Zajednica izvršitelja

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Krajnji korisnik

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IZVJEŠĆE 16 Utjecaj UPOV-a na kakvoću mora za kupanje: validiranje modela

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Utjecaj UPOV-a na kakvoću mora za kupanje: validiranje modela

25. veljače 2022

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United Nations Educational, Scientific and Cultural Organization
Institute for Water Education under the auspices of UNESCO

REPORT

HRVATSKE VODE

Sea Water Quality Modelling Istria

Water quality model validation and present situation winter 2022

25 February 2022 - version 1.0

International Marine & Dredging Consultants

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Abstract

This report is part of the sea water quality modelling study of the dispersion of sewage effluent (faecal bacteria) along the Istrian coast. As part of the study, a validation measurement campaign is performed after the implementation of the new waste water treatment plants (WWTP). Based on the measurement results the performance of the water quality model and the WWTP is assessed. The report describes the measurement data, the mid field water quality model and the validation results.. The results of the validated model are presented to illustrate the dispersion of the sewage effluent and the water quality conditions in the present situation (winter 2022) after the implementation of the new WWTP.

Table of Contents

Annexes

No table of contents entries found.

List of Figures

1. INTRODUCTION

1.1 THE ASSIGNMENT

Large investments in the public sector are ongoing along part of the Istrian coast including the renewal and extension of the existing drainage system and the construction of new waste water treatment plants for the purpose of protecting the city of Poreč and surroundings.

IMDC was requested to perform sea water quality modelling of the dispersion of sewage effluent (faecal bacteria) along the Istrian coast, Croatia. Using numerical models, the bathing water quality has been investigated in the present situation as well as after the installation of the treatment plants. The study assesses the risk of E-Coli (EC) and Intestinal Enterococci (IE) pollution (as indicator for the bathing water quality) at the beaches and the added value of treatment plants to reduce this risk. The study is part of the overall assignment "Study evaluation and monitoring of the effectiveness of the implementation of the construction project of sewerage network and analysis of the effectiveness of waste water treatment plant operation Poreč" issued by Hrvatske Vode (Croatian Waters) with the tender OP 2015/227. The work was assigned to the consortium including IMDC and represented by PRONING DHI as Lead Member with the contract on 19/07/2018, Class: 325-01/15-10/148, Reg: 374- 1- 3-18-35. A consortium agreement was concluded on 13/05/2016 and extended with annex I on 13/11/2018.

IMDC will contribute to the following requested deliverables:

- Report on hydrodynamic model setup (IMDC, 2019a);
- Report on hydrodynamic model calibration and modelling of present situation (IMDC, 2019b);
- Report on sea water quality model calibration and modelling of present situation (IMDC, 2021a);
- Report on the impact of WWTP on bathing water quality (IMDC, 2021b);
- Report on the impact of WWTP on bathing water quality: model validation (this report);
- Report on model handover and training (IMDC, 2020).

1.2 SCOPE OF THE REPORT

This report describes the validation of the mid field coastal model of the simulated effluent discharge in January 2022. The results of the model validation are presented with the prime objective to validate the effectiveness of the waste water treatment plants (WWTP) to improve the sea water quality at the beaches. This was performed based on effluent measures and sea water quality measurements around the outfalls. The validation is performed in two steps, first a model validation based on the measurements and second a validation of the performance of the WWTP based on the model results.

1.3 READING GUIDANCE

A description of the data that is used to validate the model is presented in chapter 2.

The setup of water quality validation exercise is presented in chapter 3.

The model results have been compared with measurements of the water quality at sea during January 2022 in chapter 4 together with showing the effectiveness of the WWTP to improve bathing water quality towards the beaches.

Conclusions are presented in chapter 5.

2. DATA

This section outlines the data that is used to perform the validation study, which is partly based on the information used for the water quality calibration and reference is made to the water quality calibration report for more details (IMDC, 2021a).

2.1 OUTFALL DATA

Characteristics of the outfall are required to be able to determine adequate input conditions for the water quality models. The characteristics are related to the design and position of the outfall and the upstream discharge conditions. Detailed information on the outfalls can be found in the water quality calibration report (IMDC, 2021a).

Figure 2-1 illustrates the outfalls in use after the WWTP are operational. Compared to the situation without WWTP this means that the smaller outfalls that were included in the water quality calibration exercise (IMDC, 2021a) are not considered in the scenario modelling for the effect of WWTP on bathing water quality. The smaller outfalls are Cervar (connected to Poreč North), Sint Nicholas, and Coversada (connected to Vrsar).

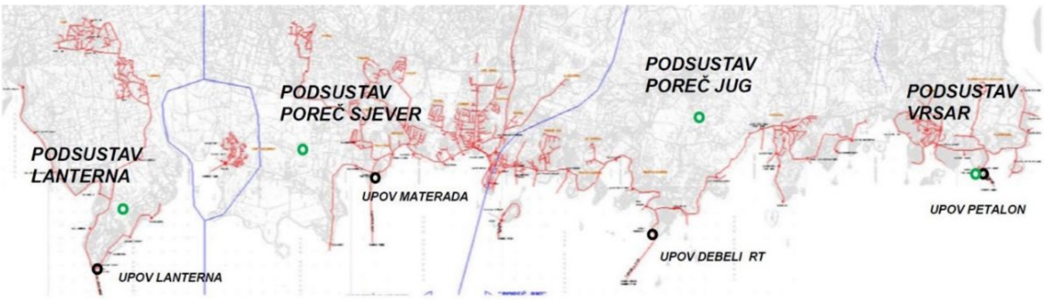

Figure 2-1: Study area, outfall locations (black circles) and treatment plants (green circles).

For the major outfalls the waste water is collected in collectors before it is either mechanically flushed or flushed by pumps towards the Adriatic Sea via a diffusor or an open end pipe. It is currently understood that the waste water is collected in the WWTP and at a certain level flushed directly, through the old collector, towards the Adriatic sea without accumulating. The remainder of the discharge configuration (diffusor or not and length of pipelines) are identical to the situation before WWTP and as used in the calibration (IMDC, 2021a) and scenario analysis (IMDC, 2021b). The characteristics for lengths and characteristics of diffusors at the different outfalls are considered as during the water quality calibration (IMDC, 2021a). Table 2-1 gives an overview of the different design and discharge conditions near the outfalls that are identical as before. Table 2-2 gives an overview of the volumes and discharge durations in this simulation compared to the settings applied in the calibration and scenario analysis.

Table 2-1: Overview of the outfall design characteristics (IMDC, 2021a).

Outfall	Type	L to diffusor [m]	L diffusor [m]	Number of opening [-]	D opening [m]	Q_{max} [m³/s]
Lanterna	Diffusor	500	86	13	0.1	0.11
Poreč North	Diffusor	900	100	20	0.1	0.11
Poreč South	Diffusor	800	90	20	0.1	0.14
Vrsar	Single pipe	488	-	1	0.5	0.075

Table 2-2: Overview of the discharge volumes and durations per disposal as previously used in the calibration and scenario analysis (IMDC, 2021b, 2021a) and the currently used values in this study based on the measurement campaign of January 2022.

Outfall	Previous		Current	
	Volume [m³]	Discharge duration [s]	Volume [m³]	Discharge duration [s]
Lanterna	50	455	280	6720
Poreč North	50	455	590	3900
Poreč South	50	357	240	3420
Vrsar	25	333	240	7140

2.2 WATER QUALITY MEASUREMENTS

A recent water quality measurement campaign has been performed by the Ruđer Bošković Institute in order to investigate effectiveness of the new implemented WWTP's in reducing the effluent faecal bacteria concentrations and to create a dataset which can be used for the numerical model validation in this current study. This campaign was held in the winter period of 17-21 January 2022.

Measurements have been done of concentrations of Coliforms, Escherichia coli (ECOLI) and Intestinal enterococci (IE), and are reported in CFU/100 ml. These measurements have been performed at different locations and at different time instances.

- Daily measurements in the sewage system near each WWTP.
- Specific campaign per outfall location to monitor the concentrations in the sea water around the outfall.

The first set of measurements give an indication of the concentration of faecal bacteria that can be expected at the entrance of each outfall. The second set of measurements at sea gives an indication on how the faecal bacteria concentrations vary around the outfall.

Faecal bacteria concentrations in the sewage system

For each WWTP the range in concentrations of faecal bacteria in the sewage system has been summarised Table 2-3. It shows that the effluent is filtered effectively, and confirms the earlier assumed reduction to 0.1% in the scenario report (IMDC, 2021b), which based on the average performance of the membrane filter in filtering out VSS particles as found in the WWTP modelling studies (ASM Design, 2021a), (ASM Design, 2021b), (ASM Design, 2021c) and (ASM Design, 2021d).

These effluent concentrations serve as input concentrations for the water quality model.

For a detailed analysis of the working method of the measurements campaign, the reader is referred to the campaign report (Korlević and Markovski, 2022).

Table 2-3: Overview influent and effluent measurements at the WWTP's in January 2022.

WWTP	Influent or Effluent	Date-from	Date-to	Coliforms (CFU/100 ml)	Escherichia coli (CFU/100 ml)	Intestinal enterococci (CFU/100 ml)
Lanterna	Influent	08:00 18-01-2022	08:00 19-01-2022	1.23E+08	1.06E+07	2.39E+06
Lanterna	Effluent	08:00 18-01-2022	08:00 19-01-2022	0.00E+00	0.00E+00	0.00E+00
Poreč-North	Influent	08:00 18-01-2022	08:00 19-01-2022	1.69E+08	1.14E+07	1.78E+06
Poreč-North	Effluent	08:00 18-01-2022	08:00 19-01-2022	2.19E+05	8.10E+03	1.50E+03
Poreč-South	Influent	08:00 18-01-2022	08:00 19-01-2022	2.39E+08	1.38E+07	1.44E+06
Poreč-South	Effluent	08:00 18-01-2022	08:00 19-01-2022	1.86E+05	7.70E+03	1.09E+03
Vrsar	Influent	08:00 18-01-2022	08:00 19-01-2022	1.82E+08	1.77E+07	2.08E+06
Vrsar	Effluent	08:00 18-01-2022	08:00 19-01-2022	3.00E+00	1.00E+00	1.78E+02

Faecal bacteria concentrations at sea

Around each of the four major outfalls the variation in faecal concentrations has been measured during the winter 2022 campaign. A measurement strategy has been set up in which the survey vessel makes a round of four points (A, B, C, D) at different locations around the outfall where at different levels of the water column samples are taken for which concentrations in faecal bacteria have been determined. This results in a set of measurements at specific locations, heights and specific time steps. An overview of the locations, where measurements have been performed during the previous summer campaign (but are still representative for the 2022 campaign), is shown in Figure 2-2.

The actual measured concentrations in January 2022 are plotted in the boxplots of Figure 2-3 and Figure 2-4. They show that the largest concentrations of both ECOLI and IE bacteria are measured at the Poreč South outfall, with maximal ECOLI and IE concentrations around 120 and 80 [CFU/100 ml], respectively. Hereafter, comes the Poreč North outfall with the second highest ECOLI and IE concentrations with maximal values around 10 and 8 [CFU/100 ml], respectively. This is in line with the higher measured effluent concentrations at the WWTP of these two locations (Table 2-3). In case of the outfalls of Lanterna and Vrsar, measured concentrations are significantly lower, but not zero. In case of the Lanterna outfall, where there was no effluent discharge during the campaign, it rises the question whether the measured presence of ECOLI and IE is reached due to a present background concentration or because the low concentrations are outside of the precision range of the measurement equipment.

Since the maximal measured concentrations are well below the thresholds for poor water quality (i.e. 300 [CFU/100 ml] for ECOLI and 200 [CFU/100 ml] for IE), it can be concluded that the installed filters in the WWTP effectively reduce the effluent bacterial concentrations.

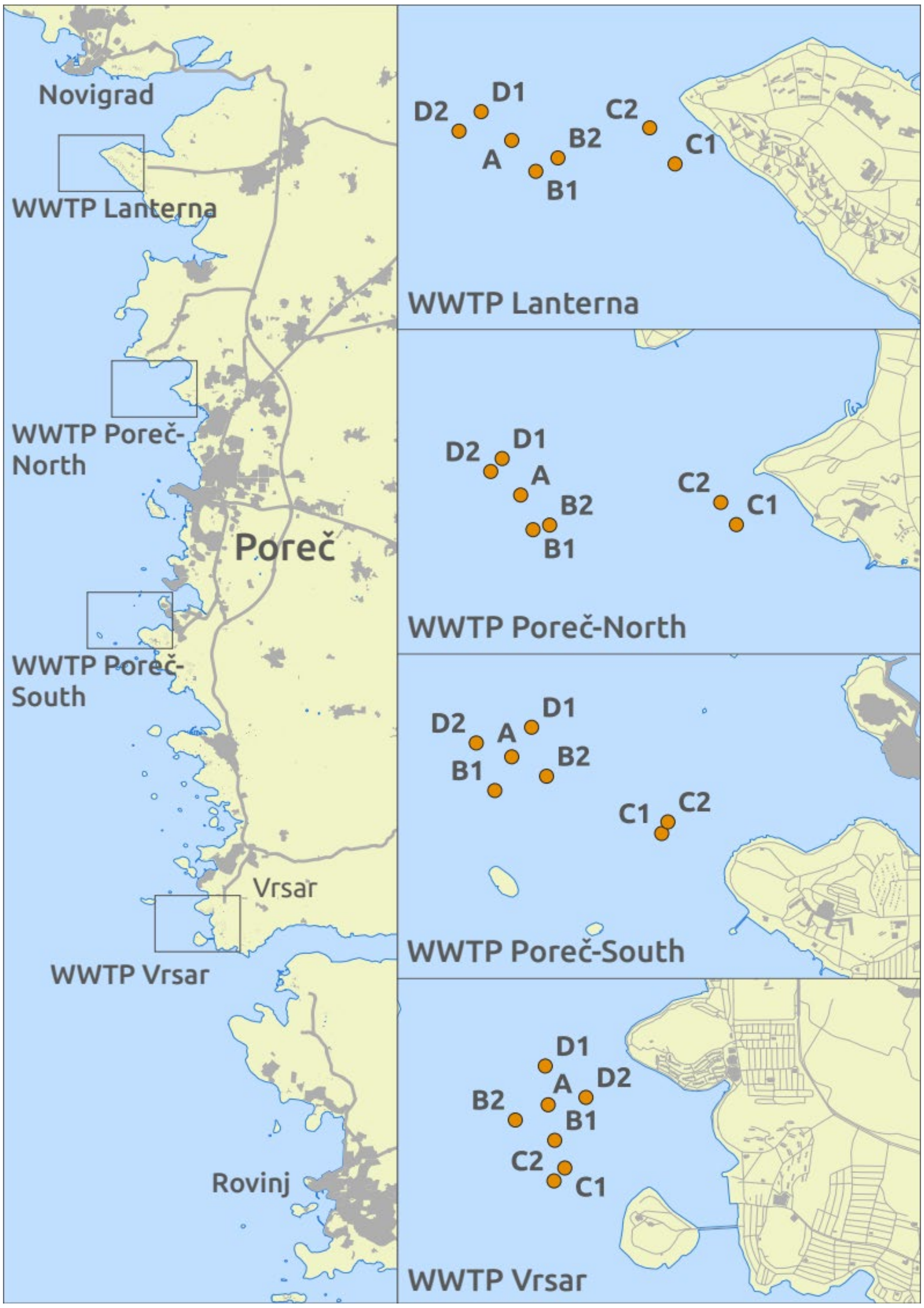

Figure 2-2: Map of the measured locations during the summer water quality campaign around the different major outfalls, from Korlević and Markovski (2022),.

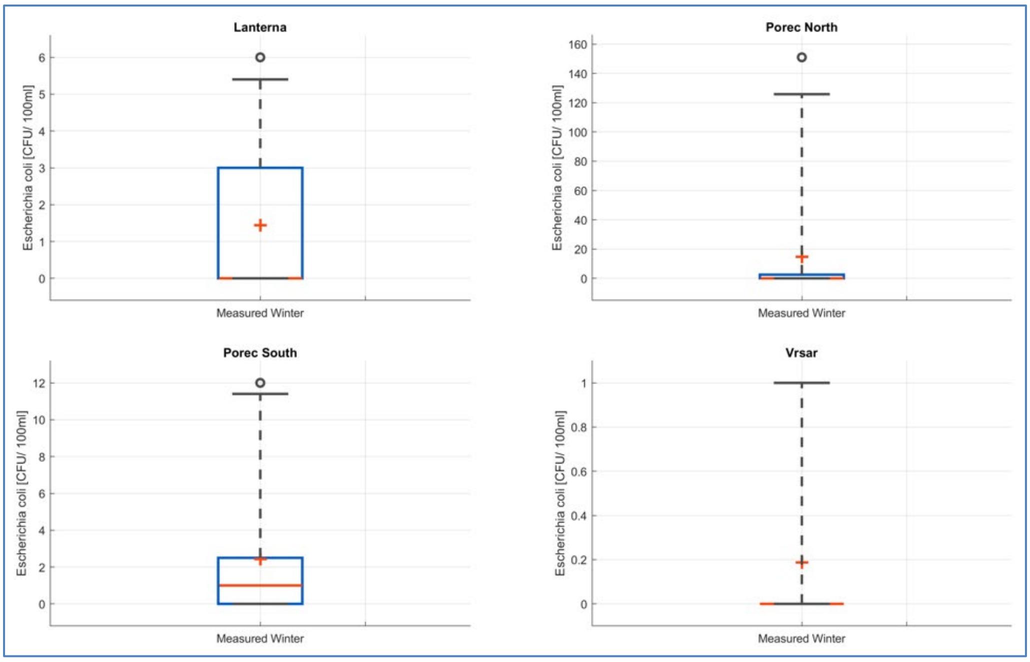

Figure 2-3 Box plots of measured ECOLI concentrations [CFU/100 ml] for the 2022 winter campaign per station. Red line indicates median value, blue boxes the first and third quartile, gray lines provide 5% and 95% whiskers and the red cross the average value. Please note that no uniform scale is used and the maximum observed values varies per location.

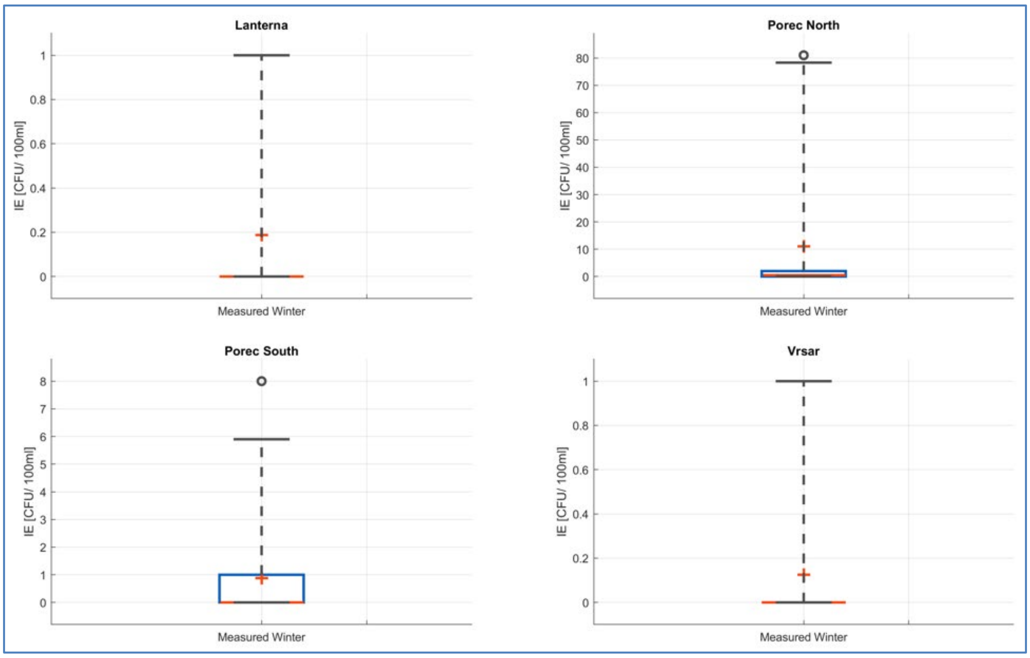

Figure 2-4 Box plots of measured IE concentrations [CFU/100 ml] for the 2022 winter campaign per station. Red line indicates median value, blue boxes the first and third quartile, gray lines provide 5% and 95% whiskers and the red cross the average value. Please note that no uniform scale is used and the maximum observed values varies per location.

2.3 WATER QUALITY PARAMETERS

The water quality parameters used by the model to calculate the impact of the effluent, are based on the calibrated water quality model (IMDC, 2021a). Reference is made to this report for a detailed discussion on the parameters. The most important calibrated water quality parameter is the decay rate. The final selected decay rates have been based on the experiments performed by Ruđer Bošković Institute (Korlević and Markovski, 2019) that have been subsequently calibrated in the water quality model to represent the faecal dispersion behaviour. A distinction between day and night is made. Table 2-4 gives an overview of the applied decay rates.

Table 2-4 Decay rates (T_{90}-values) [h] of faecal bacteria (IMDC, 2021a).

Parameter	Combined decay rate (T_{90}-value) [h]
ECOLI (day)	9.5
IE (day)	10.5
ECOLI (night)	54
IE (night)	84

3. VALIDATION SIMULATION SETUP

3.1 INTRODUCTION

The dispersion of the Escherichia coli (ECOLI) and Enterococci (IE) bacteria, which are introduced to the Adriatic sea through outfall discharges, is studied along the Istrian coast by performing simulations with the mid-field water quality model presented in (IMDC, 2021a).

In this study, a validation simulation is performed with the four waste water treatement plants (WWTP) fully operational in order to investigate the implications of the current faecal discharge on the water quality near Istria. For this, a simulation is performed of a ten-day period that corresponds to the dates of the measurement campaigns of January 2022.

3.2 MODEL SETUP

The mid-field water quality model (Figure 3-1) is based on the hydrodynamic model of IMDC (IMDC, 2019a). Details regarding the setup of the model (model grid resolution, boundary conditions, settings, etc.) can be found in the hydrodynamic model setup report (IMDC, 2019a). For this part of the study, the hydrodynamic model is coupled to the in TELEMAC available water quality module WAQTEL. The TELEMAC-3D part of the mid-field water quality model has the same setup as the hydrodynamic model, though it includes some extra features which are required for modelling of water quality:

- Module for introducing the bacterial discharge, coupling the near field and mid field model
- Implementation of the decay rate of the bacteria

Details regarding the setup of the water quality model and its calibration can be found in the calibration report (IMDC, 2021a).

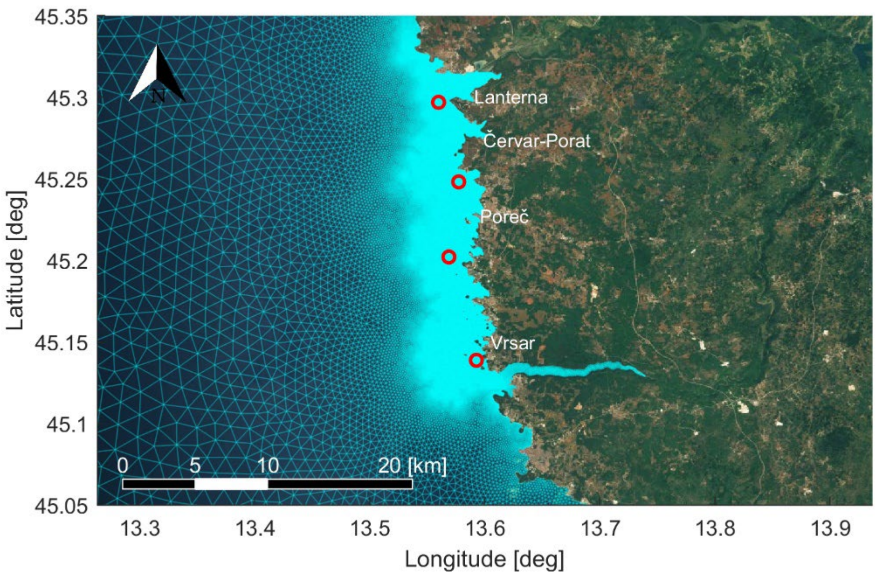

Figure 3-1 Mesh of the mid-field water quality model near Istria, overlaid with the four outfall locations (red circles).

3.2.1 Mixed conditions – winter scenario

The period of the winter scenario with mixed conditions is from 14-01-2022 till 24-01-2022 and corresponds to the period, when measurements were performed at the outfalls by the Ruđer Bošković Institute.

For this period, first the Adriatic model has been run to generate boundary conditions (water levels, currents, temperature and salinity) for the mid field coastal model. The near field mixing characteristics corresponding to a winter case as simulated in (IMDC, 2021a) have been applied to generate the discharge boundary conditions in the mid field water quality coastal model.

Figure 3-2 shows the water density variation in the vertical over the ten day modelling period of January 2022. It shows that density variations are minor with a maximum of 0.2 [kg/m^3] and that these variations are randomly mixed throughout the water column. During this period the water conditions can be considered well mixed. The wind conditions during this simulation period (Figure 3-3) were directed predominantly towards the south / south-west.

The parameters applied for the winter scenario are shown in Table 3-1. Only the single discharge event that was measured at each WWTP is taken into account for the effluent discharge in the mid-field water quality model. This approach differs from the discharge with time intervals, which is being used in the calibration and scenario reports (IMDC, 2021b, 2021a).

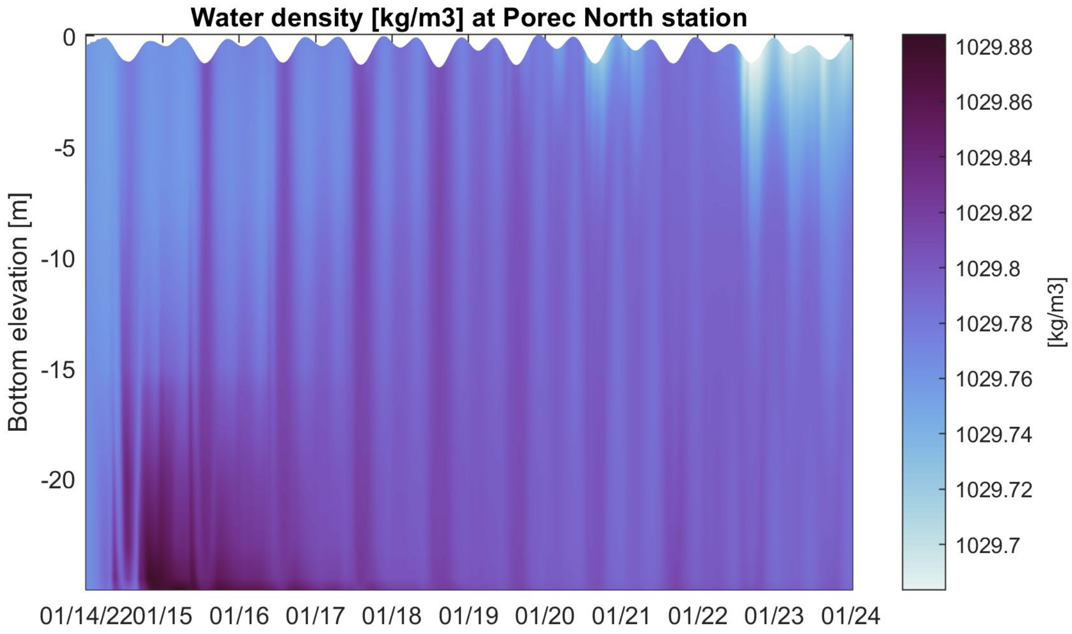

Figure 3-2 Evolution of the water density [kg/m^3] in time (14 till 24-January 2022) over the water column at Poreč North station.

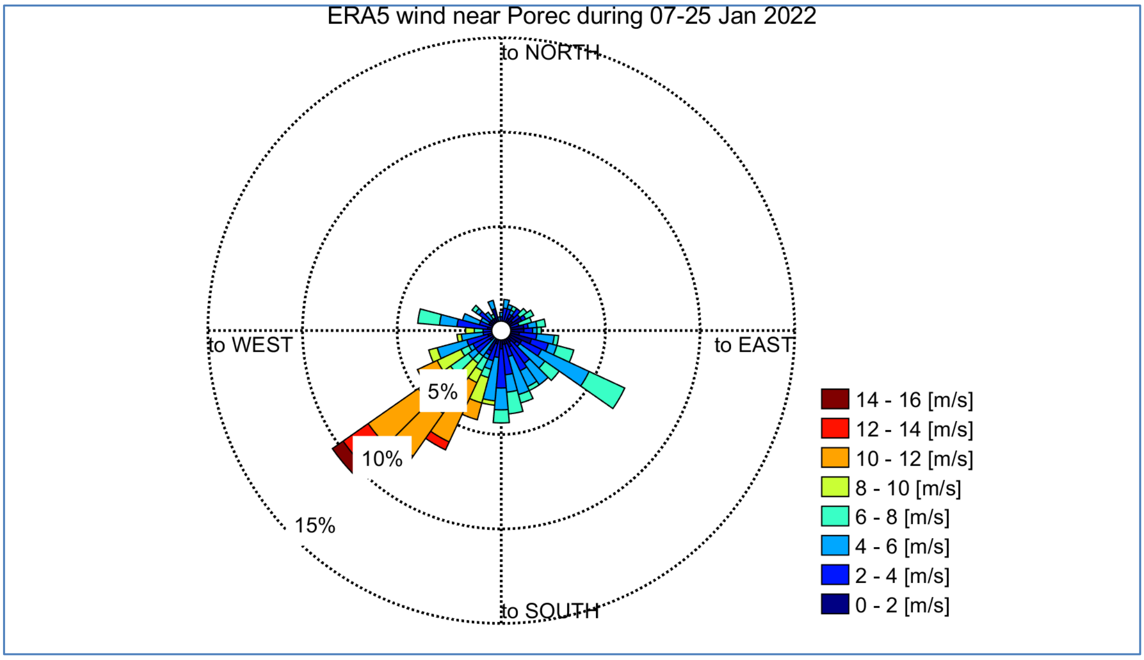

Figure 3-3 Wind rose displaying occurrence of ERA5 wind direction and speed conditions near Poreč during the winter simulation period of 07 till 25-January-2022.

Table 3-1 Parameter settings for faecal bacteria plume simulations in TELEMAC-3D based on near field simulations (Mixed conditions – winter scenario 2022). Here is Zmin the minimal depth of the plume, Zmax the maximal depth of the plume, L the horizontal halflength of the plume, B the horizontal halfwidth of the plume, θ is the angle of the plume with respect to the vertical (θ = 0 [deg] is vertical plane) and Φ the angle of the plume with respect to the horizontal (Φ = 0 [deg] is east-west orientation).

Parameter	**ECOLI Flux [KVE/s]**	**IE Flux [KVE/s]**	**Time flush [s]**	**Z_{min} [m]**	**Z_{max} [m]**	**L [m]**	**B [m]**	**θ [deg]**	**Φ [deg]**
Laterna	0.00E+00	0.00E+00	6720	Z_{max} - 24	Water surface	10	110	0	110
Poreč North	8.10E+03	1.50E+03	3900	-16	Water surface	10	60	0	97
Poreč South	7.70E+03	1.09E+03	3420	Z_{max} - 10	Water surface	10	10	0	94
Vrsar	1.00E+00	1.78E+02	7140	Z_{max} - 3	Water surface	10	39	0	94

4. VALIDATION RESULTS

4.1 INTRODUCTION

In this chapter, the results of the validation simulation and the behaviour of the faecal bacterial plumes are presented. Reference values for the assessment of microbial sea quality are adapted from Korlević and Markovski (2019) and shown in Table 4-1. Based on this, the water quality in this study is assessed as insufficient for concentrations of IE > 200 [CFU/ 100 ml] and ECOLI > 300 [CFU/ 100 ml].

Table 4-1 Reference values for the assessment of microbial sea quality after each examination specified by the Republic of Croatia (NN 73/2008). Adapted from Korlević and Markovski (2019)

Parameter	Excellent quality	Good quality	Sufficient	Reference methods
Intestinal enterococci [CFU / 100 ml)]	< 60	61 - 100	101 - 200	HRN EN ISO 7899-1 or HRN EN ISO 7899-2
Escherichia coli [CFU / 100 ml]	< 100	101 - 200	201 - 300	HRN EN ISO 9308-1 or HRN EN ISO 9308-3

The comparison between measurements and model is illustrated by comparison of the boxplot figures with typical bacteria concentrations based on the measurements and the model around the different outfalls.

A further analysis of the dispersion behaviour of the bacteria with the WWTP in operation is illustrated based on maps with maximal concentrations at the water surface during the simulation period.

4.2 MIXED CONDITIONS – WINTER 2022

4.2.1 Validation of mid-field model

A comparison between the measured and simulated ECOLI & IE concentrations [CFU/100 ml] for the 2022 winter measurement campaign are shown in Figure 4-1 and Figure 4-2. For the Lanterna and Vrsar outfalls, it is visible that the measured concentrations are very small but higher than simulated. As explained in the data analysis chapter 0, the small but higher measured values are likely to originate from a background concentration, which is not present in the model. The measured and modelled concentrations at the outfall of Poreč south match, especially for the ECOLI bacteria, good with maxima near 10 [CFU/100 ml]. In case of the Poreč north outfall the average measured and modelled concentration match quite well. The measured values show lower maxima for both ECOLI and IE (20 [CFU/100 ml] compared to 120 [CFU/100 ml] for ECOLI), but given that the concentrations are fairly low compared to the calibration phase with maximal values near 6000 [CFU/100 ml], the comparison can still be considered reasonable.

In all, the mid-field water quality model is found to reproduce realistic concentrations at the outfalls where actual effluent has been discharged during the January 2022 sampling campaign. It is therefore deemed valid for the modelling purposes of this water quality study.

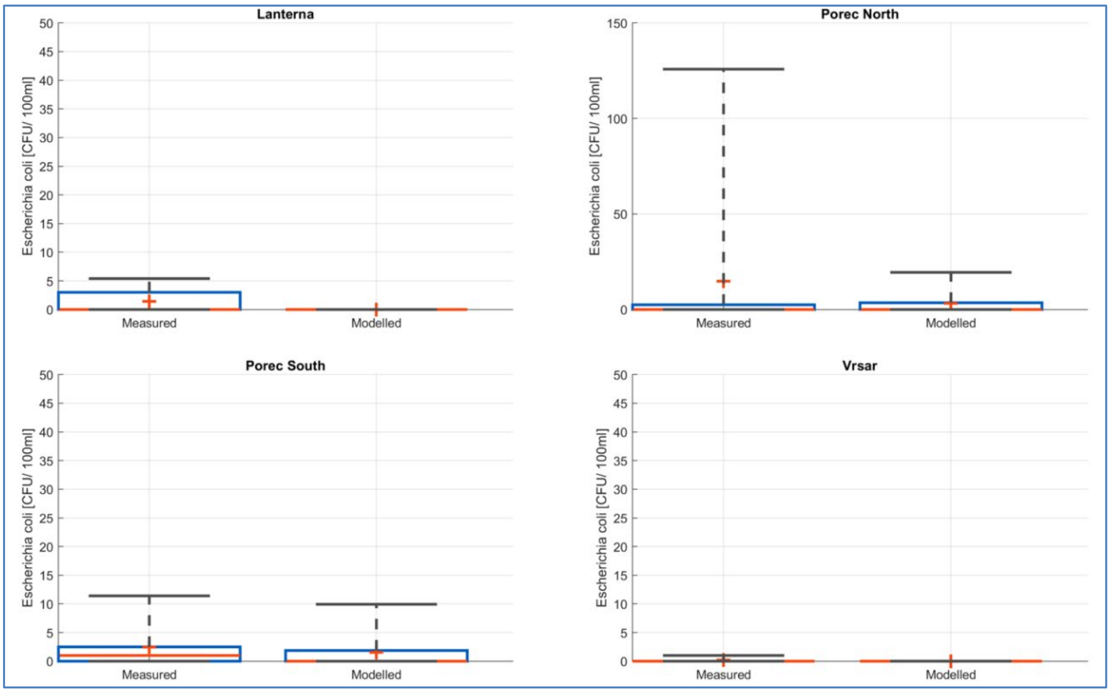

Figure 4-1 Box plots of measured and simulated ECOLI concentrations [CFU/100 ml] for the 2022 winter campaign per station. Red line indicates median value, blue boxes the first and third quartile, gray lines provide 5% and 95% whiskers and the red cross the average value.

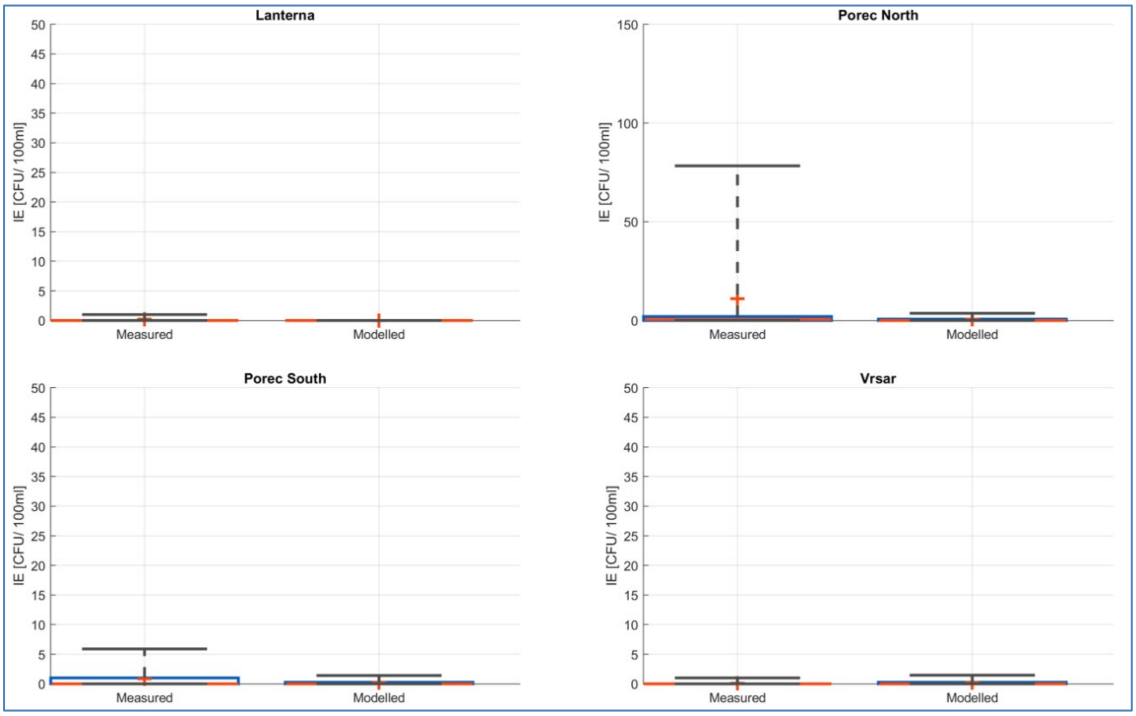

Figure 4-2 Box plots of measured and simulated IE concentrations [CFU/100 ml] for the 2022 winter campaign per station. Red line indicates median value, blue boxes the first and third quartile, gray lines provide 5% and 95% whiskers and the red cross the average value.

4.2.2 Validation of WWTP effectiveness

Spatial maps of maximal bacterial concentrations at the water surface are shown in Figure 4-3 till Figure 4-5 (for ECOLI) and Figure 4-8 till Figure 4-10 (for IE).They show that the range of the dispersed plume with noticeable concentrations is limited to only one kilometre distance from the outfalls. Figure 4-6 shows that for this mixed winter condition, the highest concentrations are to be found at the water surface. Since the maximal simulated concentrations are well below the thresholds for poor water quality (i.e. 300 [CFU/100 ml] for ECOLI and 200 [CFU/100 ml] for IE), it can be concluded that the installed filters in the WWTP effectively reduce the effluent bacterial concentrations and improve the water quality along the Istrian coastline. Furthermore, the longer discharge periods compared to the previous more frequent discharge fluxes from the smaller collector near the outfall, gives rise to a more gradual input of effluent in the Istrian sea, which prevents the occurrence of smaller but more concentrated effluent plumes.

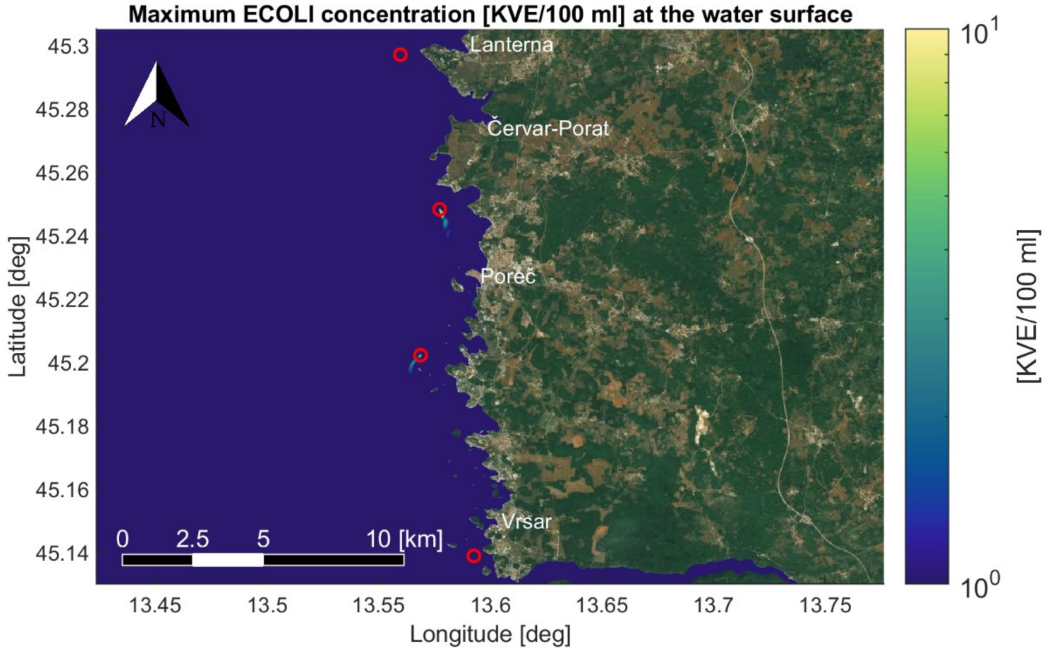

Figure 4-3 Winter 2022 scenario: Maximum ECOLI concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

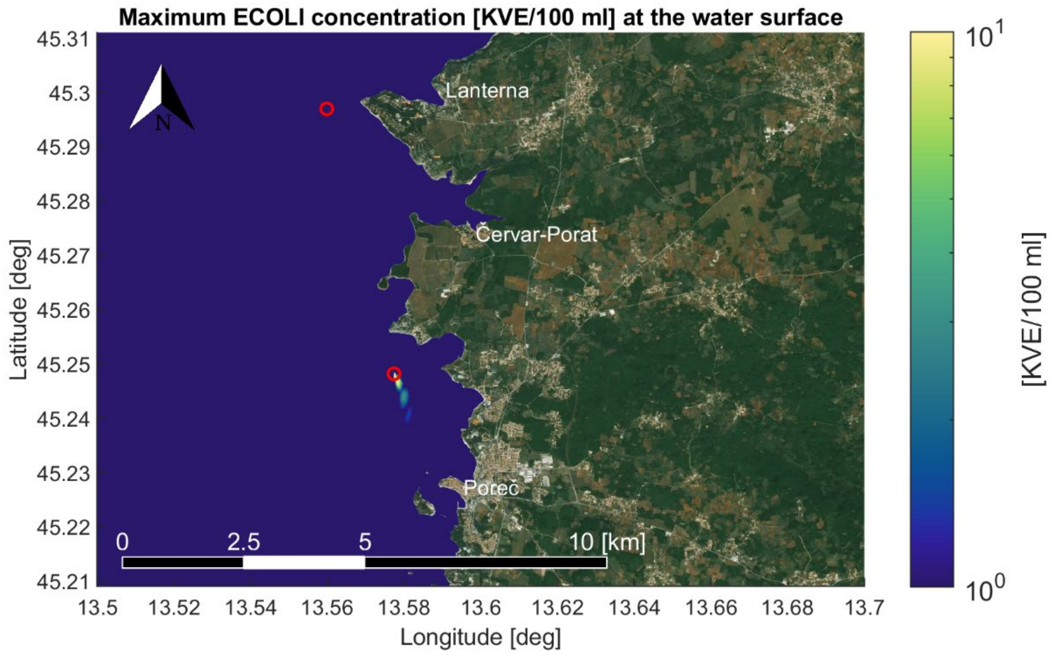

Figure 4-4 Winter 2022 scenario (north zoom): Maximum ECOLI concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

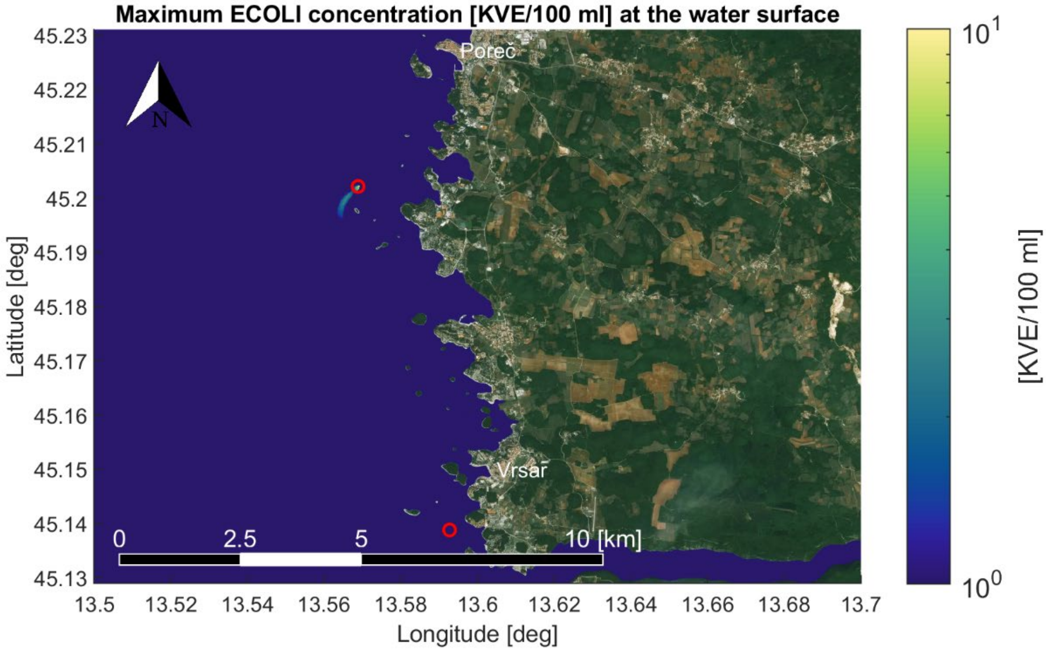

Figure 4-5 Winter 2022 scenario (south zoom): Maximum ECOLI concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

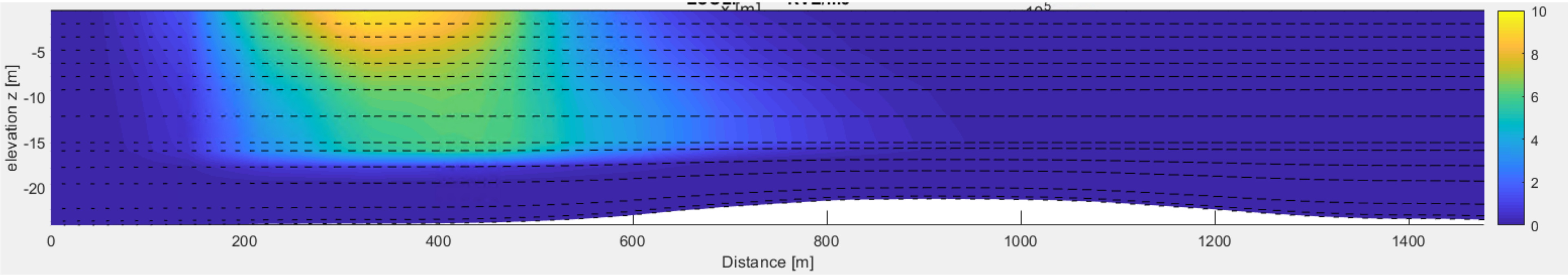

Figure 4-6 Vertical cross-section of ECOLI concentrations [CFU/100 ml] taken at the outfall location of Poreč North at 18-January-2022 10:00. The position of the outfall Is at x = 350 [m].

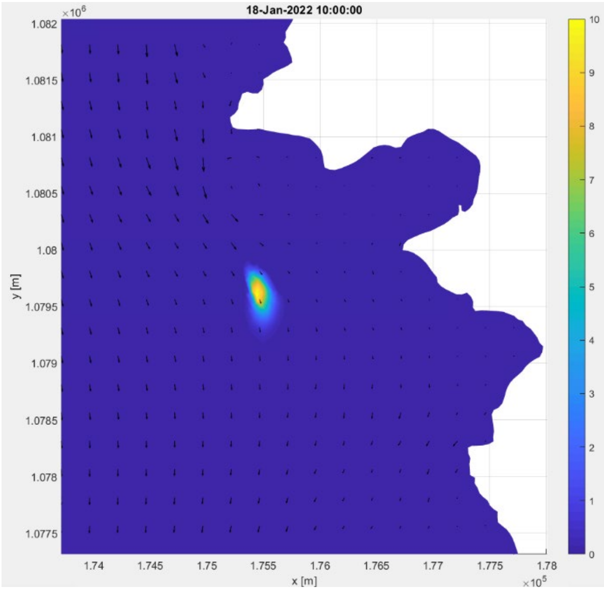

Figure 4-7 Map around Poreč North outfall with ECOLI concentrations [CFU/100 ml] at the water surface (18-January-2022 10:00).

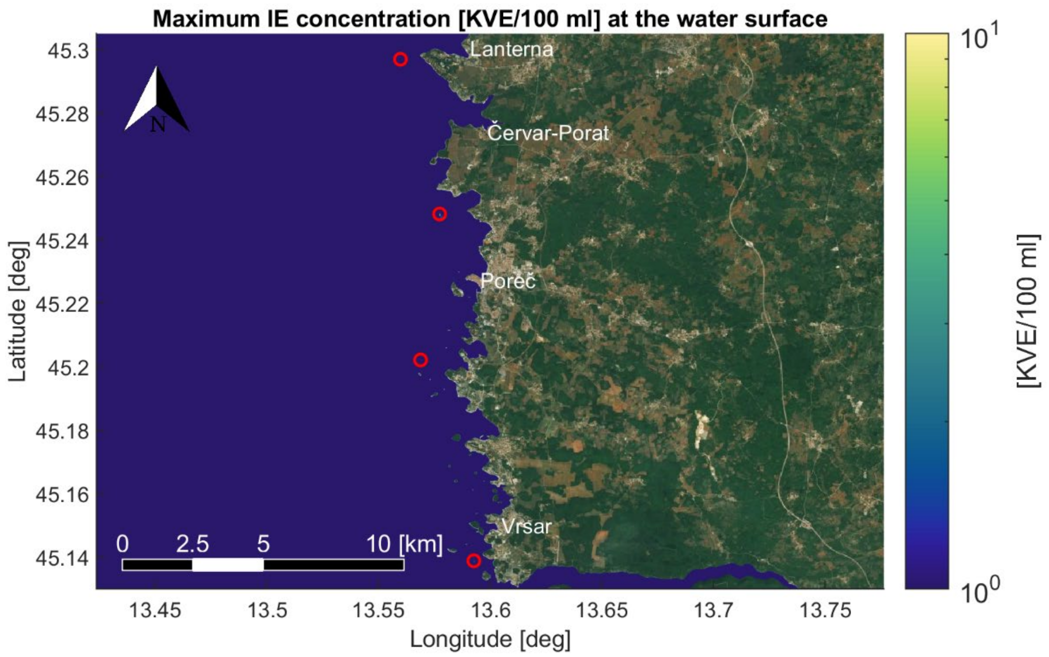

Figure 4-8 Winter 2022 scenario: Maximum IE concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

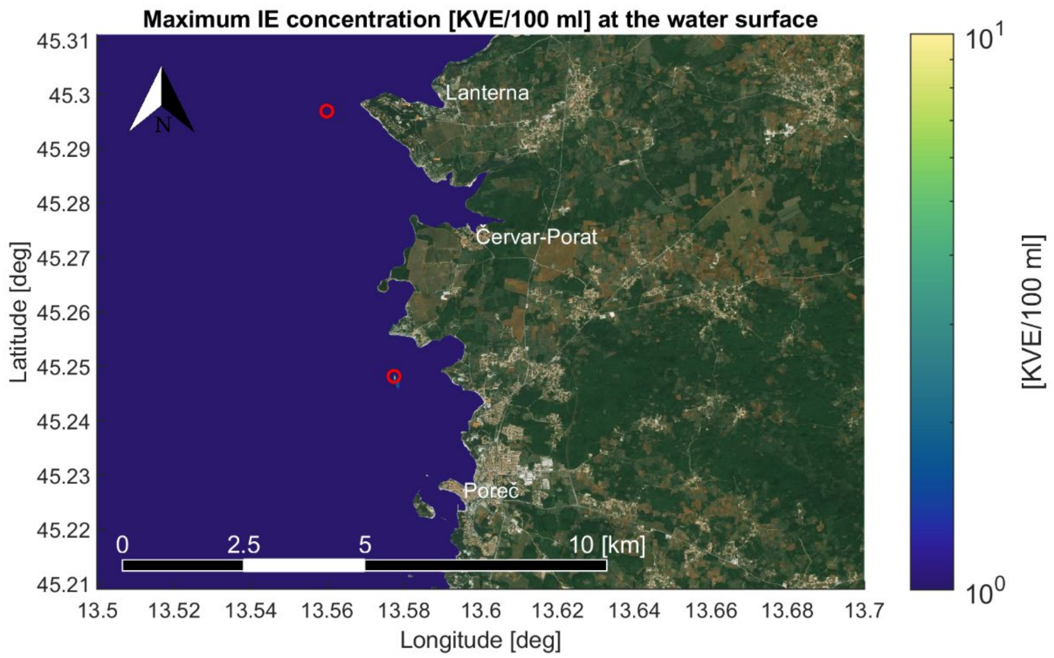

Figure 4-9 Winter 2022 scenario (north zoom): Maximum IE concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

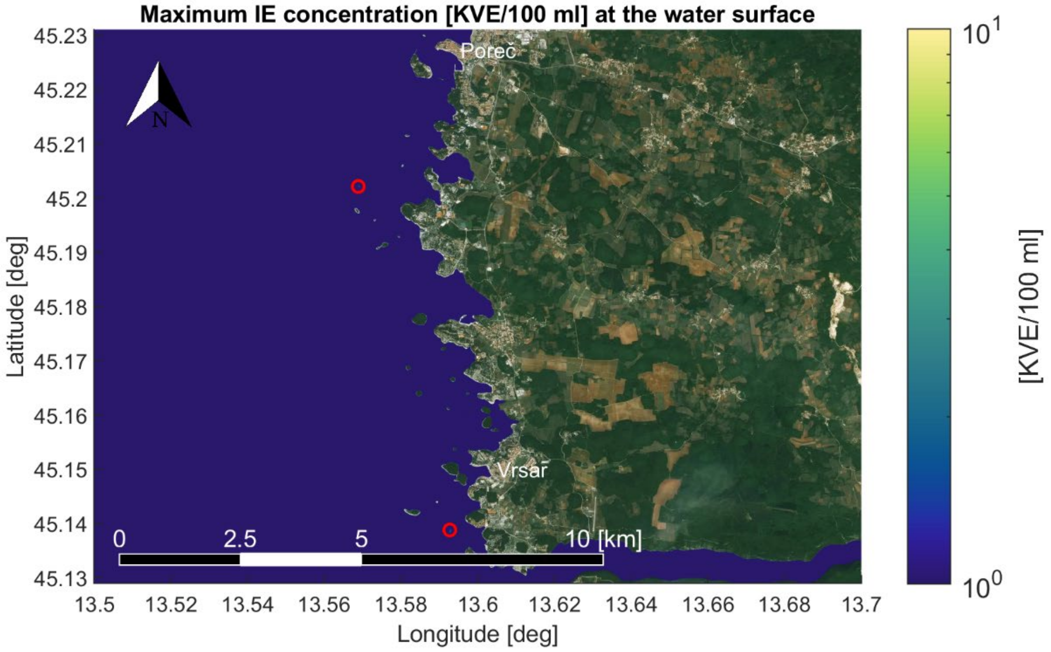

Figure 4-10 Winter 2022 scenario (south zoom): Maximum IE concentrations [CFU/100 ml] at the water surface. Red circles indicate outfall locations.

5. CONCLUSIONS

This report presents the results of the model validation with the prime objective to validate the effectiveness of the waste water treatment plants (WWTP) to improve the sea water quality at the beaches. This was performed based on effluent measures and sea water quality measurements around the outfalls. The validation is performed in two steps, first a model validation based on the measurements and second a validaiton of the performance of the WWTP based on the model results.

Using the available data, it has been verified that the 0.1% assumption on the membrame filtering efficiency was valid and that the model can represent the faecal bacteria variations in the project area around the outfalls during a winter scenario with mixed water conditions. Based on this validation, it was concluded that the model setup is valid to be used to perform scenario analysis studying the impact of waste water treatment plants on the water quality and the results of the water quality scenario analysis that showed the efficiency of the WWTP to improve water quality as presented in (IMDC, 2021b) can be considered reliable.

Subsequently the performance of the WWTP to improve sea water quality has been assessed for this simulation period. Maps with maximal simulated bacterial concentrations at the water surface show that the range of the dispersed faecal bacteria plume with noticeable concentrations is limited to only one kilometre distance from the outfalls. Furthermore, it is found that for the mixed winter condition, the highest concentrations are to be found at the water surface. Since the maximal simulated concentrations are well below the thresholds for poor water quality (i.e. 300 [CFU/100 ml] for ECOLI and 200 [CFU/100 ml] for IE), it can be concluded that the installed filters in the WWTP effectively reduce the effluent bacterial concentrations and improve the water quality along the Istrian coastline and at the beaches.

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