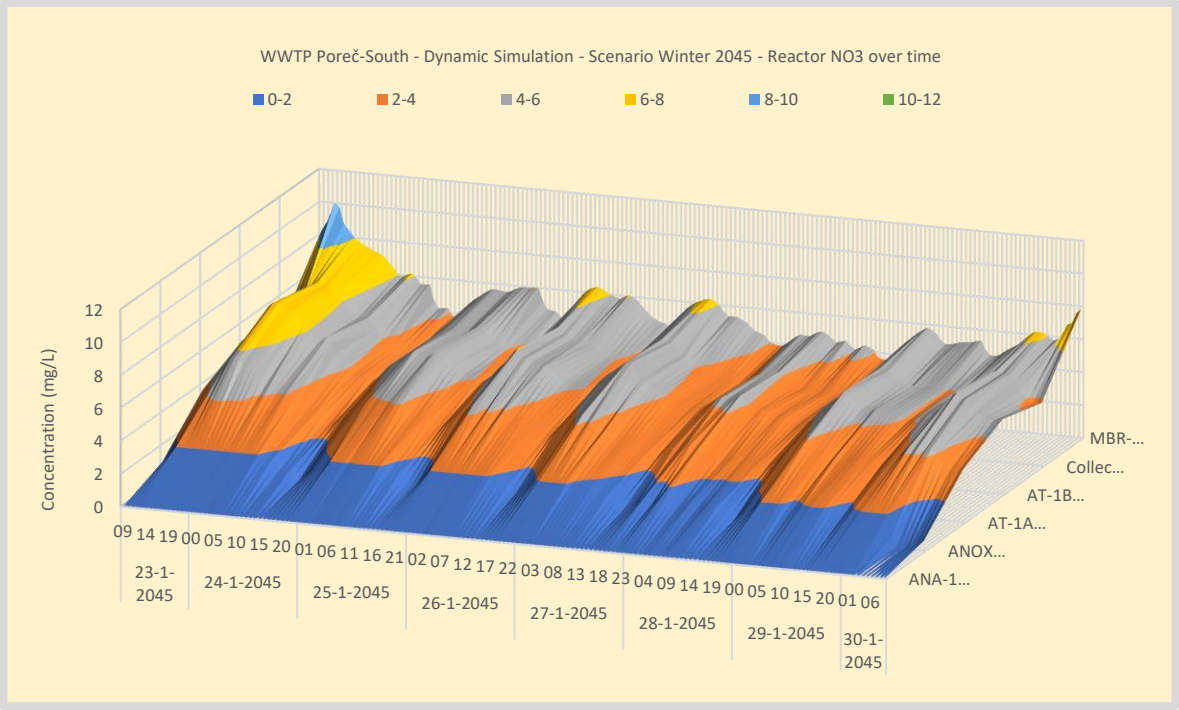


Figure 34. Simulation WWTP Poreč-North - Scenario Winter 2045 - NO3 concentration profile over the waterline.

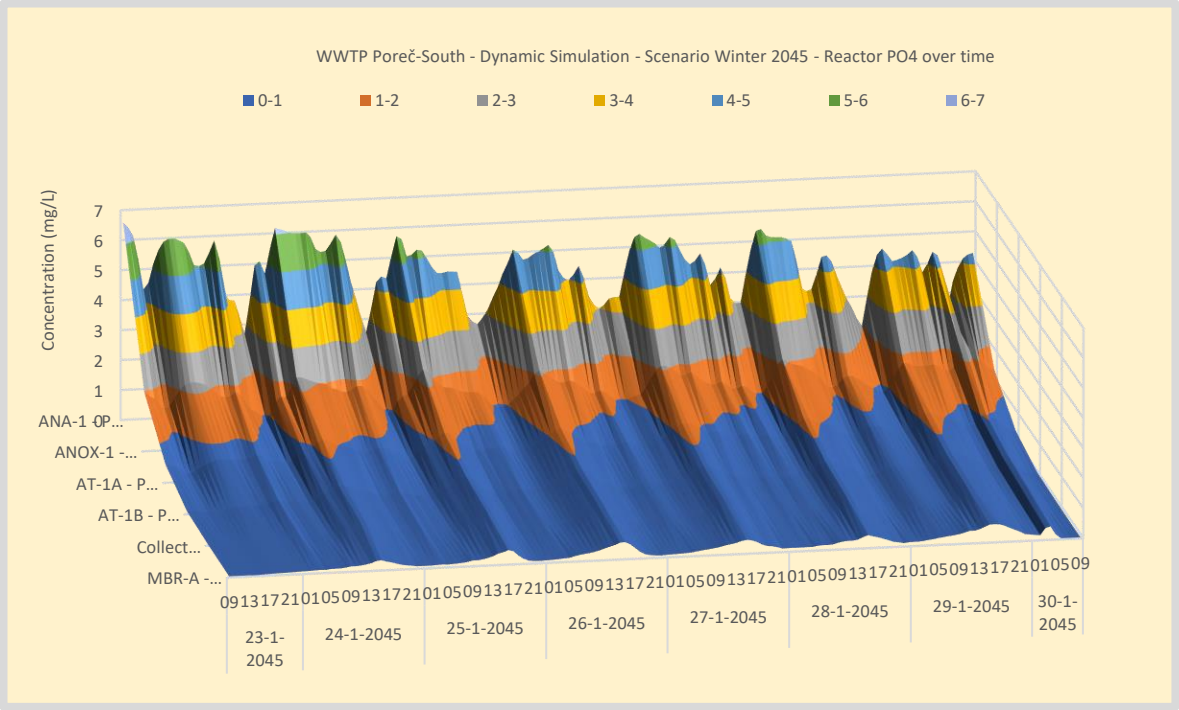


Figure 35. Simulation WWTP Poreč-North - Scenario Winter 2045 - PO4 concentration profile over the waterline. Effluent peaks are the result of too little nitrate and oxygen present for P-uptake.

5.8 Aeration and DO concentration modelling results

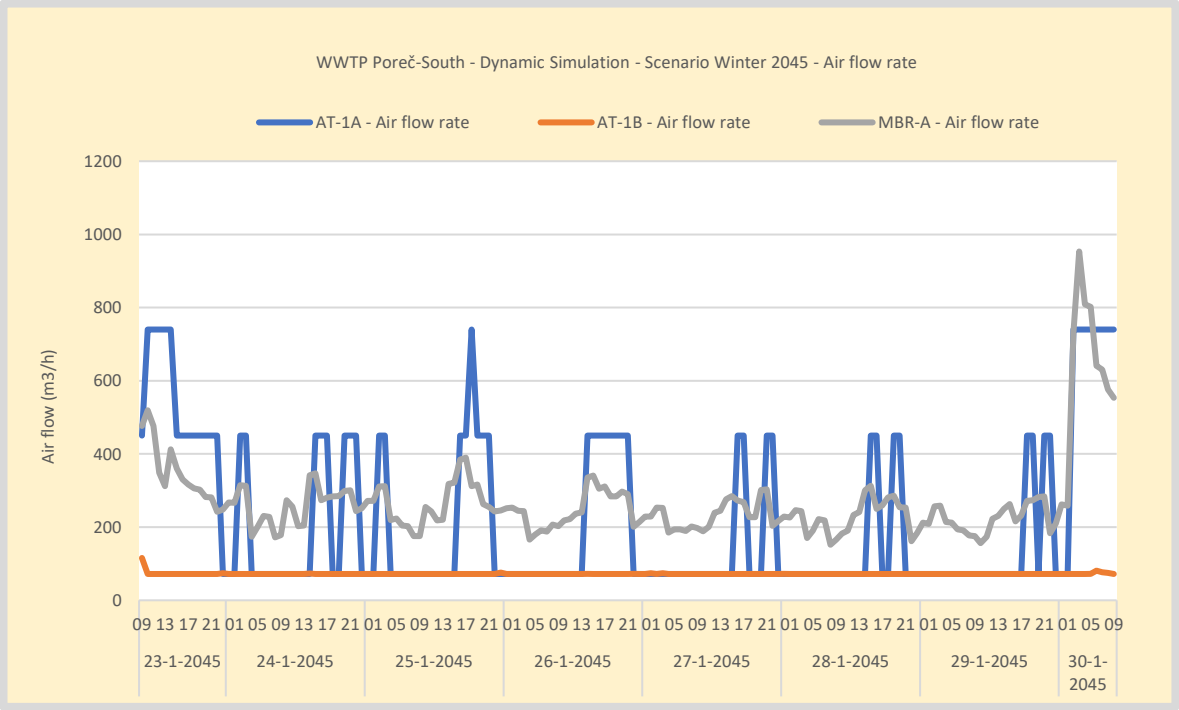


Figure 36. Simulation WWTP Poreč-North - Scenario Winter 2045 - Air flow of the aerated reactors. The MBR is continuously aerated on maximum design capacity. AT-A is controlled based on NH4 measured in the outflow of AT-B. AT-B is setpoint controlled on 3 mgO2/L. During daily TKN peak loading the nitrification capacity is limiting.

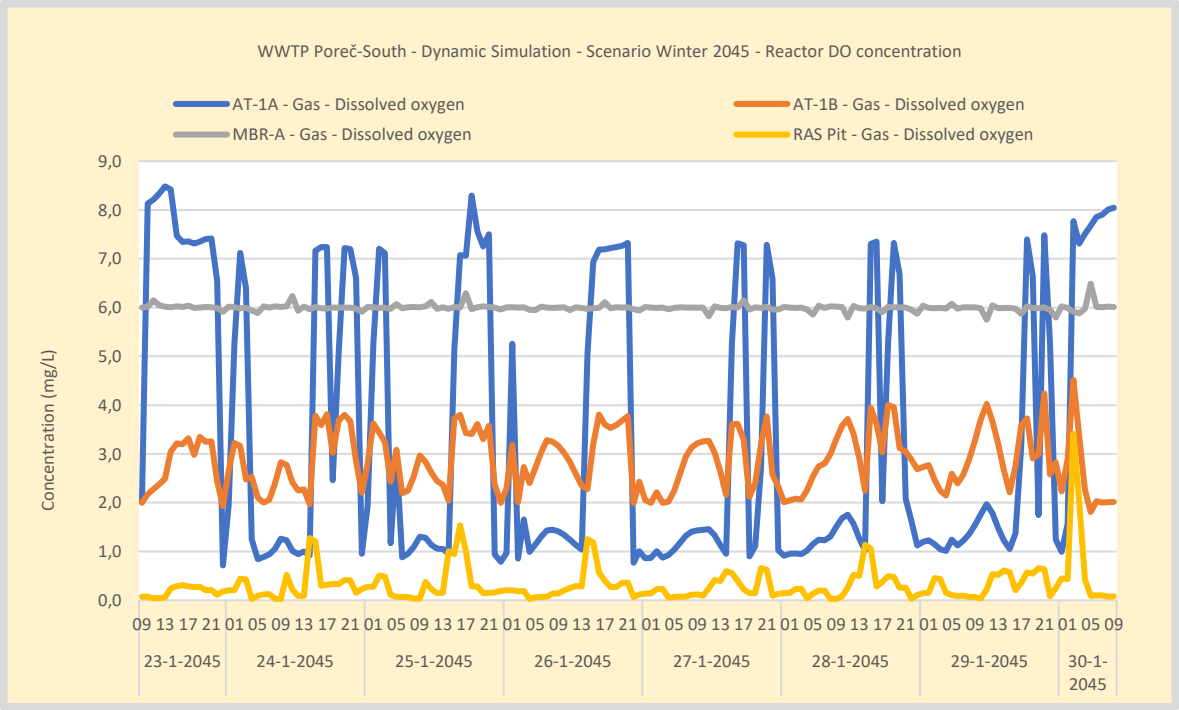


Figure 37. Simulation WWTP Poreč-North - Scenario Winter 2045 - DO concentration gradients. The MBR is continuously aerated on the maximum capacity. DO is controlled in the AT-B at 3 mgO2/L. AT-A is controlled on NH4 in the outflow of AT-B. For the most time there is sufficient oxygen in the system, however due to long anaerobic HTR the nitrification capacity may be reduced to the point of becoming limiting.

5.9 pH and alkalinity profiles modelling results

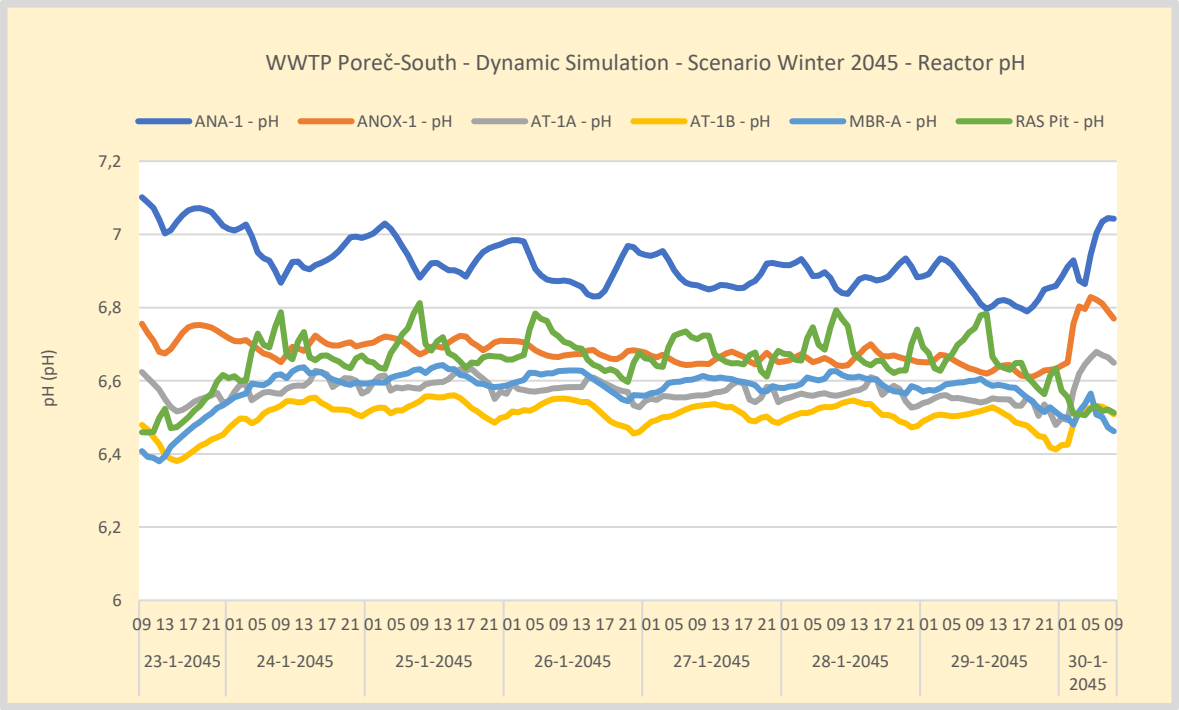


Figure 38. Simulation WWTP Poreč-North - Scenario Winter 2045 - pH profile over the activated sludge reactors. Influent pH is measured continuously and not limiting.

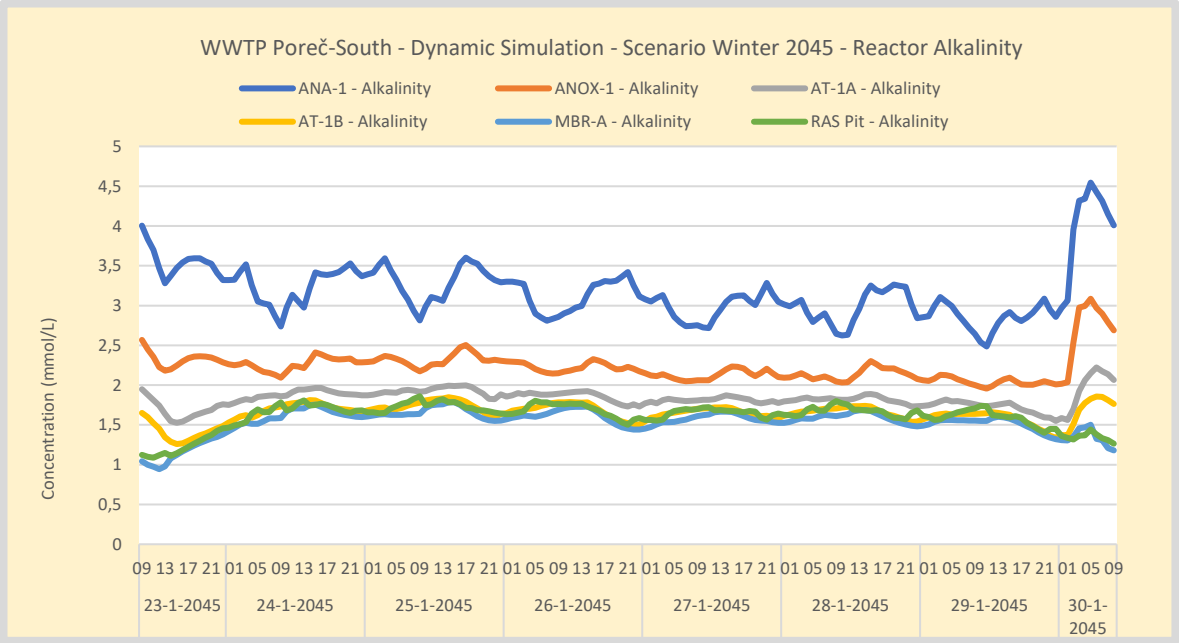


Figure 39. Simulation WWTP Poreč-North - Scenario Winter 2045 - alkalinity profile over the activated sludge reactors. Influent alkalinity is estimated from local drinking water quality measurements at 7,46 mmol/L. Alkalinity is sufficient. However, limitation of alkalinity in the winter may occur depending on operational conditions due to CO2 stripping caused by over aeration.

5.10 Chemical load and flow modelling results

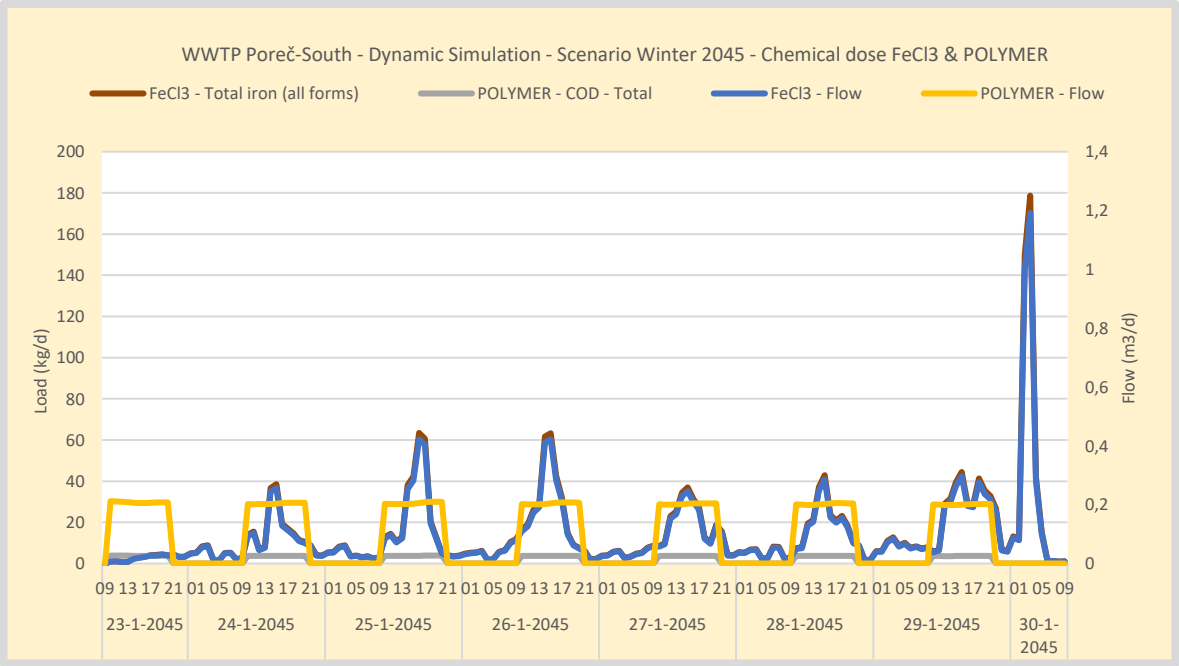


Figure 40. Simulation WWTP Poreč-North - Scenario Winter 2045 - load and flow of Iron and PE. Iron is dosed proportionally to a PO4 measurement in the outflow of the MBR. PE is dosed to the dewatering and is assumed to be particulate biodegradable COD with a COD/VSS ratio of 1,42 gCOD/gTSS. Dosage is proportional to the WAS load based on 8 kg PE (dry weight) dosed per 1000 kg WAS (dry weight).

5.11 Sludge line operation modelling results

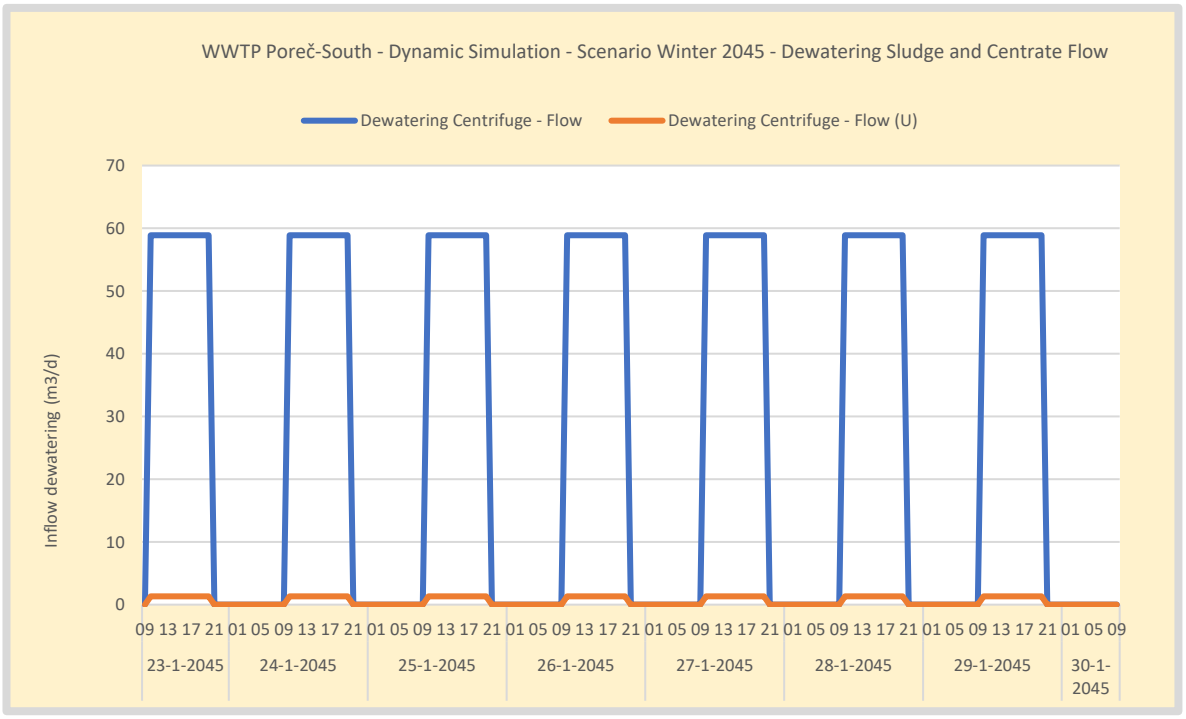


Figure 41. Simulation WWTP Poreč-North - Scenario Winter 2045 - dewatered sludge and centrate flow. Dewatering is operated 10 hours per day 7 days per week.

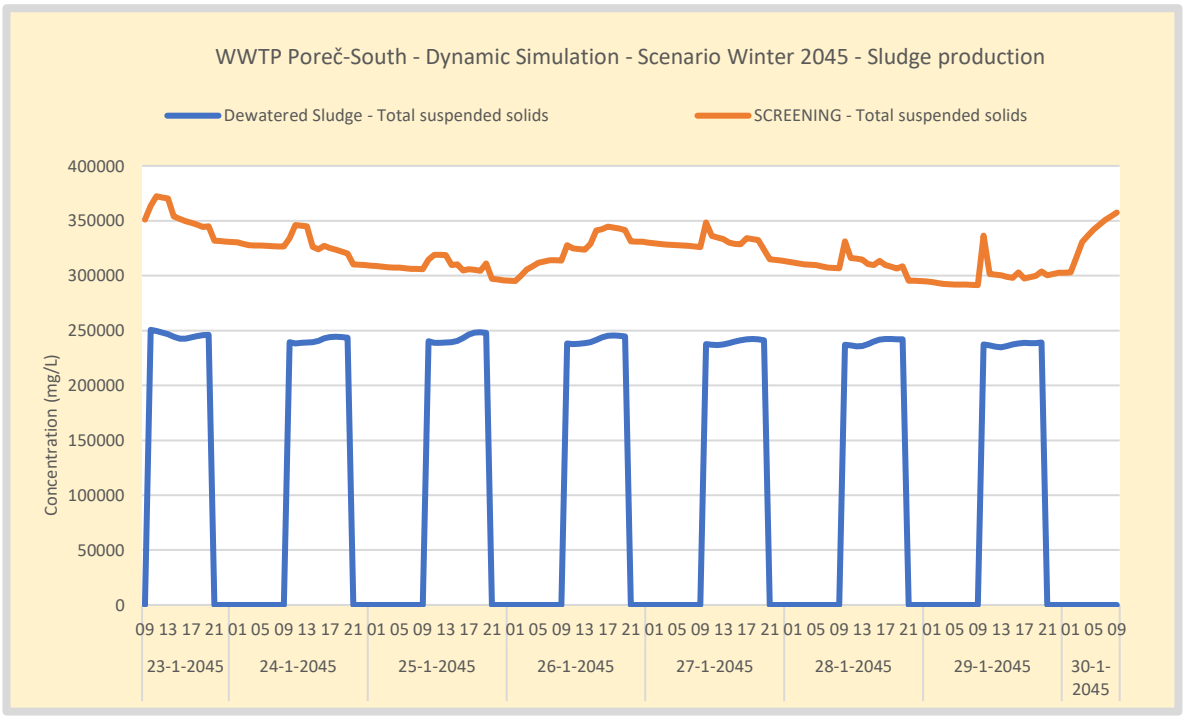


Figure 42. Simulation WWTP Poreč-North - Scenario Winter 2045 - dewatered sludge and screening sludge concentration. The design assumes dewatered sludge at approximately 23% dry matter. Screening is an estimated concentration as the result of the press operation.

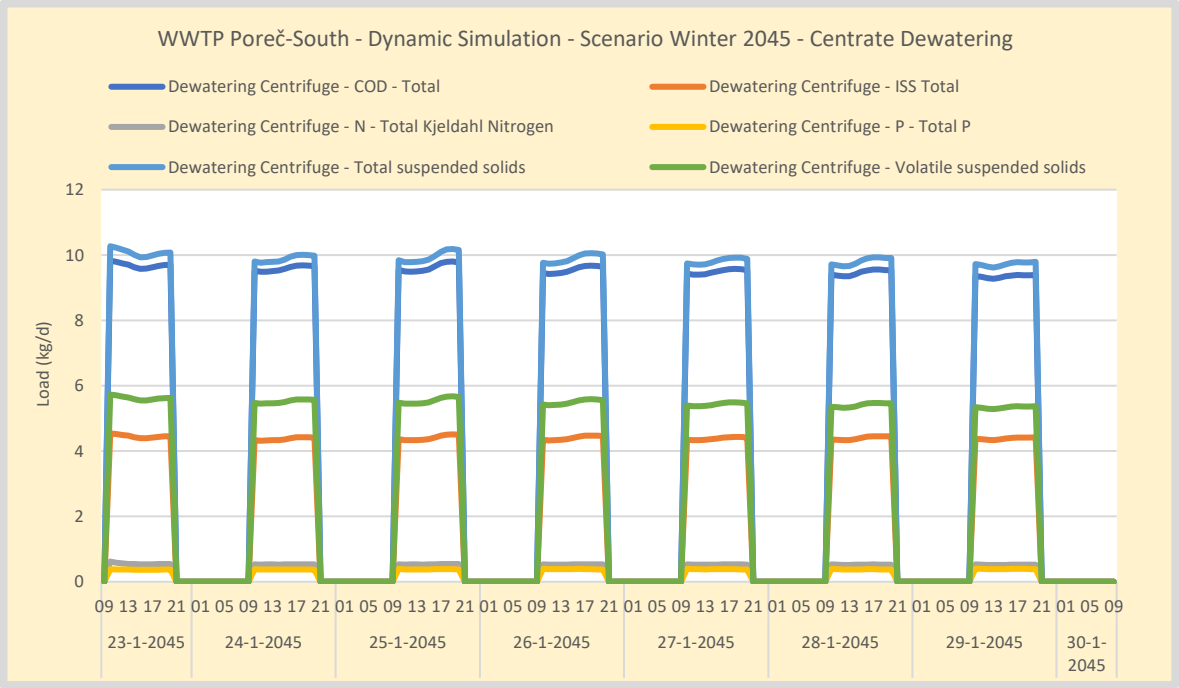


Figure 43. Simulation WWTP Poreč-North - Scenario Winter 2045 - Centrate load dewatering. Centrate is fed back to the waterline. P in the centrate is reduced by reducing the HRT of the WAS storage.

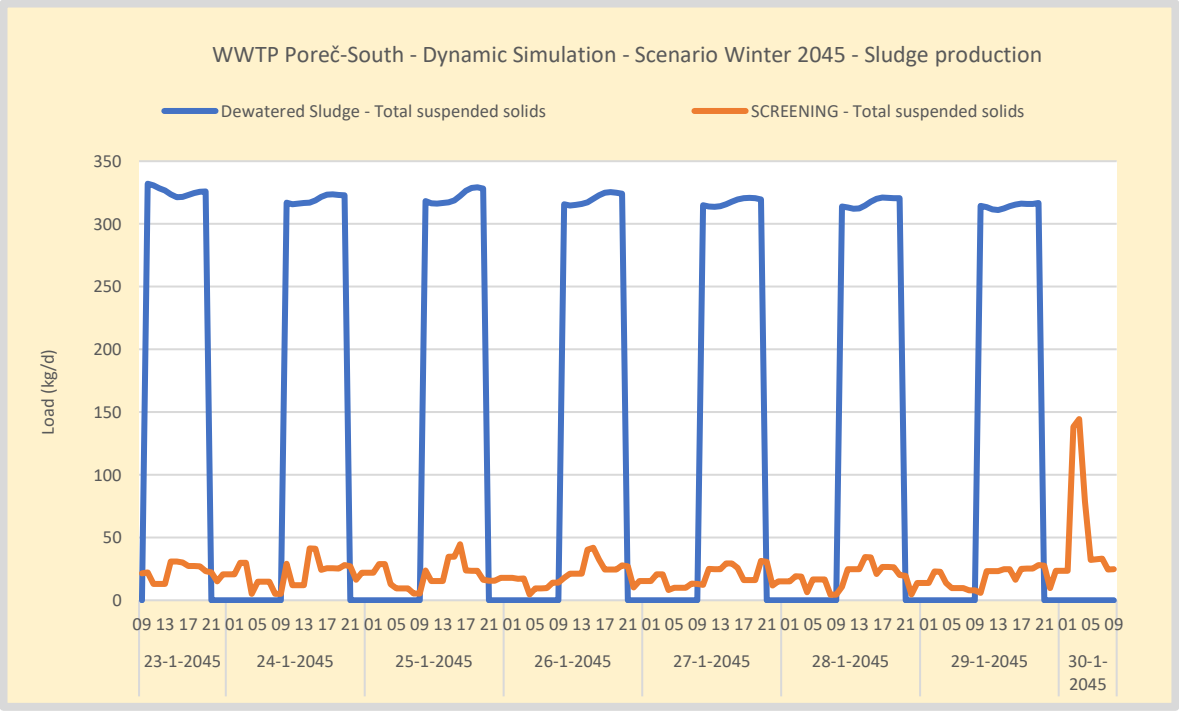


Figure 44. Simulation WWTP Poreč-North - Scenario Winter 2045 - dewatered sludge load and compacted screening load. Dewatered sludge is operated 10 hours a day at approximately 23%. Screening is produces continuously as a factor of the influent. Sludge and screening are assumed to be stored separately.

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.

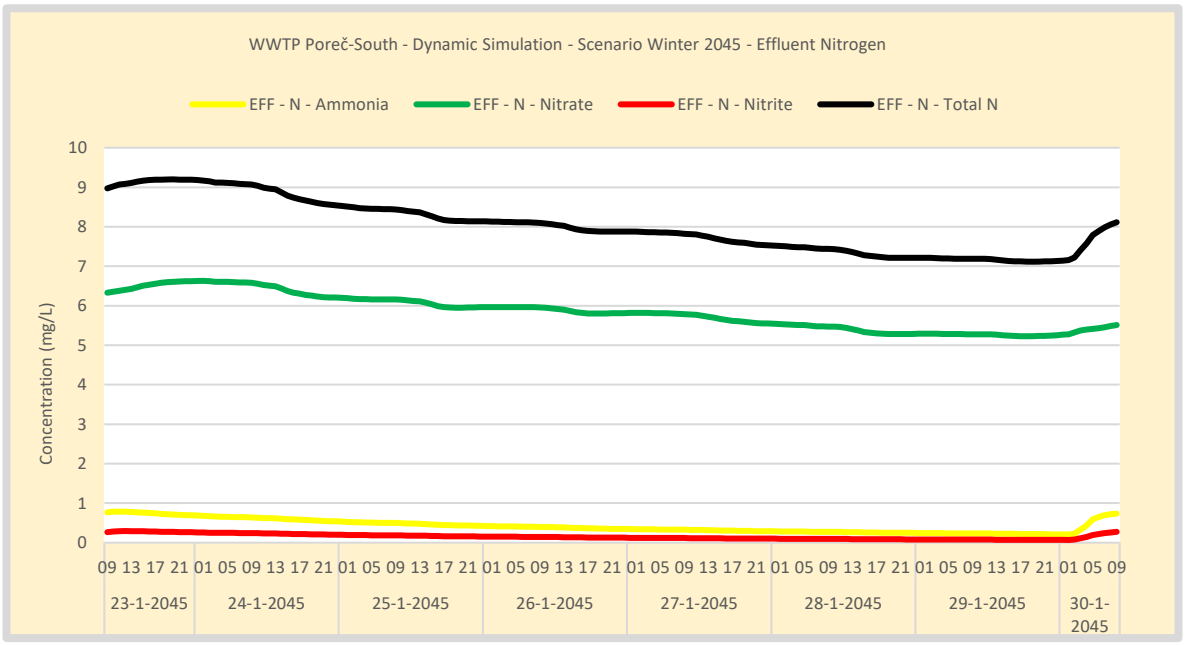


Figure 45. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent nitrogen concentration. Effluent is measured in the outflow of the effluent buffer. TN is below the required maximum concentration. However, the system is limited in nitrification capacity and effluent ammonium by time is high.

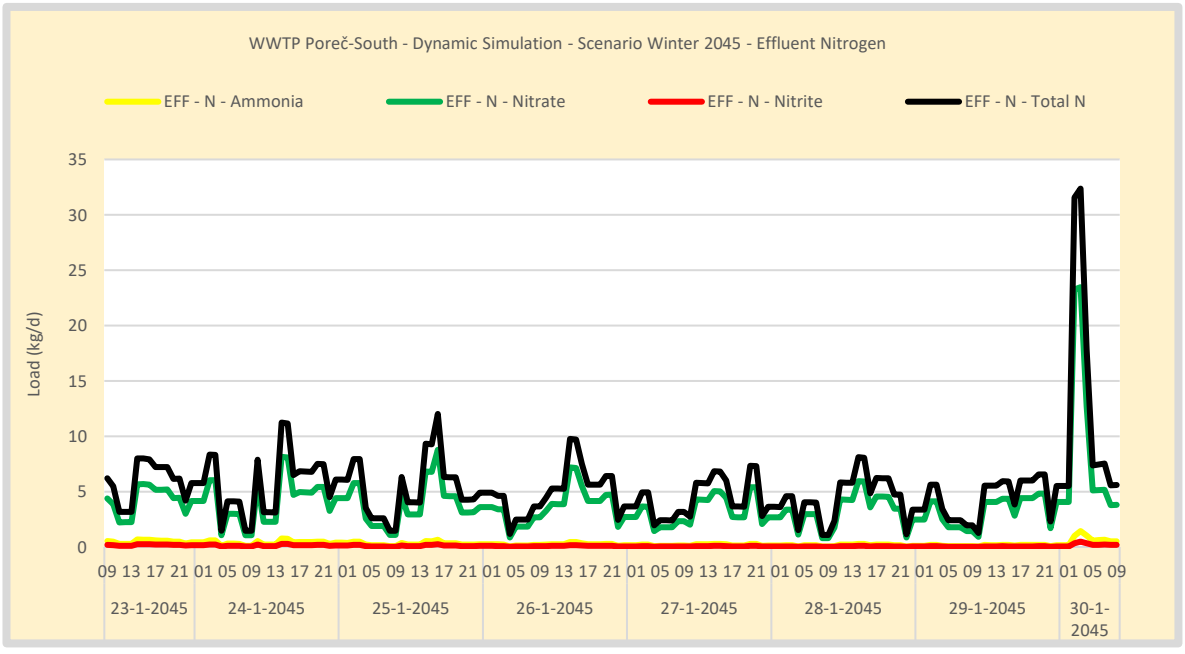


Figure 46. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent nitrogen load. Effluent is measured in the outflow of the effluent buffer. Variations in the effluent load are mainly the result of variations the flow.

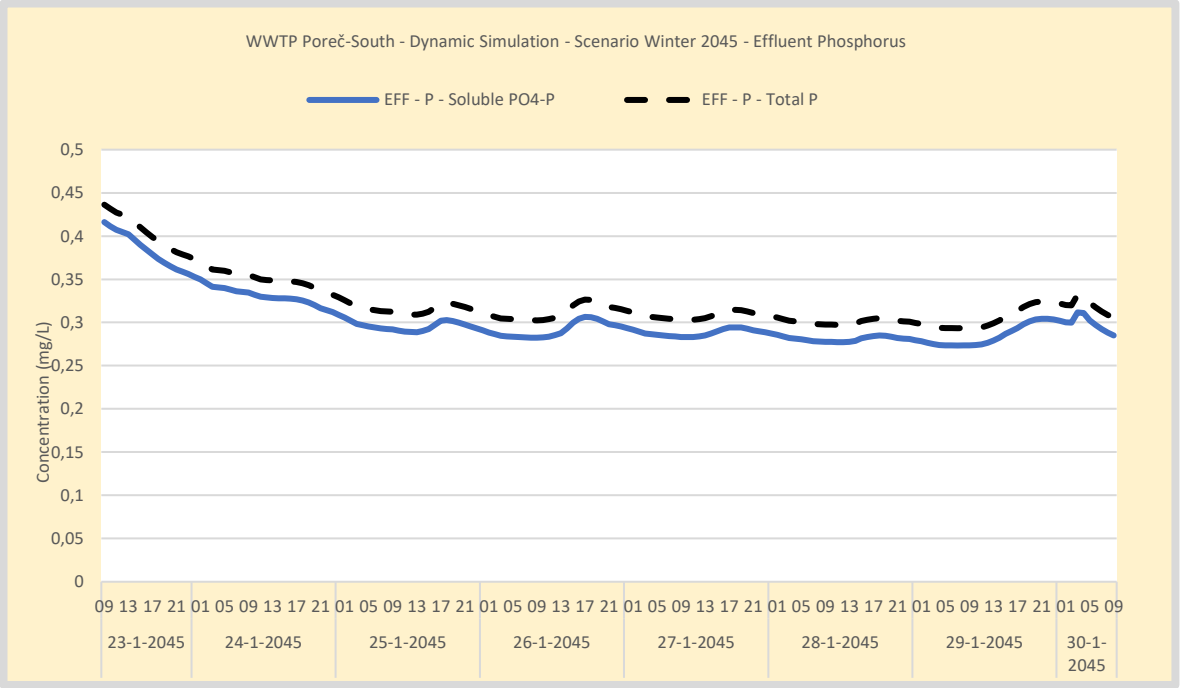


Figure 47. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent phosphorus concentration. Effluent is measured in the outflow of the effluent buffer. Chemical P-removal is used to maintain TP is below the maximum required concentration.

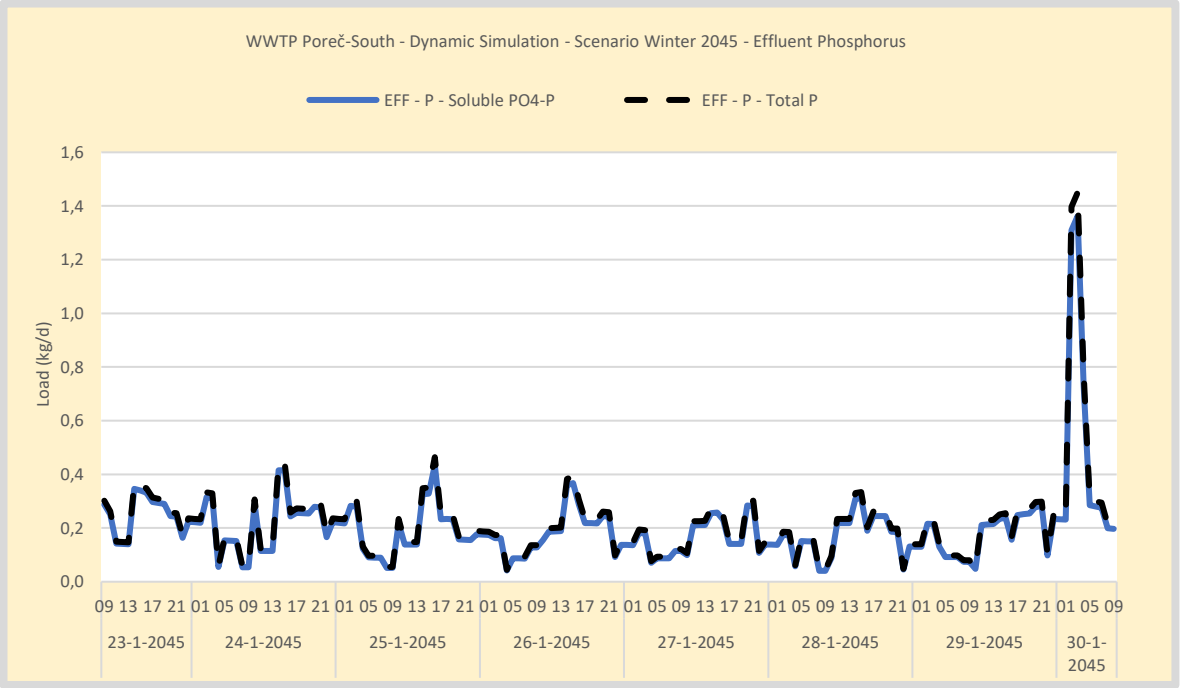


Figure 48. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent phosphorus load. The last day is a major rain event negatively affecting P-removal. Effluent is measured in the outflow of the effluent buffer. Variations in the effluent load are mainly the result of variations the flow.

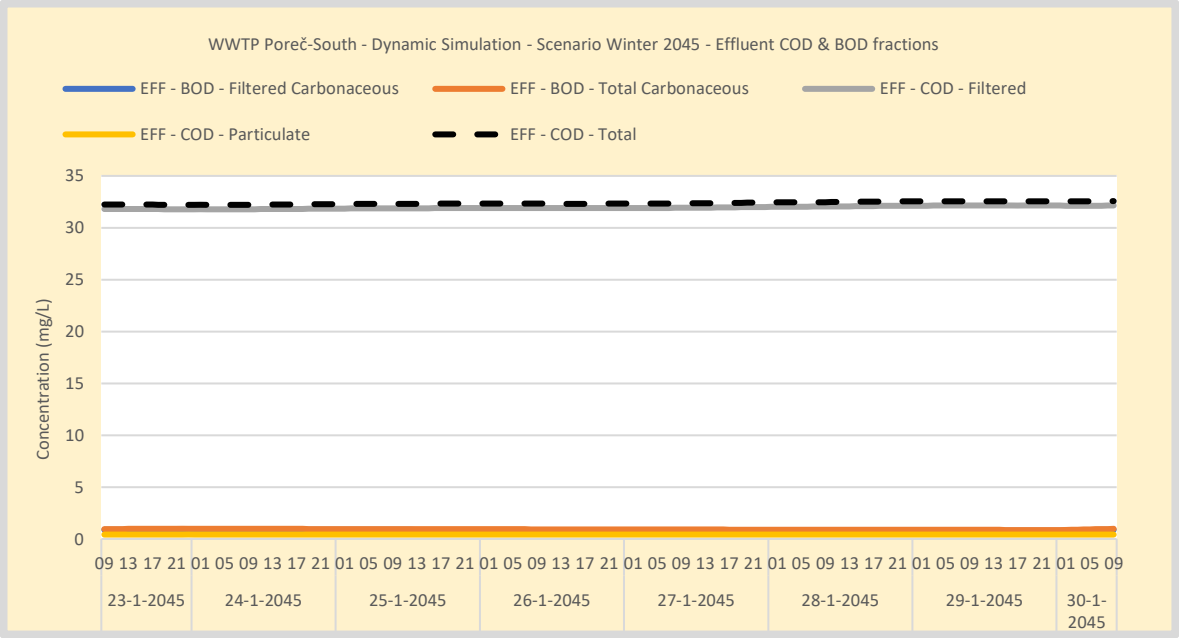


Figure 49. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent COD and BOD concentration. Effluent is measured in the outflow of the large effluent buffer. COD is below the maximum required concentration. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. On day 3, an influent COD peak is simulated coinciding with a shortage of oxygen and nitrate. This results in a temporary overload and increased soluble COD and BOD in the effluent.

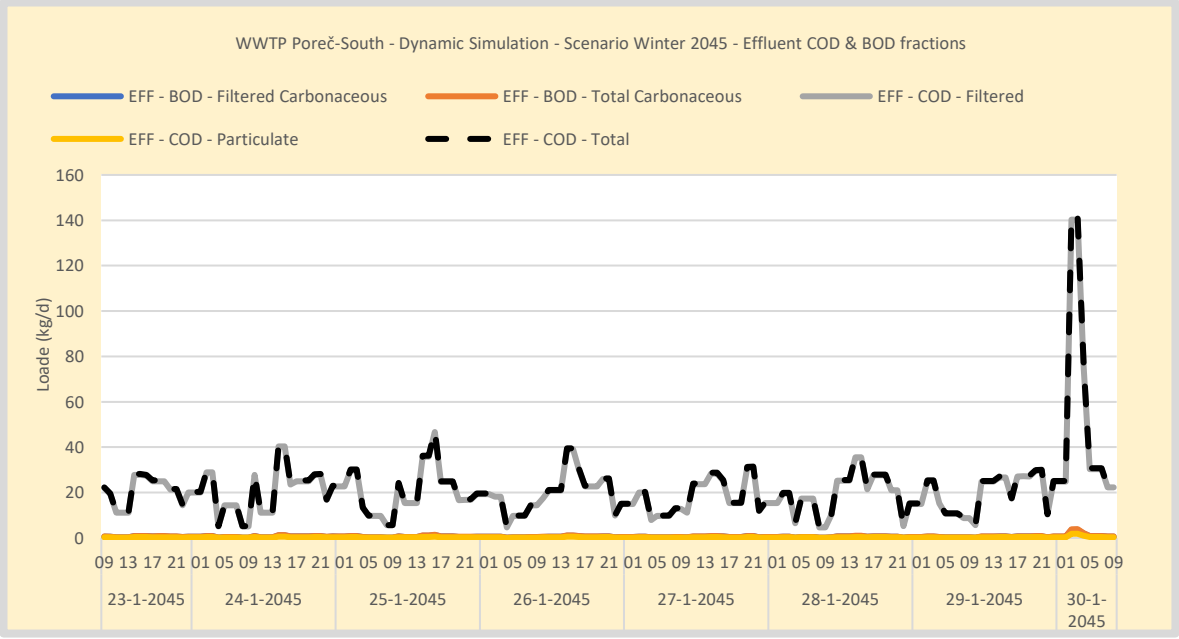


Figure 50. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent COD and BOD load. Effluent is measured in the outflow of the large effluent buffer. Variations in the load are largely the result of flow variations. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. On day 3, an influent COD peak is simulated coinciding with a shortage of oxygen and nitrate. This results in a temporary overload and increased soluble COD and BOD in the effluent.

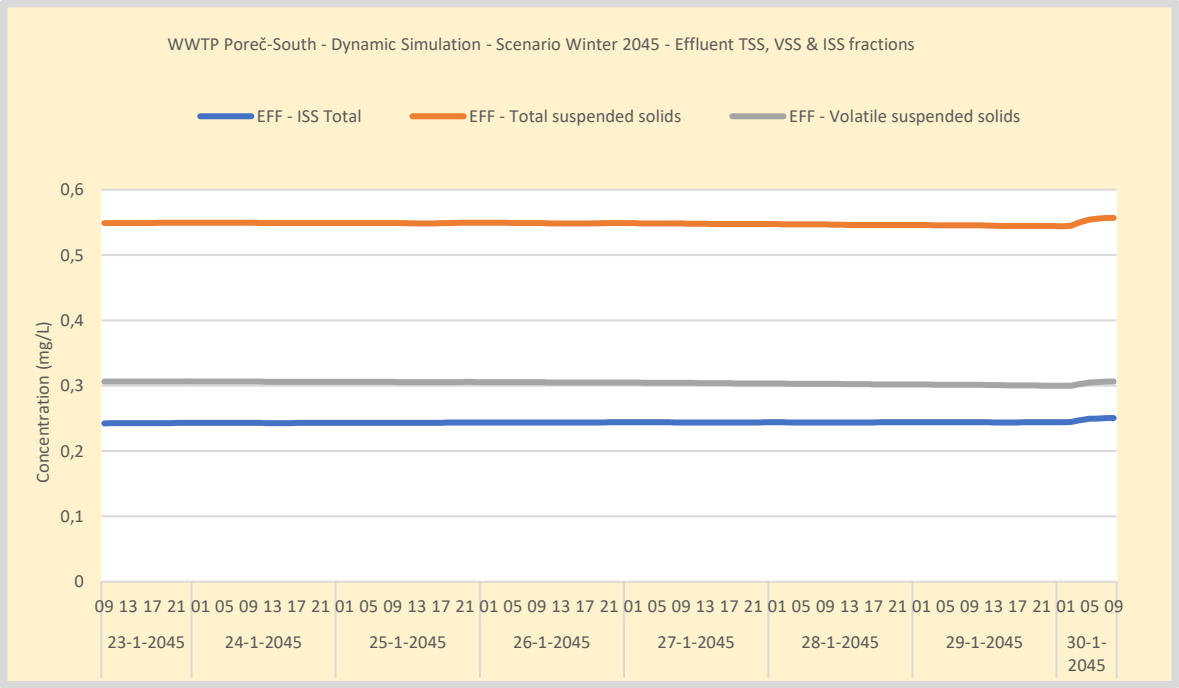


Figure 51. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent suspended solids concentration. Effluent is measured in the outflow of the effluent buffer. It is assumed that the MBR has a 99,9% removal efficiency for solids and 99,99% for colloidal material and that this performance is not affected in time.

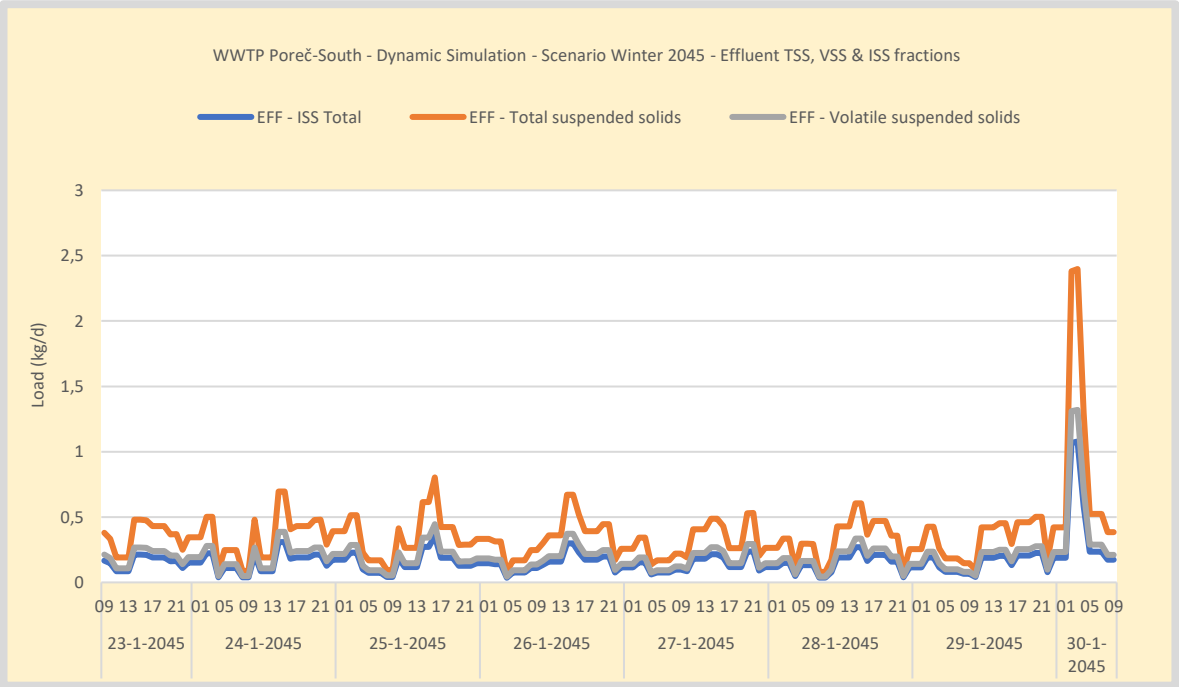


Figure 52. Simulation WWTP Poreč-North - Scenario Winter 2045 - Effluent suspended solids load. Effluent is measured in the outflow of the effluent buffer. The effluent load dynamics are the result of the flow dynamics. It is assumed that the MBR has a 99,9% removal efficiency for solids and 99,99% for 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 however, the plant is at its maximum capacity.

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 may become limiting for nitrification.

The plant is fully aerated including the MBR. This does not result in a drop of alkalinity and the pH however, in winter over-aeration may result in a drop of alkalinity and pH limitation.

During low loading conditions the unaerated (anaerobic and anoxic) volume may become too large resulting in decay of nitrification. It is advised to use the maximum internal recycle flow to reduce this effect, also during low loading conditions and low effluent nitrate.

During the winter loading conditions the plant may require dosage of Iron to remove phosphate chemically, especially with rain conditions. During the summer TKN peak loading may result in temporary low oxygen and nitrate which can result in increased effluent PO4.

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 and summer operation are similar in respect to the operated SRT and no lines are taken out of operation during the winter.

Specific potential problems of winter operation are:

- Too low internal recycle flows resulting in anaerobic zones, decay of biomass and reduction of nitrification and Bio-P capacity.
- Alkalinity may become limiting under winter operational conditions and when the system is over aerated.
- P-release in the WAS storage tank operated at HRT > 2-3 hours.
- Reduced availability of oxygen and nitrogen for Bio-P resulting in increased effluent PO4 and requirement of Iron to remove phosphate chemically.

6 Scenario summer 2045 results dynamic modelling

6.1 Summer operation process flow diagram

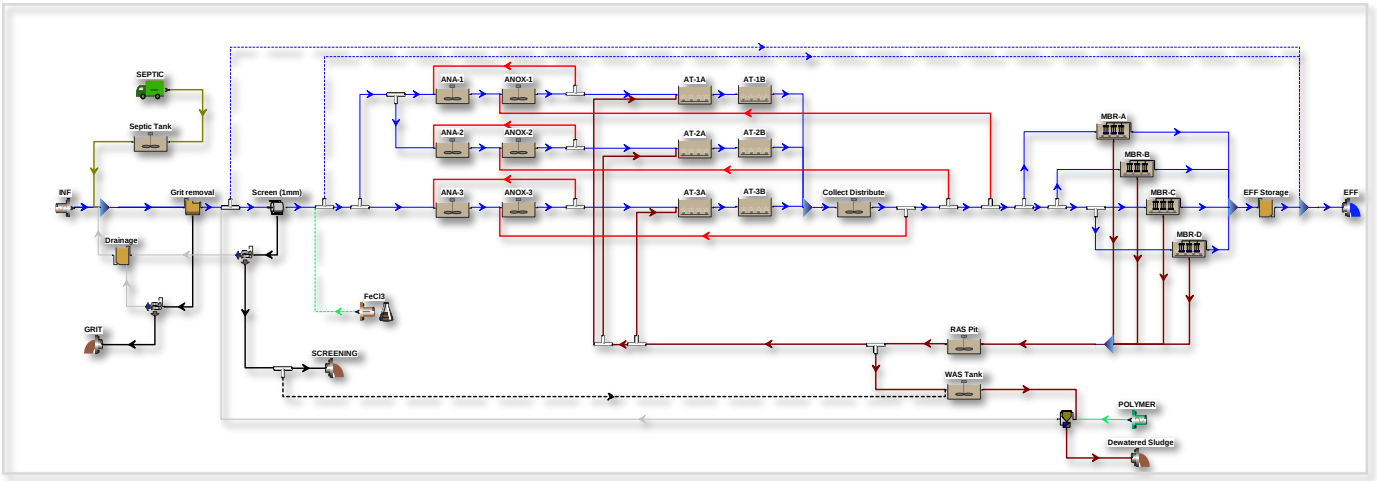


Figure 53. WWTP Poreč-North - BioWin model summer operation. All lines and MBRs are operated the whole year round. Dashed lines are bypasses not used/operated. No Iron is required. Screening is assumed to be stored separately from the dewatered sludge.

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 Poreč-South - Scenario Summer 2045 - Dynamic average effluent concentration (mg/L)			
EFF	Temperature	Concentration	20,0
EFF	COD - Total	Concentration	36,1
EFF	N - Total N	Concentration	8,6
EFF	P - Total P	Concentration	0,1
EFF	Total suspended solids	Concentration	1,3

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

WWTP Poreč-South - Scenario Summer 2045 - Dynamic average Air flow rate (m3/h)			
AT-1A	Air flow rate	Flow	428,8
AT-1B	Air flow rate	Flow	703,6
AT-2A	Air flow rate	Flow	428,8
AT-2B	Air flow rate	Flow	703,5
AT-3A	Air flow rate	Flow	428,8
AT-3B	Air flow rate	Flow	703,6
AT-4A	Air flow rate	Flow	428,8
AT-4B	Air flow rate	Flow	703,6
MBR-A	Air flow rate	Flow	980,0
MBR-B	Air flow rate	Flow	980,0

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

WWTP Poreč-South - Scenario Summer 2045 - Dynamic average Flows (m3/d)			
ANA-R1	Flow (S)	Flow	2.050,0
ANA-R2	Flow (S)	Flow	2.050,0
ANA-R3	Flow (S)	Flow	2.050,0
ANA-R4	Flow (S)	Flow	2.050,0
ANOX-R1	Flow (S)	Flow	22.140,0
ANOX-R2	Flow (S)	Flow	11.070,0
ANOX-R3	Flow (S)	Flow	5.535,0
ANOX-R4	Flow (S)	Flow	5.535,0
AS Emergency Bypass	Flow (S)	Flow	0,0
Dewatering Centrifuge	Flow (U)	Flow	8,3
Grit removal	Flow (U)	Flow	0,7
MBR-A	Flow (U)	Flow	11.108,6
MBR-B	Flow (U)	Flow	11.108,6
MBR-C	Flow (U)	Flow	11.108,6
Screen (1mm)	Flow (U)	Flow	1,3
Screen Emergency Bypass	Flow (S)	Flow	2,9

Table 10. Dynamic average SRT and HRT simulation results

WWTP Poreč-South - Scenario Summer 2045 - Dynamic average SRT and HRT		
Temperature	20	°C
Average waste sludge production	1908,6	kgTSS/d
SRT Total	15,0	d
SRT Aerobic	7,5	d
SRT AT+ANOX	10,3	d
WAS Tank HRT	2,2	hour
ANA HRT to influent	2,8	hour

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

WWTP Poreč-South - 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	24,5
POLYMER	Flow	Flow	1,8

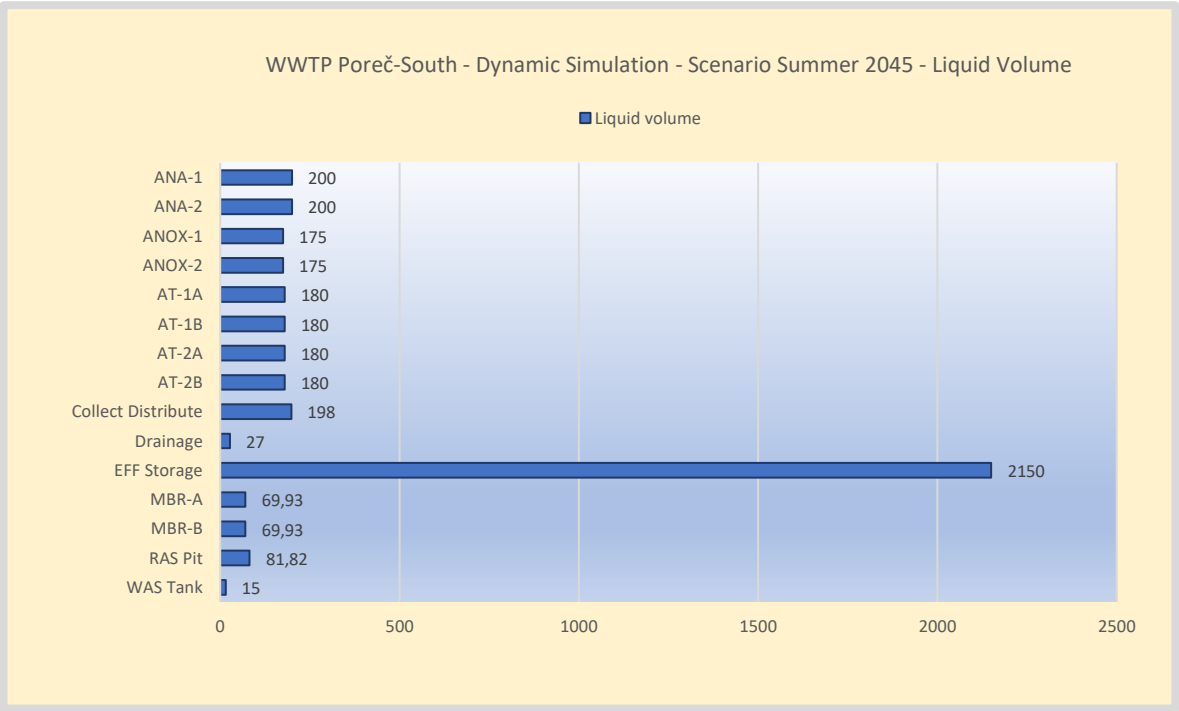


Figure 54. Simulation WWTP Poreč-North - Scenario Summer 2045 - Volume distribution of modelled reactor elements. The actual WAS tank is 150 m3 however the sludge volume is modelled based on an HRT less than 2,5 hours to avoid P-release. From the model it is concluded the WAS tank should not be used for storage of Bio-P sludge.

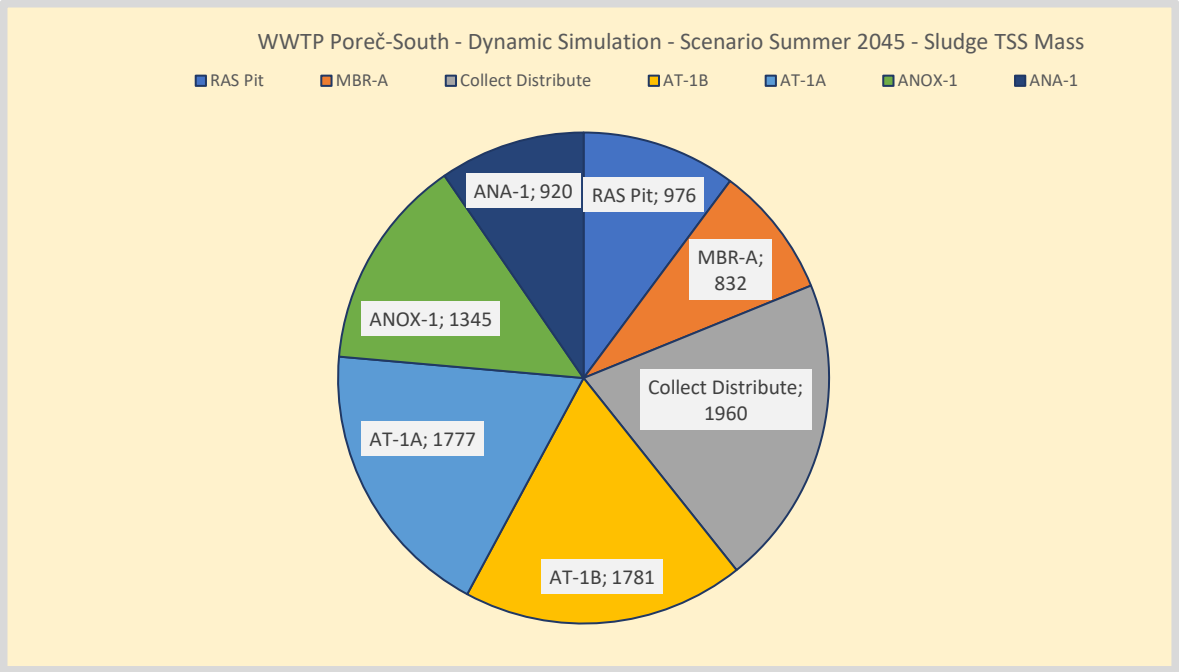


Figure 55. Simulation WWTP Poreč-North - Scenario Summer 2045 - Sludge mass distribution (kgTSS) in the activated sludge reactors. This data is used to calculate the SRT of the WWTP. Idle reactors containing sludge are not included in SRT calculations.

6.3 Process controllers: Summer

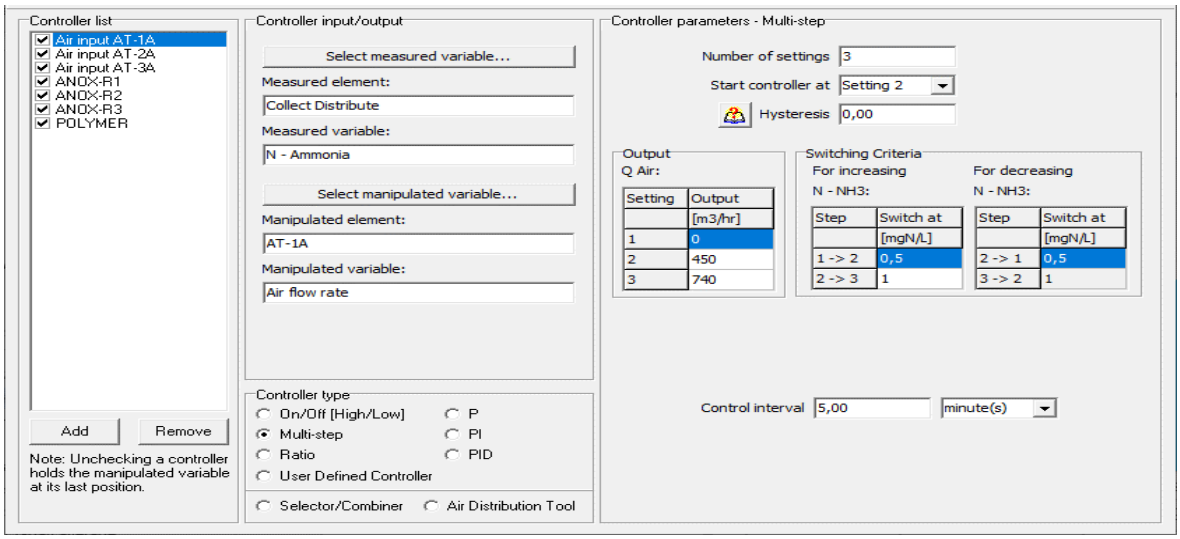


Figure 56. Simulation WWTP Poreč-North - Scenario Summer 2045 - Controlling the air input of AT-A. The measured variable is NH4 in the collect distribute tank. The manipulated variable the air flow in AT-A. There are 3 settings for the air flow depending on the NH4 concentration.

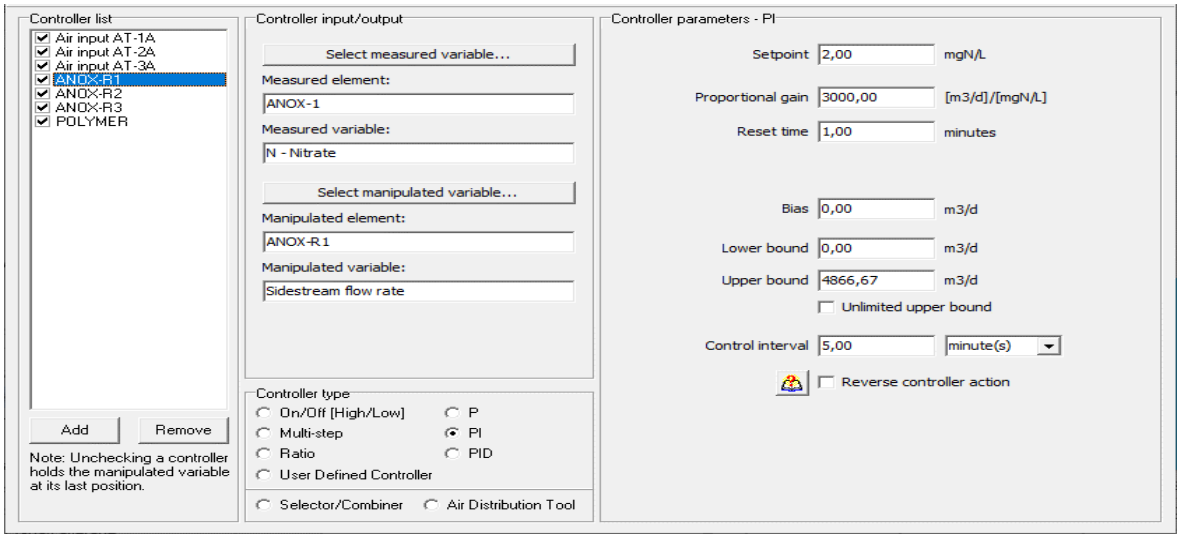


Figure 57. Simulation WWTP Poreč-North - Scenario Summer 2045 - Controlling the anoxic recycle ANOX-R. Indicated are the measured variable being NO3 in the anoxic tank and manipulated variable the recycle flow ANOX-R. The PI controller has an upper bound equal to the maximum installed pump capacity per lane.

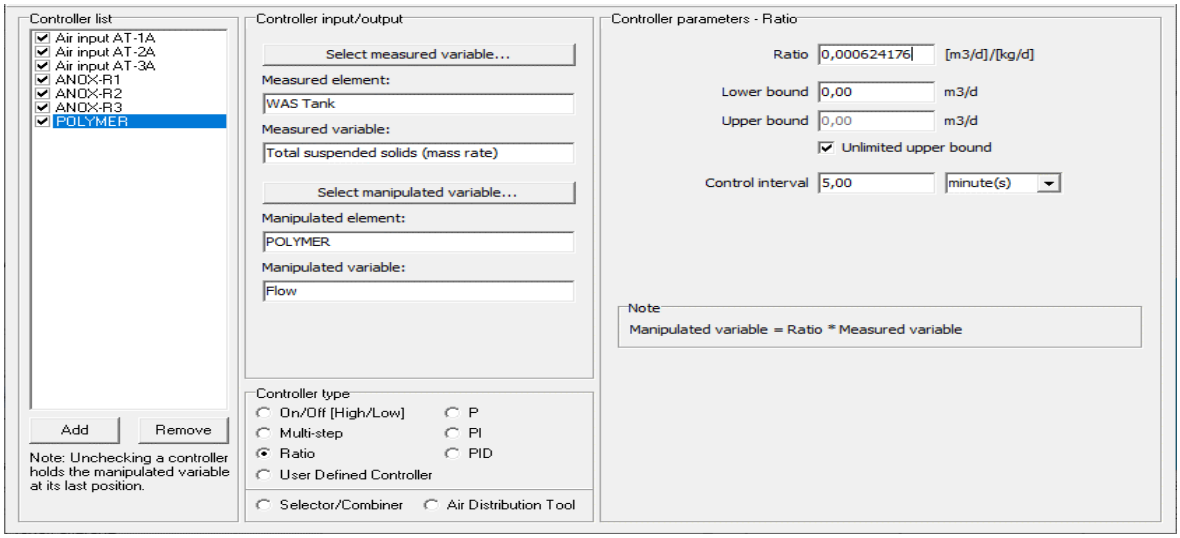


Figure 58. Simulation WWTP Poreč-North - Scenario Summer 2045 - Controlling the polymer dosage of the dewatering. Indicated are the measured variable being the TSS load entering the dewatering and manipulated variable the PE flow. The applied control ratio is 8 kg PE per 1000 kg TSS based on dry weight. PE is assumed to be particulate substrate with a COD/VSS ratio of 1,42.

6.4 Influent modelling results

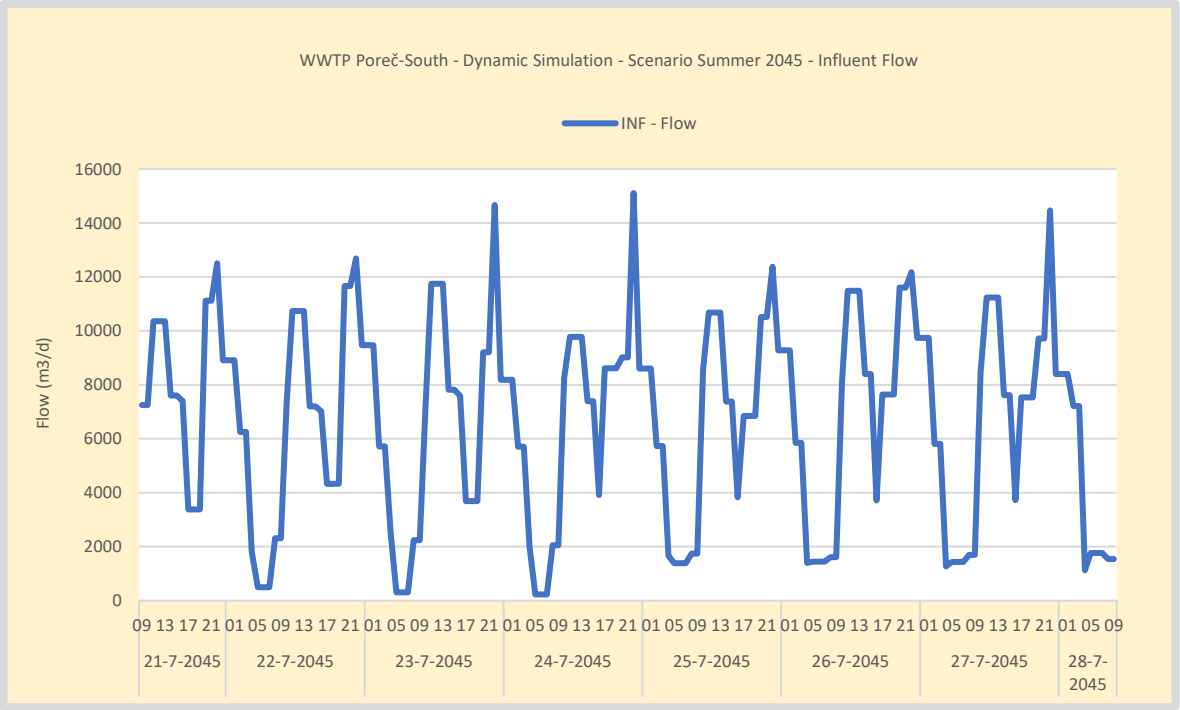


Figure 59. Simulation WWTP Poreč-North - Scenario Summer 2045 - Influent flow. No rain event occurred.

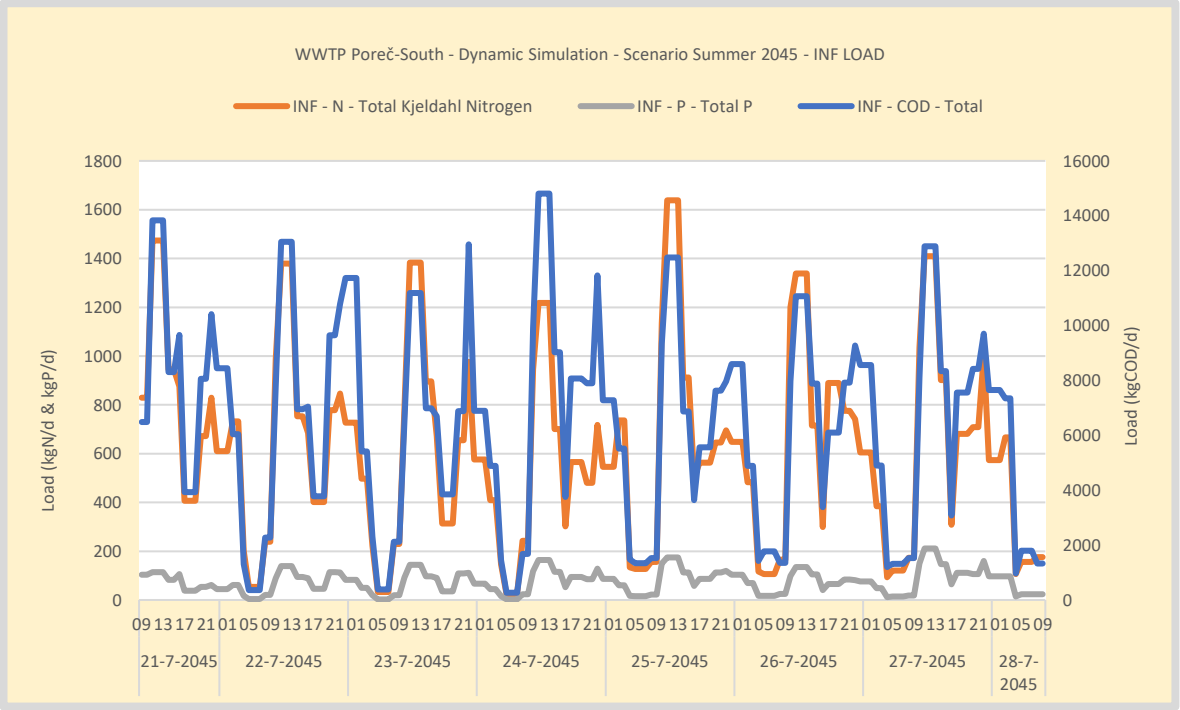


Figure 60. Simulation WWTP Poreč-North - Scenario Summer 2045 - Influent loads COD, TKN and TP. There are no rain events in the summer data.

6.5 Process and recycle flows modelling results

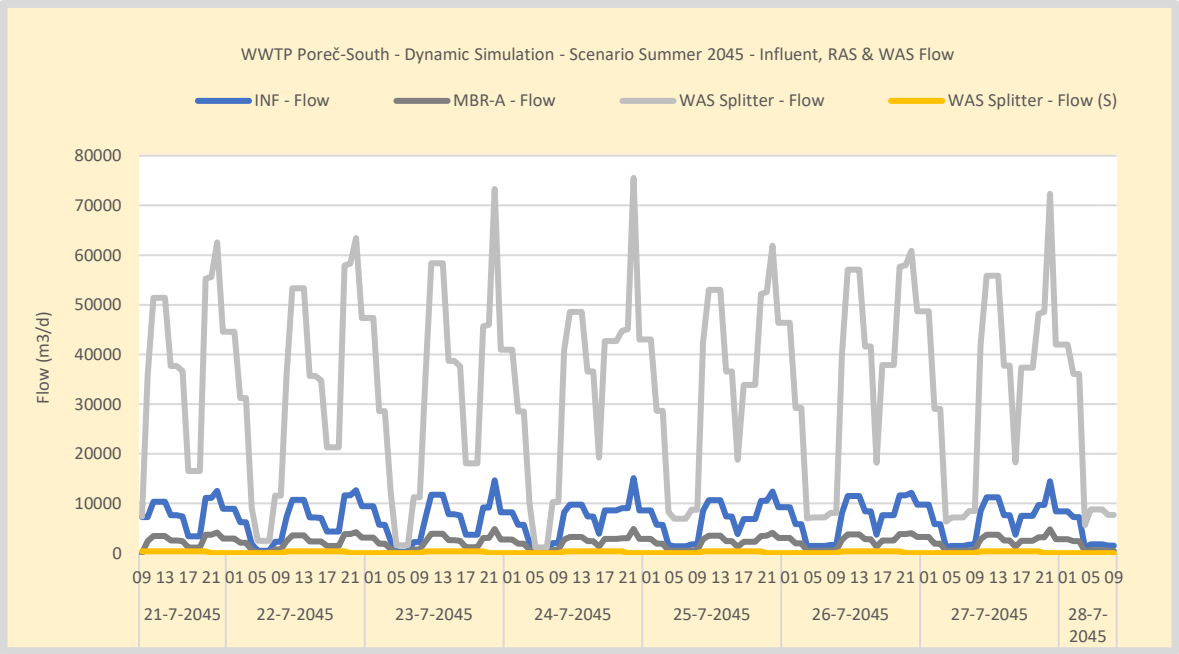


Figure 61. Simulation WWTP Poreč-North - Scenario Summer 2045 - flow rate settings and control. The MLSS sludge return flow is controlled proportional to the influent. The WAS flow is time controlled and operated 10 hours a day on a constant flow.

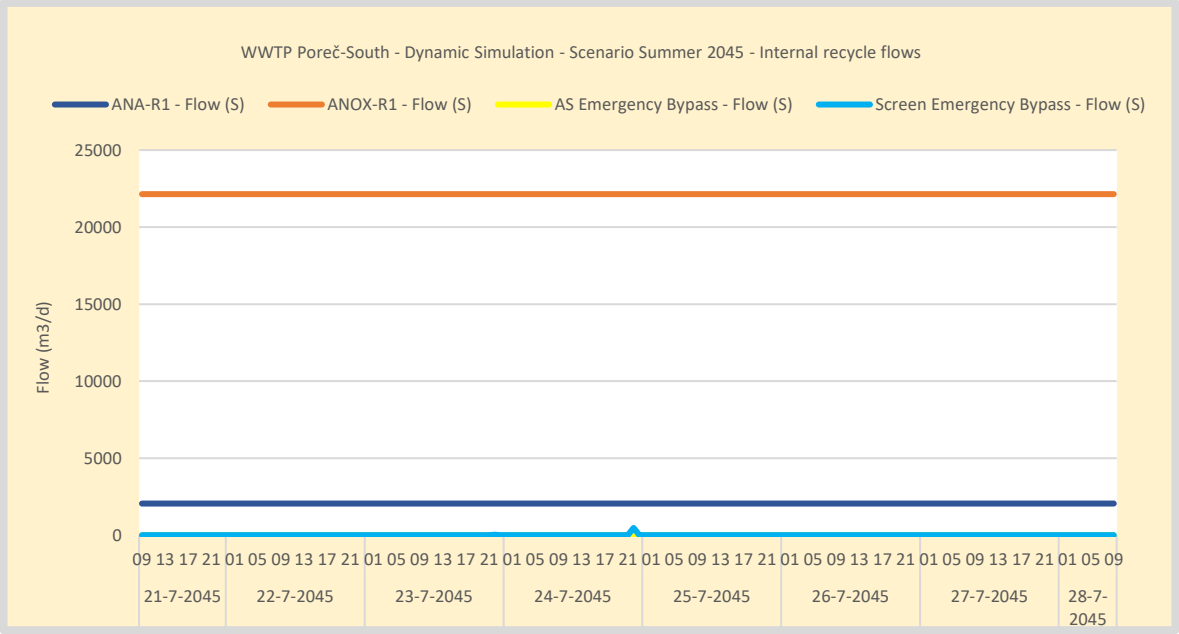


Figure 62. Simulation WWTP Poreč-North - Scenario Summer 2045 - flow rate settings and control. The anoxic recycle is controlled based on nitrate in the anoxic tank. This setpoint cannot be reached resulting in maximum recirculation during the whole period of operation. This indicates that the recycle flow is limiting or the anoxic tank is designed too large. The anaerobic recycle is set to its maximum value to minimize the decay of nitrification capacity and reduce anaerobic HRT.

6.6 Waterline operation modelling results

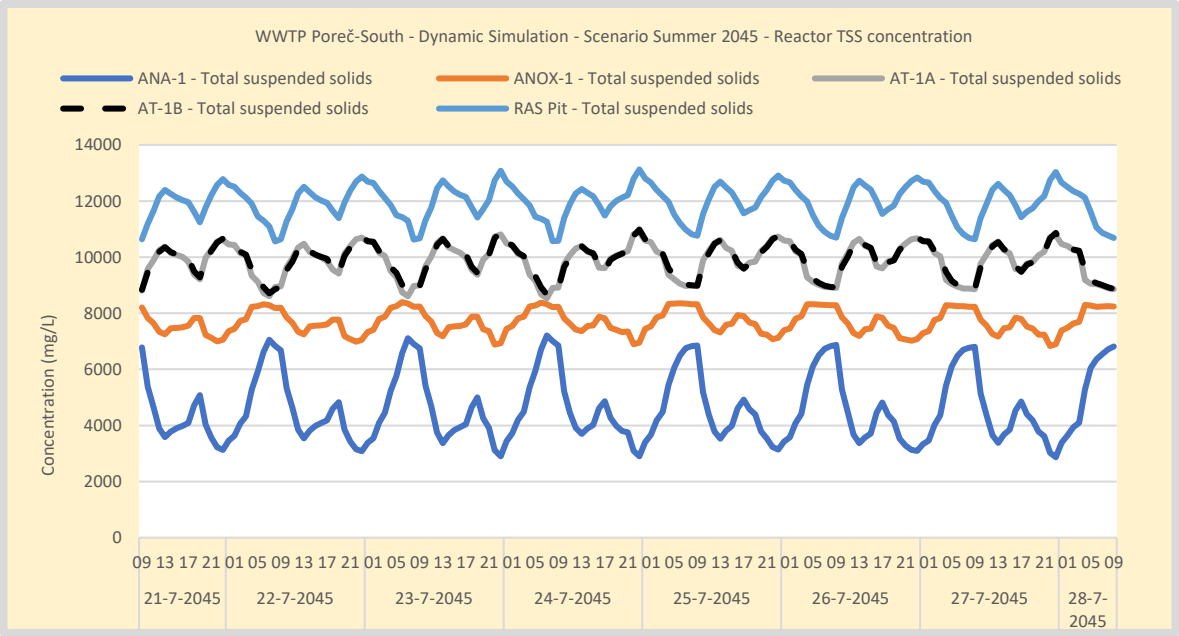


Figure 63. Simulation WWTP Poreč-North - Scenario Summer 2045 - TSS profile in the waterline. TSS in the MBR is controlled on approximately 12 gTSS/L by adjusting the WAS flow and by maintaining a high MLSS recycle from the MBR. SRT is sufficient for summer operation and according to the design. Minimum aerobic SRT excluding the MBR is 6,4 days. Classic SRT including the anoxic 8,6 days.

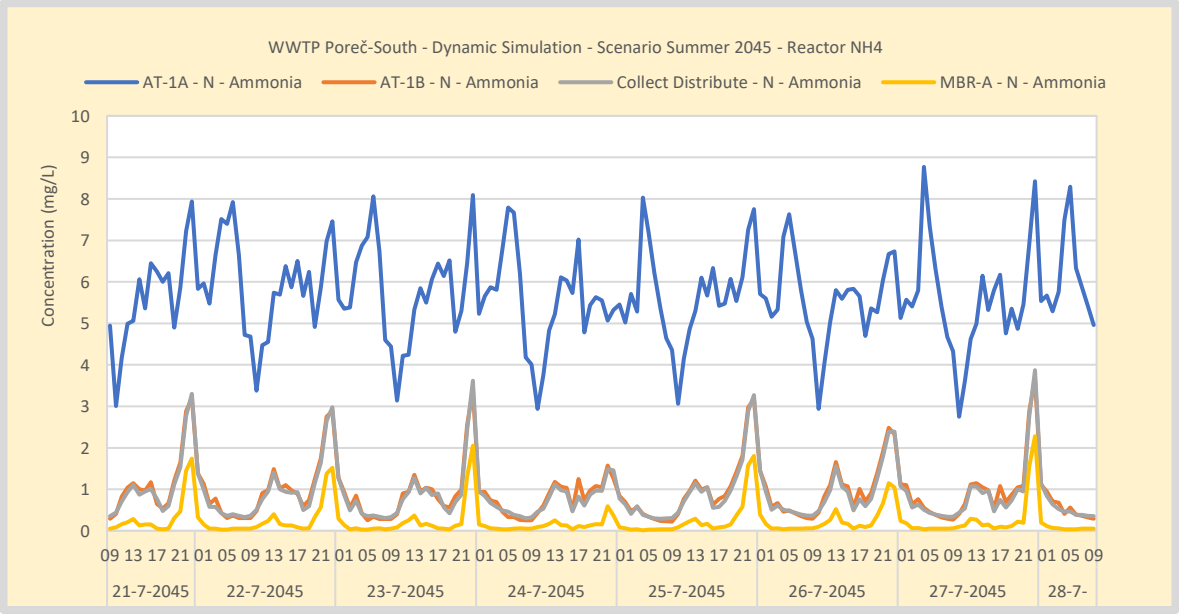


Figure 64. Simulation WWTP Poreč-North - Scenario Summer 2045 - ammonium profile in the waterline. The air input of AT-A is controlled based on NH4 in the collect distribute tank using a 3-step controller. Above 1,0 mgNH4/L the air input goes to its maximum value. Below 0,5 air shuts off. AT-B is DO controlled on 3,0 mgO2/L. During the daily peak loading at 13:00 hour the nitrification capacity is limiting and NH4 accumulates. This is the result of too long anaerobic HRT and decay of biomass. Under normal conditions 6,4 days aerobic SRT at 20 C is more than sufficient.

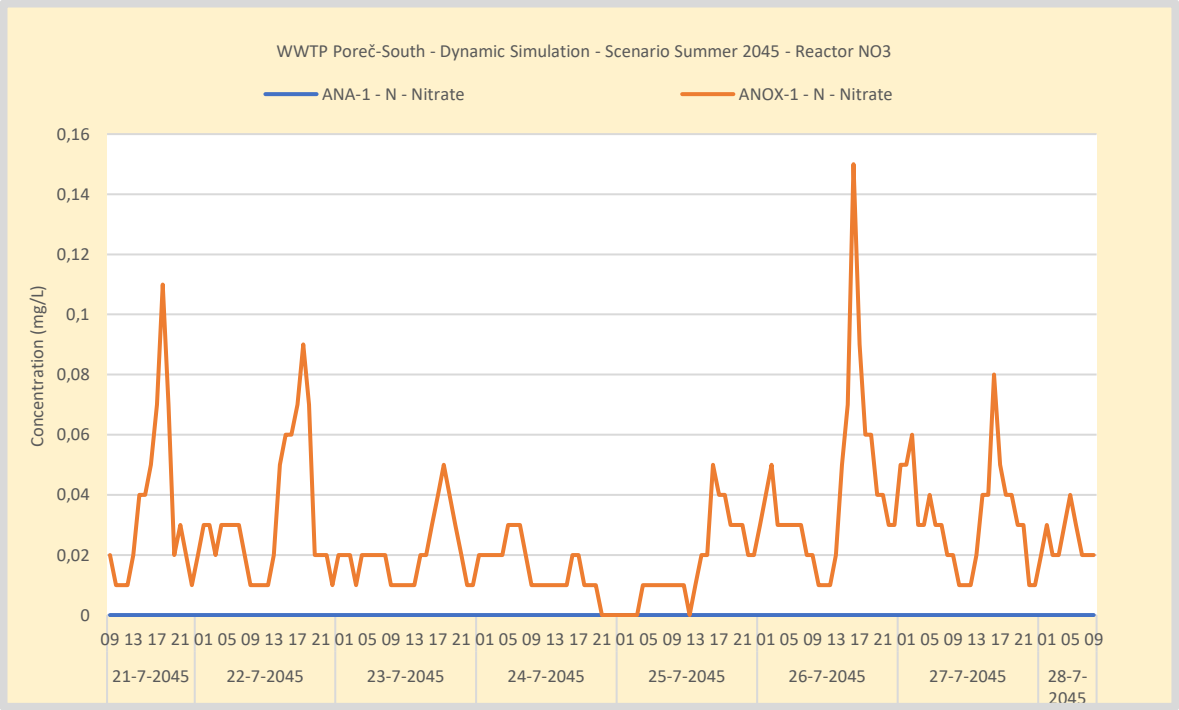


Figure 65. Simulation WWTP Poreč-North - Scenario Summer 2045 - nitrate in the anoxic tank. The anoxic recycle rate is controlled on a nitrate setpoint of 2 mgNO3/L in the anoxic tank. Internal recycle capacity is not sufficient to reach this setpoint.

6.7 Waterline concentration profiles modelling results

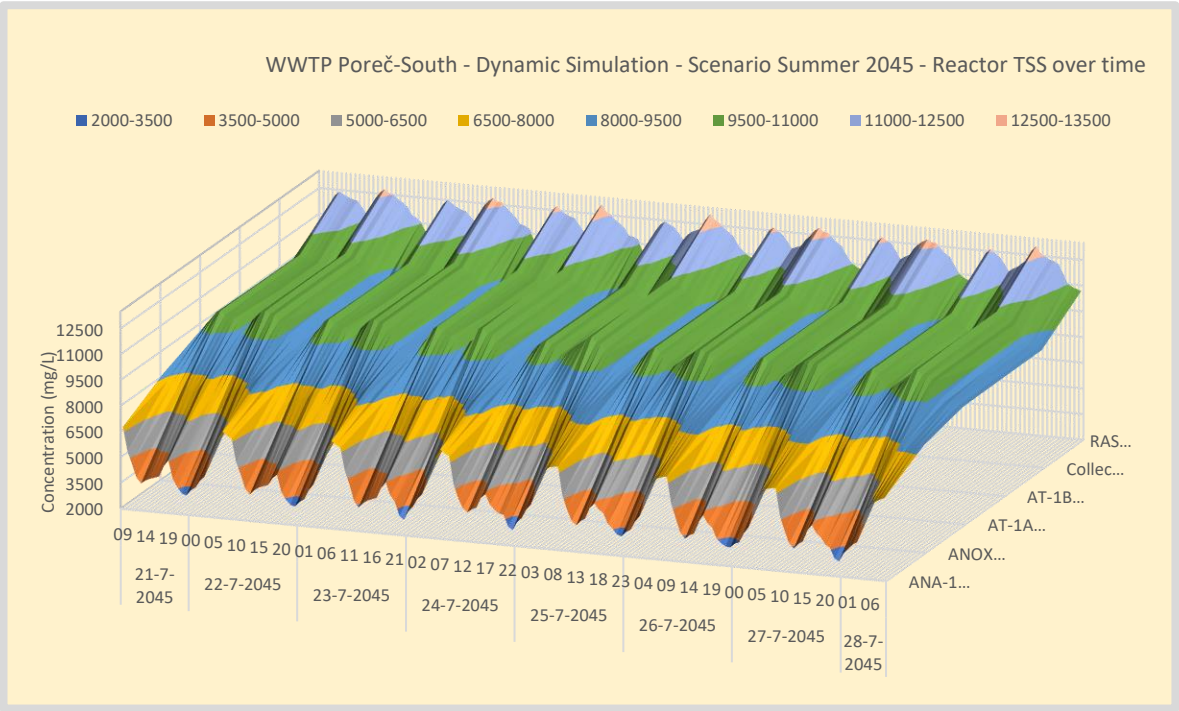


Figure 66. Simulation WWTP Poreč-North - Scenario Summer 2045 - TSS concentration profile over the waterline.

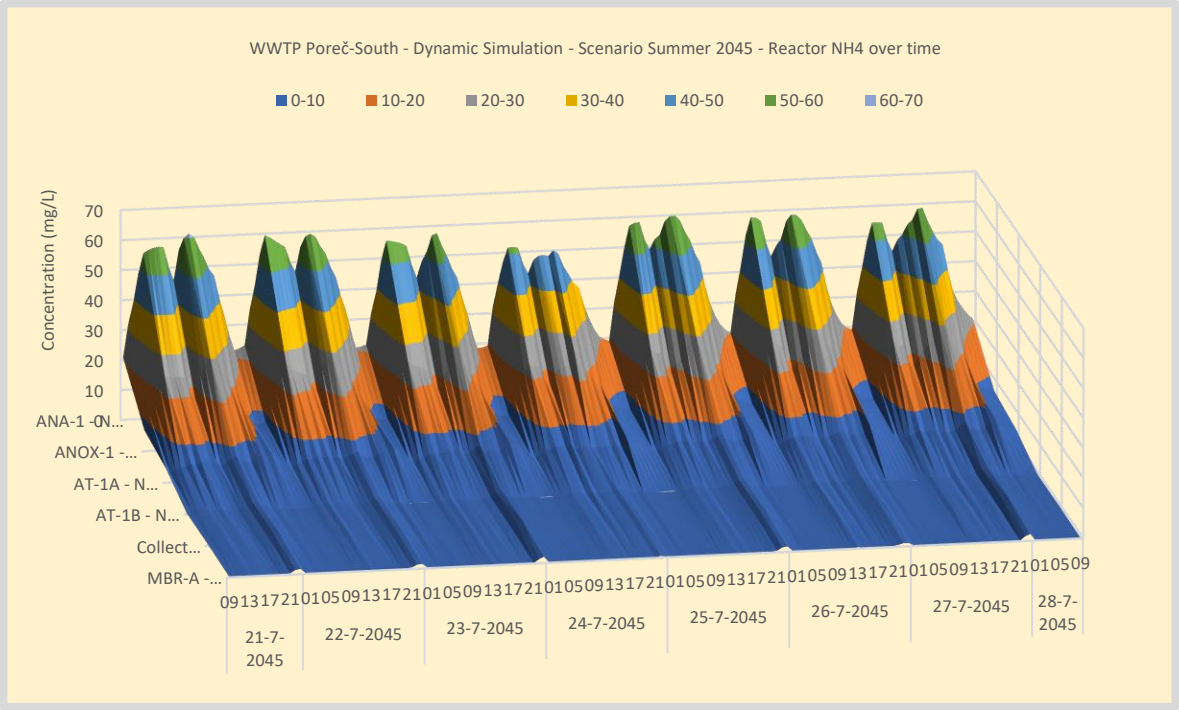


Figure 67. Simulation WWTP Poreč-North - Scenario Summer 2045 - NH4 concentration profile over the waterline.

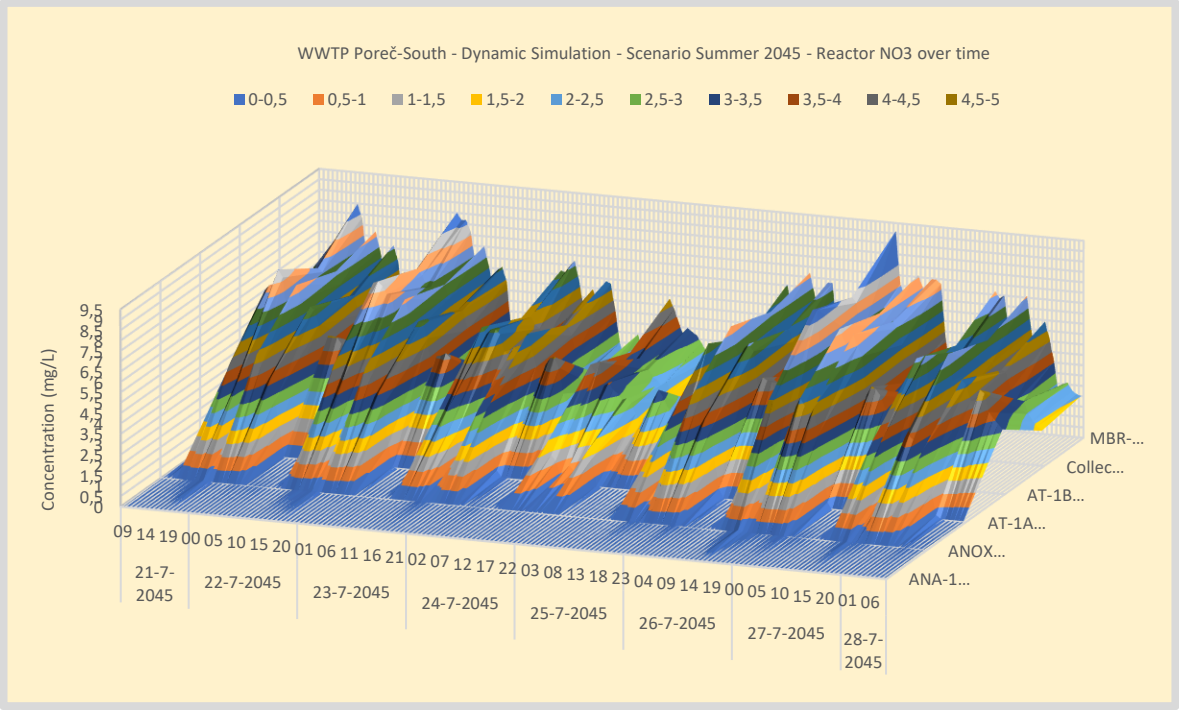


Figure 68. Simulation WWTP Poreč-North - Scenario Summer 2045 - NO3 concentration profile over the waterline.

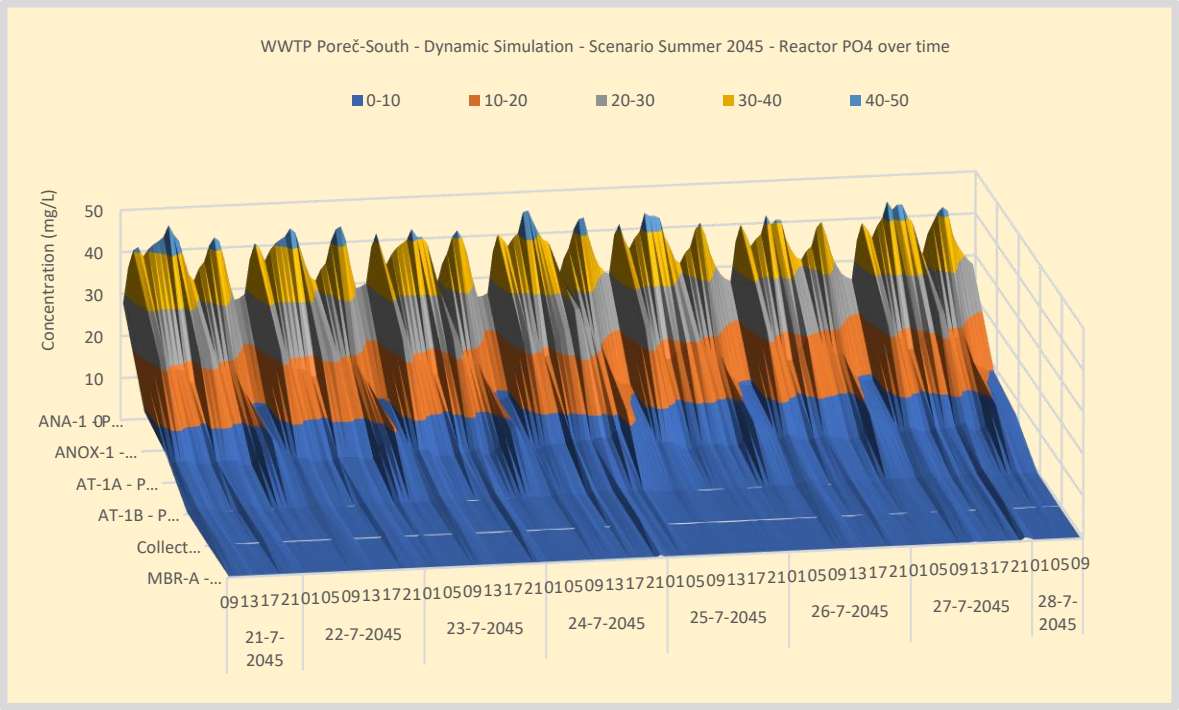


Figure 69. Simulation WWTP Poreč-North - Scenario Summer 2045 - PO4 concentration profile over the waterline.

6.8 Aeration and DO concentration modelling results

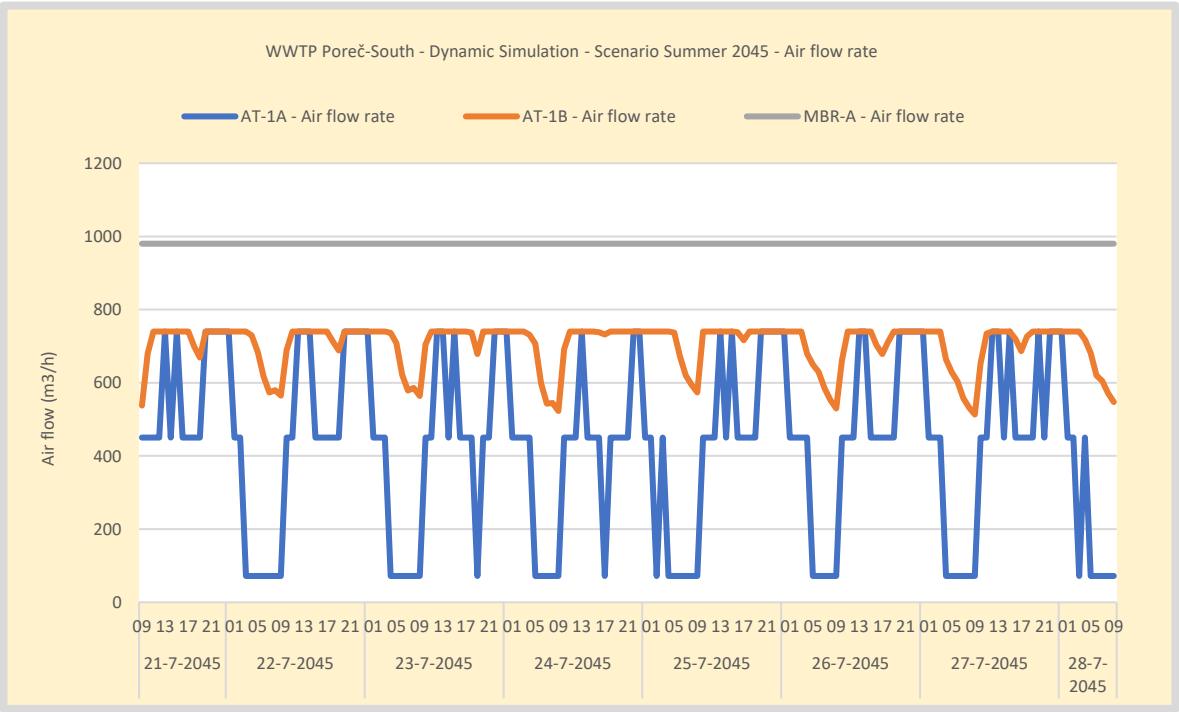


Figure 70. Simulation WWTP Poreč-North - Scenario Summer 2045 - air input in the different aerated reactors. AT-A is step controlled on NH4 in the outflow of AT-B. AT-B is setpoint controlled on the DO on 3 mgO2/L. This setpoint cannot be reached and the controller is at maximum air flow. The MBR is aerated to its maximum design capacity.

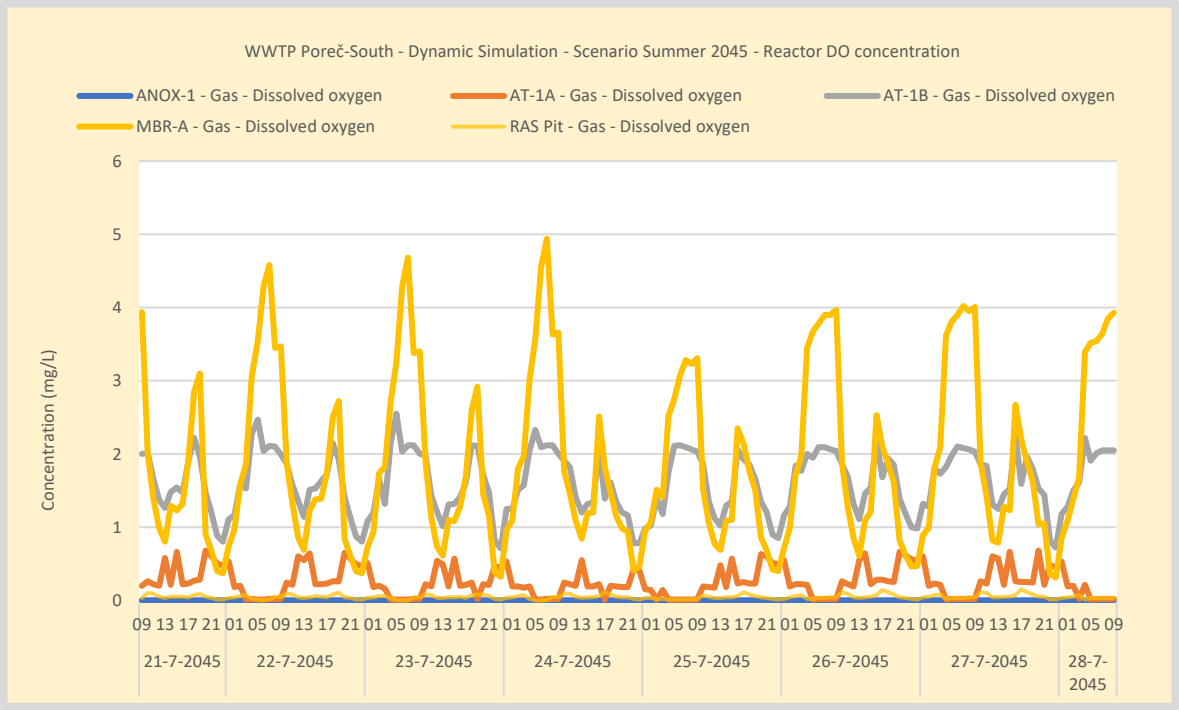


Figure 71. Simulation WWTP Poreč-North - Scenario Summer 2045 - DO concentration gradients. DO is controlled in the AT-B on 3 mgO2/L and the air flow of AT-B on NH4 concentration in the outflow of the aeration. During influent TKN peak loading the air flow of AT-B is not sufficient to maintain the DO setpoint. The DO in the MBR is the result of the designed maximum air input. No oxygen is observed in the anoxic zone.

6.9 pH and alkalinity modelling results

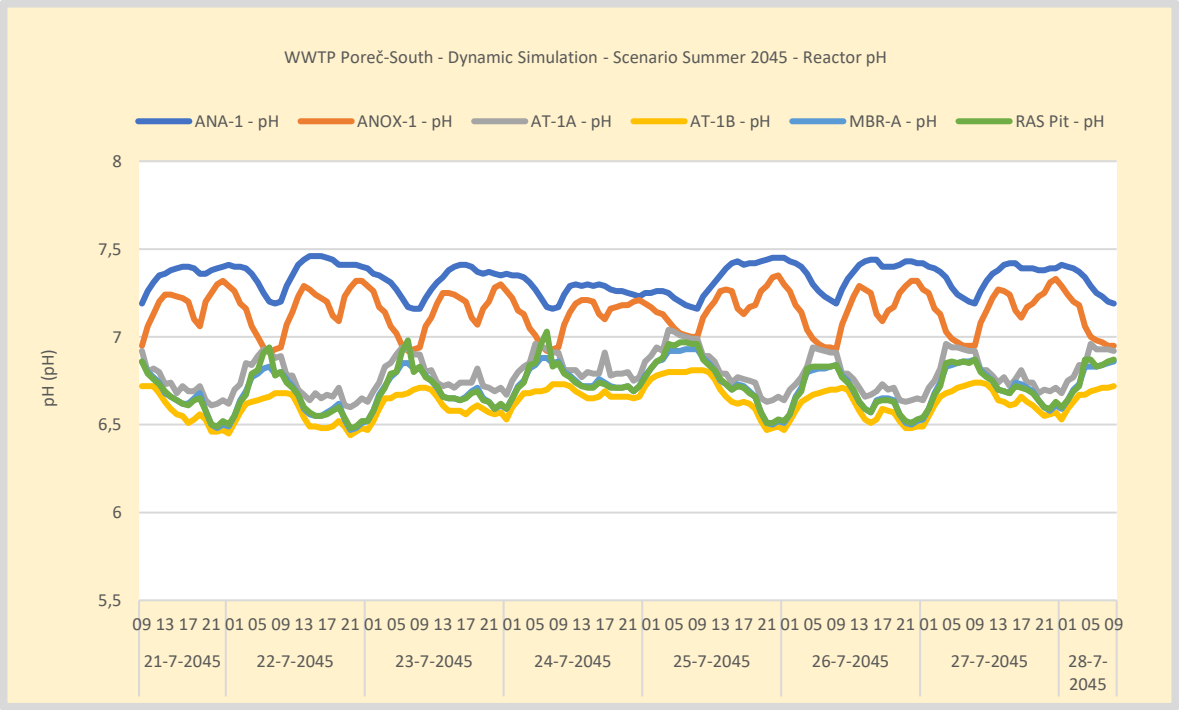


Figure 72. Simulation WWTP Poreč-North - Scenario Summer 2045 - pH profile over the activated sludge reactors. Influent pH is measured continuously and not limiting.

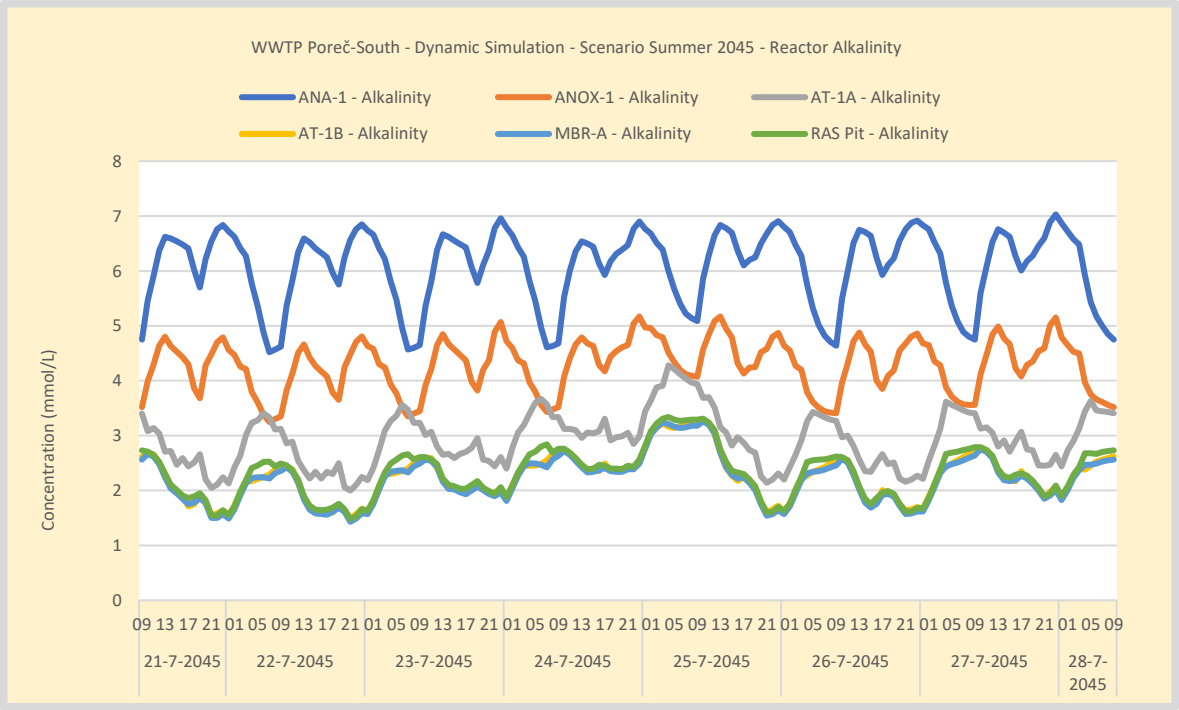


Figure 73. Simulation WWTP Poreč-North - Scenario Summer 2045 - alkalinity profile over the activated sludge reactors. Influent alkalinity is estimated from local drinking water quality measurements at 7,46 mmol/L. Alkalinity drops occur however alkalinity is unlikely to become limiting.

6.10 Chemical load and flow modelling results

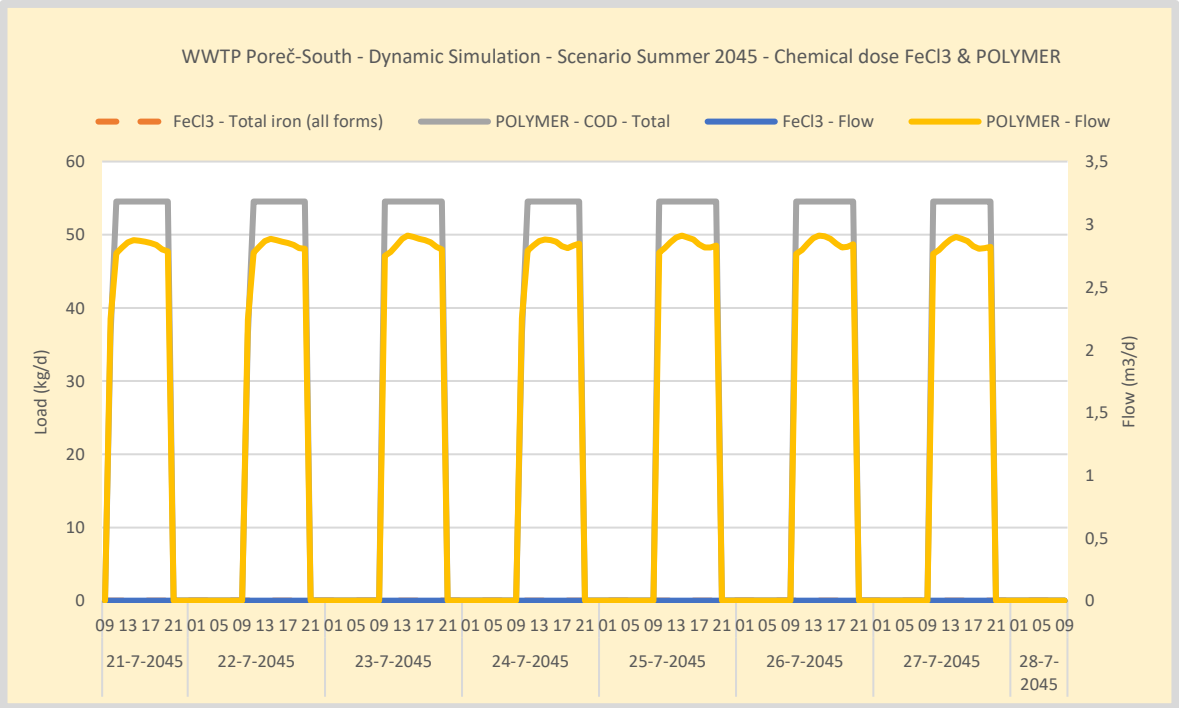


Figure 74. Simulation WWTP Poreč-North - Scenario Summer 2045 - load and flow of Iron and PE. No iron is dosed. PE is assumed particulate biodegradable COD with a COD/VSS ratio of 1,42 gCOD/gTSS and dosed proportional to the WAS load based on 8 kg PE (dry weight) dosed per 1000 kg WAS (dry weight) flowing in the dewatering.

6.11 Sludge line operation modelling results

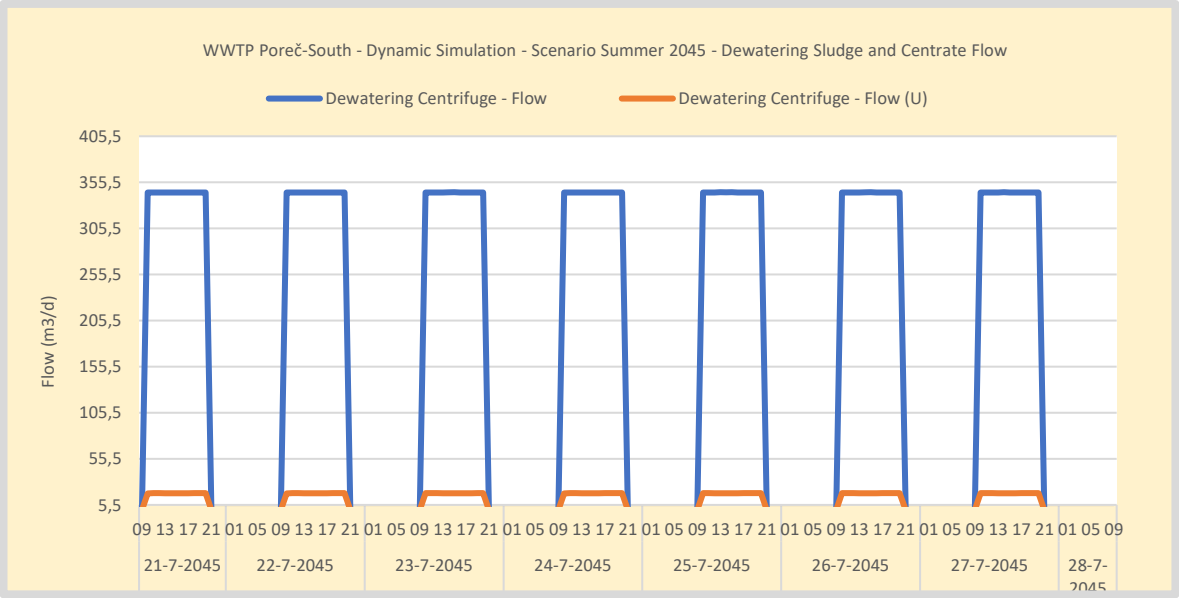


Figure 75. Simulation WWTP Poreč-North - Scenario Summer 2045 - dewatered sludge and centrate flow. Dewatering is operated 10 hours per day 7 days per week.

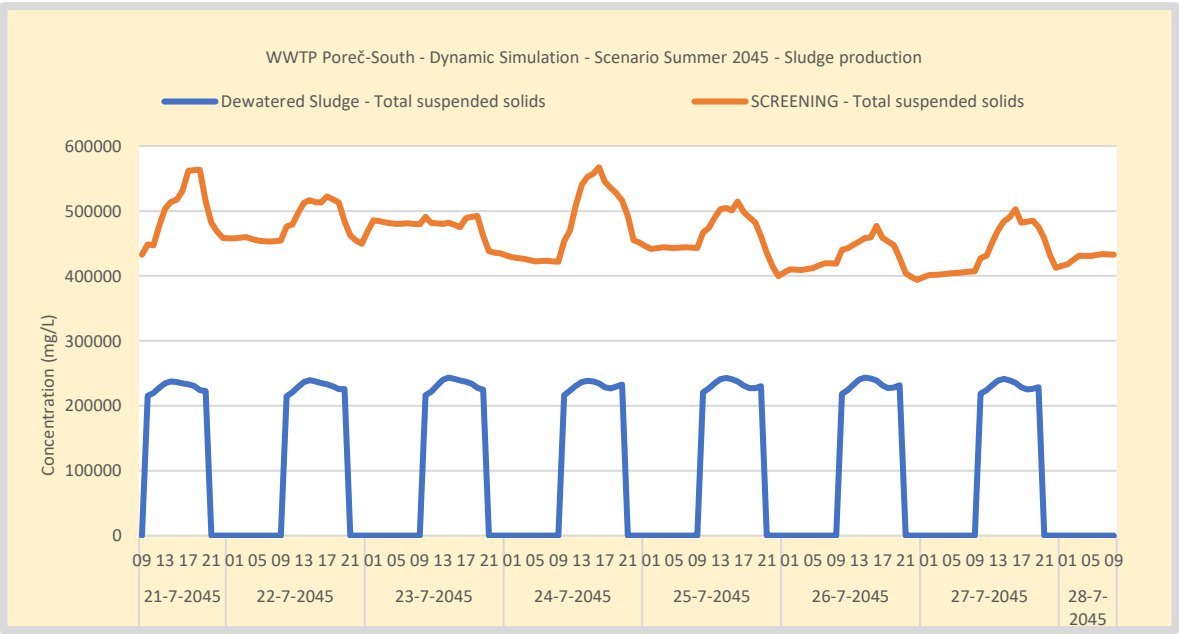


Figure 76. Simulation WWTP Poreč-North - Scenario Summer 2045 - dewatered sludge and screening sludge concentration. The design assumes dewatered sludge at 23% dry matter. Screening is an estimated concentration as the result of the press operation.

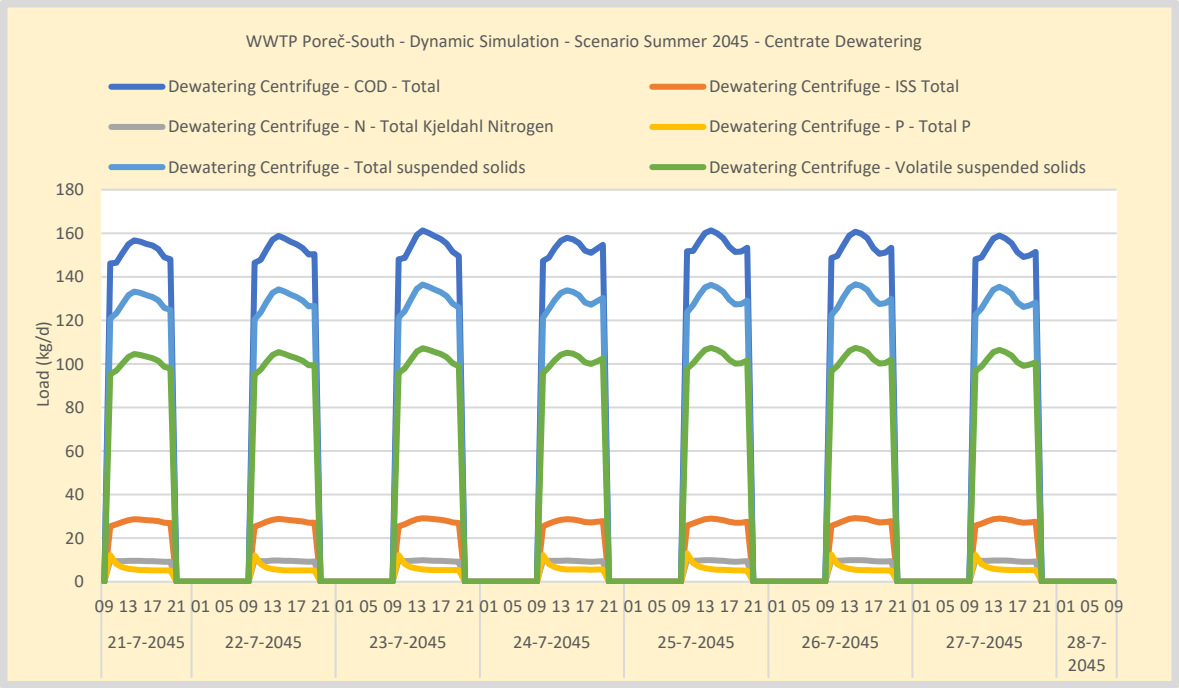


Figure 77. Simulation WWTP Poreč-North - Scenario Summer 2045 - Centrate load dewatering. Centrate is fed back to the waterline in the dirty water.

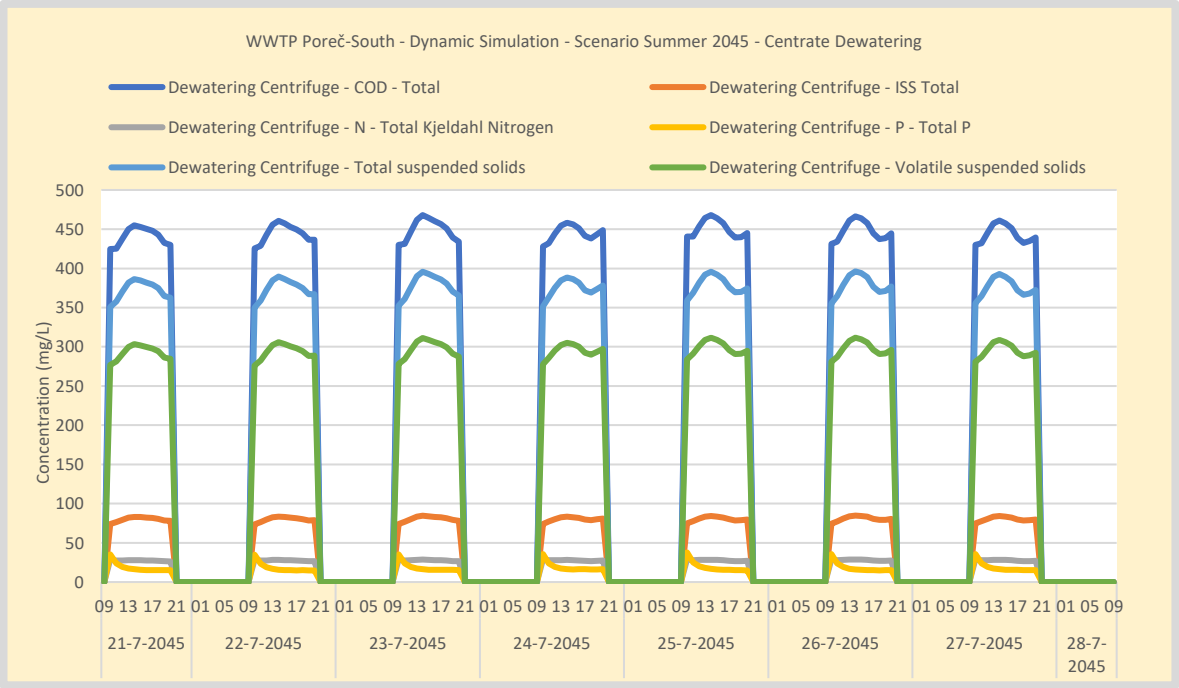


Figure 78. Simulation WWTP Poreč-North - Scenario Summer 2045 - Centrate concentrations dewatering. P-in the centrate is limited by reducing the storage time in the WAS tank.

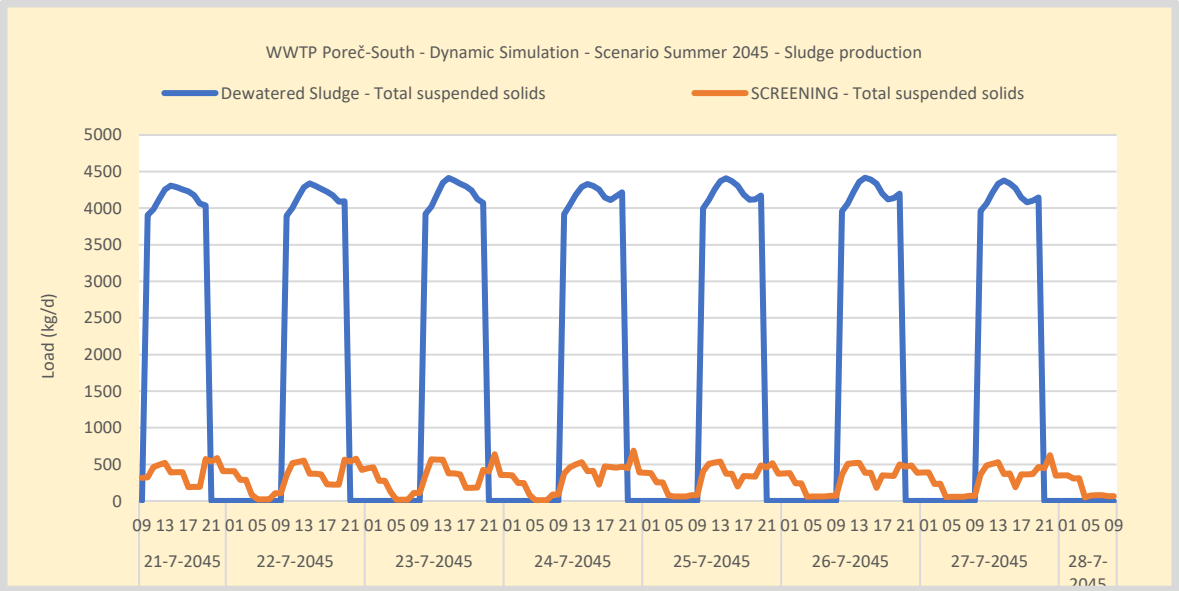


Figure 79. Simulation WWTP Poreč-North - Scenario Summer 2045 - dewatered sludge load and compacted screening load. Dewatered sludge is operated 10 hours a day at 23%. Screening is produces continuously as a factor of the influent and stored separately from the dewatered sludge.

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.

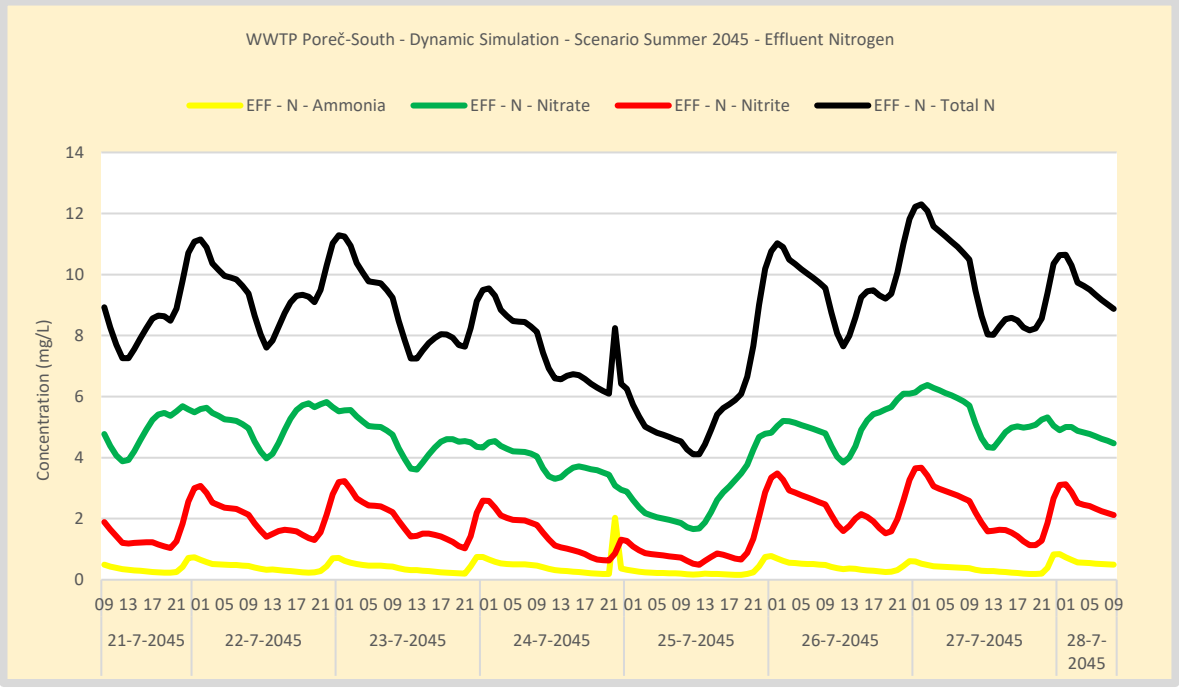


Figure 80. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent nitrogen concentration. Effluent is measured in the outflow of the large effluent buffer. Some Nitrite is produced indication limiting aeration capacity during peak loading. The average effluent concentration is below the maximum requirement.

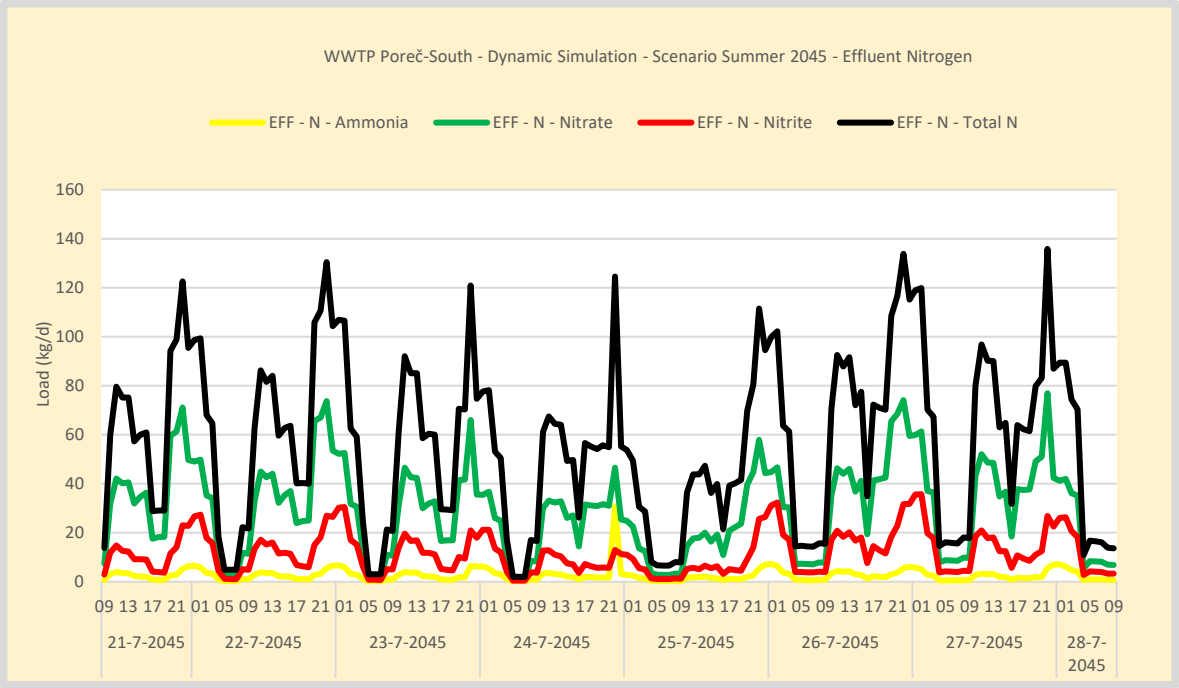


Figure 81. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent nitrogen load. Effluent is measured in the outflow of the large effluent buffer causing the increasing nitrogen buildup. Fluctuations are mainly the result of flow variation.

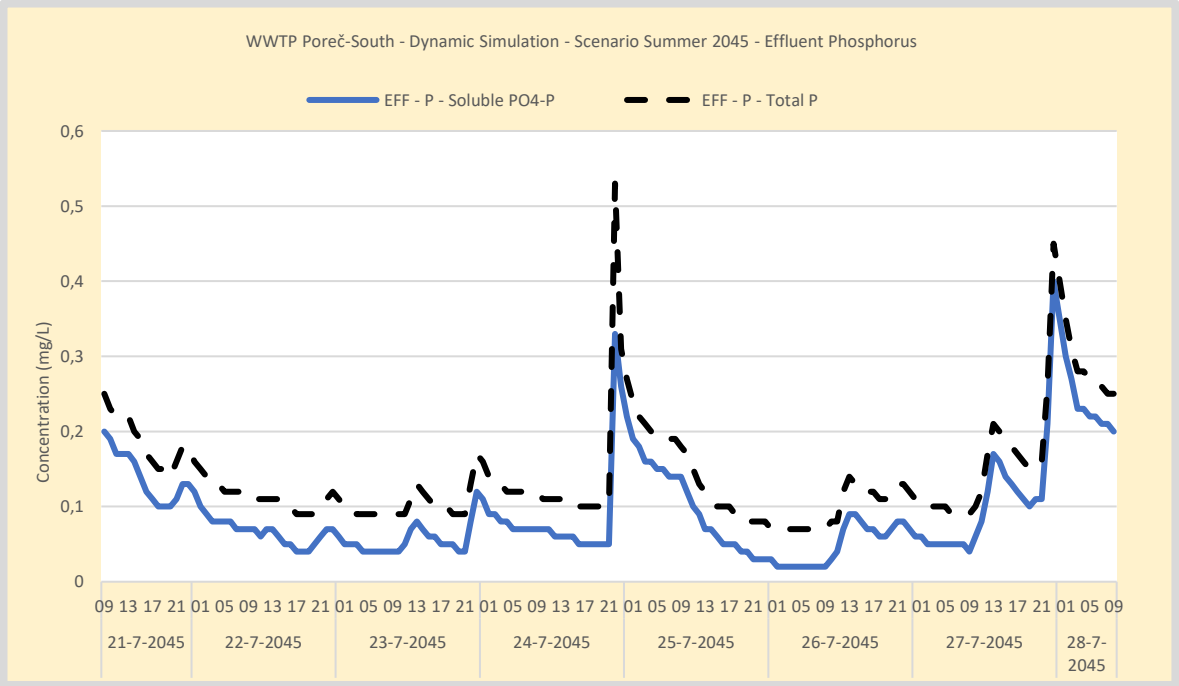


Figure 82. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent phosphorus concentration. No Iron is dosed. Effluent is measured in the outflow of the large effluent buffer. The average effluent concentration is below the maximum requirement. The peaks in the effluent are occurring when there is both low oxygen and nitrate in the activated sludge system. This reduces the P-uptake capacity.

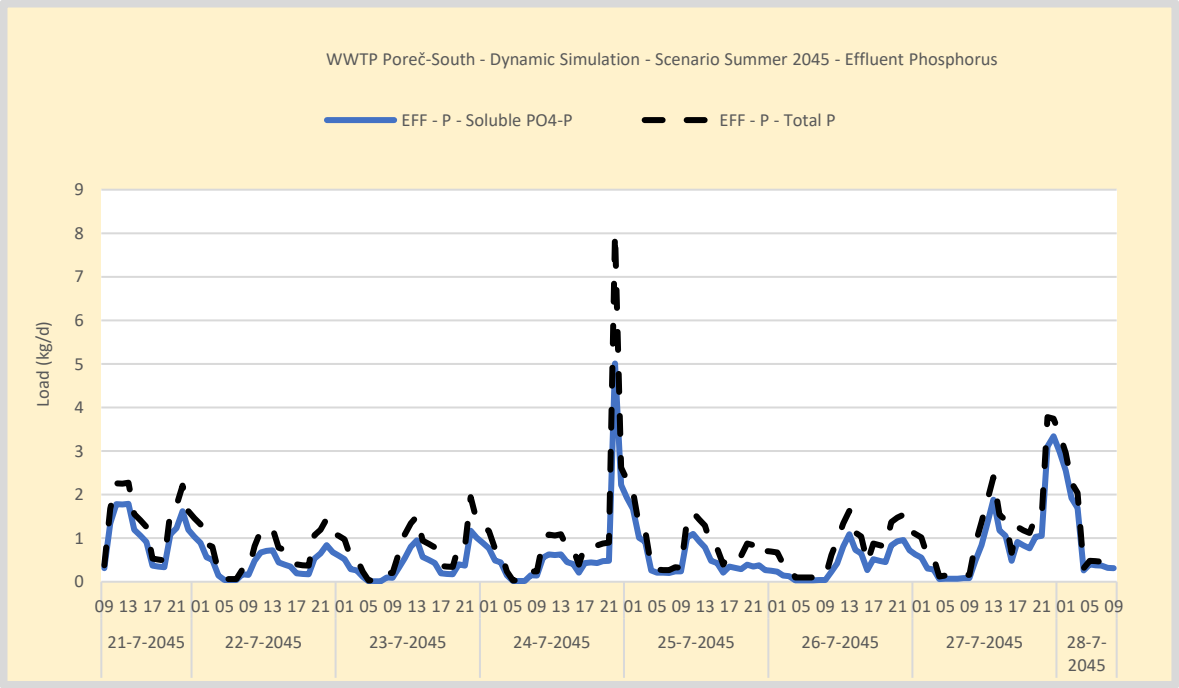


Figure 83. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent phosphorus load. No Iron is dosed. Effluent is measured in the outflow of the large effluent buffer. The peaks in the effluent are occurring when there is both low oxygen and nitrate in the activated sludge system. This reduces the P-uptake capacity.

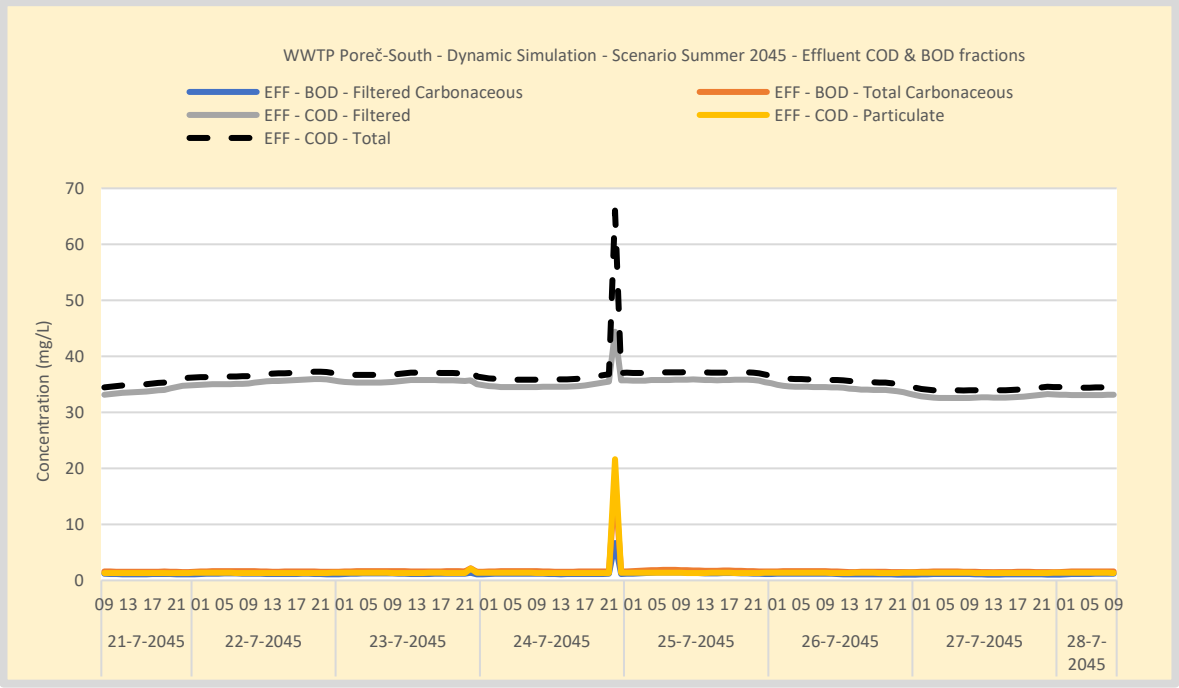


Figure 84. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent COD and BOD concentration. Effluent is measured in the outflow of the large effluent buffer. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Effluent is measured in the outflow of the large effluent buffer. The average effluent concentration is below the maximum requirement.

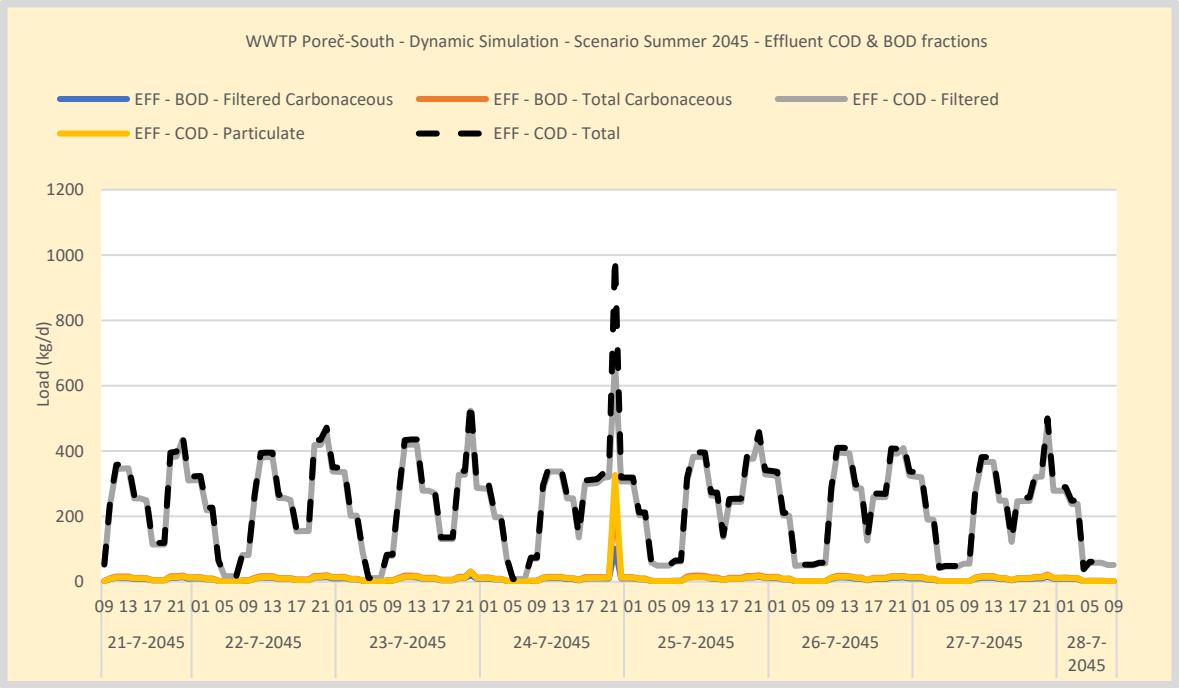


Figure 85. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent COD and BOD load. Effluent is measured in the outflow of the large effluent buffer. Variations in the load are largely the result of flow variations. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material.

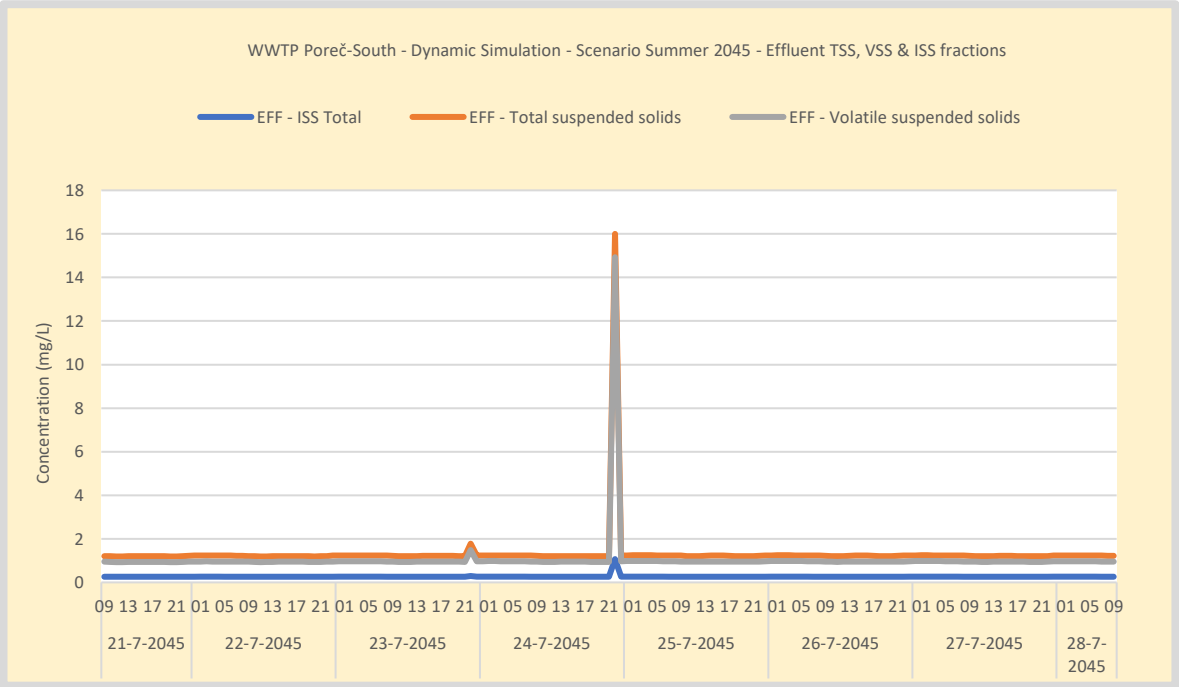


Figure 86. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent TSS, VSS and ISS concentration. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Load variations are mainly due to the flow. Effluent is measured in the outflow of the large effluent buffer reducing concentration variations.

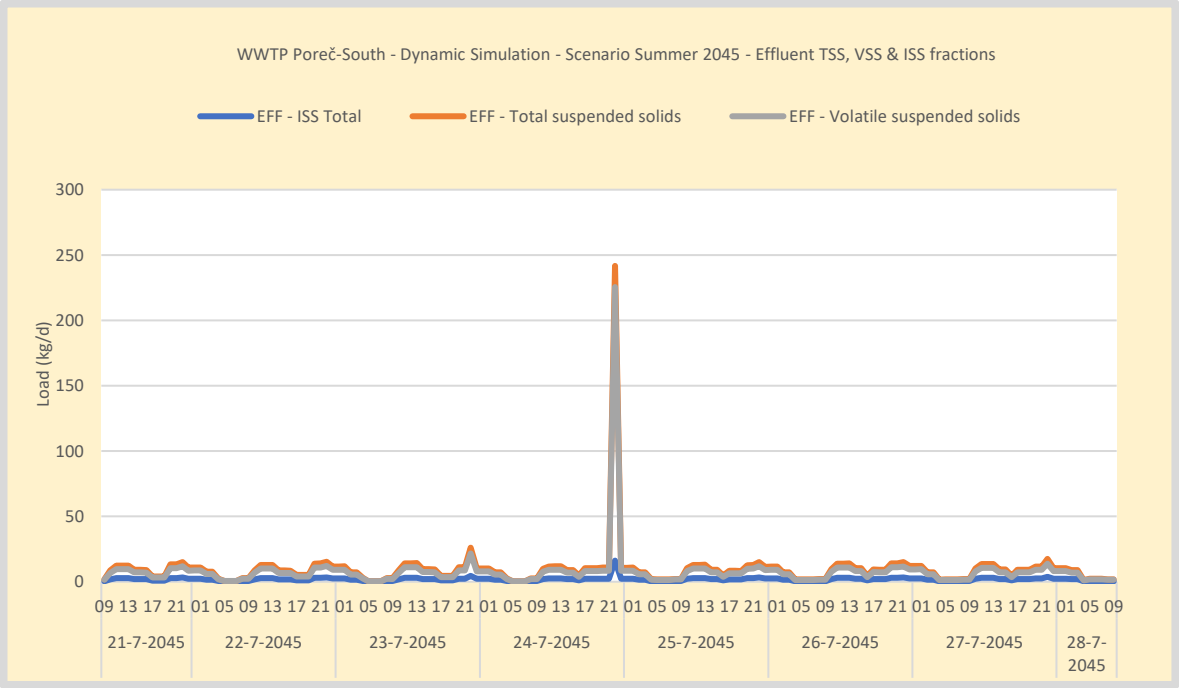


Figure 87. Simulation WWTP Poreč-North - Scenario Summer 2045 - Effluent TSS, VSS and ISS load. The Particulate fraction is the result of a MBR efficiency of 99,9% for particulate and 99,99% for colloidal material. Load variations are mainly due to flow variations. Effluent VSS is related to the fecal 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 aerobic SRT is limiting for nitrification during daily TKN peak loading casing temporarily accumulation of ammonium and nitrite (NO2). The airflow is limiting and likely the effective anaerobic HRT (which may include the anoxic when there is no nitrate) is too long resulting in decay of nitrification.

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 flow 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 reduce anaerobic conditions in the anoxic tanks.

Phosphorus is removed from the wastewater by Bio-P and without dosage of iron. During periods of low nitrate and low oxygen in the activated sludge tanks effluent P may peak.

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.

During summer no shortage of alkalinity is simulated and unlikely to become limiting under operated conditions. Influent alkalinity is an estimated value in the model based on the local drinking water quality.

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 effluent requirement for all parameters is within the required design limits. In the winter the capacity of the plant is however at its maximum limit for Bio-P and nitrification.
- The model is simulated based on typical default settings and no biological parameter adjustments are required to obtain these results.
- The model is simulated under dynamic conditions. For realistic scenario modelling, 2019 measured dynamic flow data is extrapolated towards loading conditions expected in the year 2045.
- Based on the 2019 dynamic flow profile on an hourly basis the flow is extrapolated towards 2045 by adding the estimated growth of households and tourist activity. This is adapted from the detailed design. It is assumed that the wastewater concentration, frequency of peak discharges and rain events do not change towards 2045.
- Simulations show that the design can treat wastewater to the desired level and that there is sufficient operational flexibility to cope with seasonal and peak loading conditions.
- Winter and summer operation are similar in respect to the operated SRT, and no lines are taken out of operation during the winter.
- 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.
- In the summer alkalinity is not likely to become limiting. In the winter over-aeration may result in a drop of alkalinity and pH limitation. Influent alkalinity is an estimated value in the model based on the local drinking water quality.
- During the winter the plant may require dosage of Iron to remove phosphate chemically, especially with rain conditions. During summer, TKN peak loading may result in temporary low oxygen and nitrate in the tanks which can result in increased effluent PO4.
- The anoxic recycle flow is limiting for the size of the anoxic tank resulting in anoxic tanks becoming anaerobic for large part of the operation. It is advised to use the maximum internal recycle flow the whole year round to reduce the effect of too long anaerobic HRT thereby reducing the effect of decay of nitrification.
- In summer, during daily TKN peak loadings, nitrification is limiting resulting in accumulation of ammonium and nitrite (NO2).
-

- During summer aeration capacity may become limiting under peak loading conditions resulting in the production of nitrite. In average ammonium is fully oxidized.
- 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:
    - possible drop in alkalinity and potentially pH limitation due to over-aeration in the winter.
    - Too little flow recycle capacity resulting in too long anaerobic HTR and decay of nitrification capacity.
    - P-release in the WAS storage tank with operational HRT > 2-3 hours.
    - Too oxygen and nitrate to meet the Bio-P requirement.
- 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.
- The large effluent buffer reduces effluent fluctuations.

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.