FROM SHARED RESOURCES
TO JOINT SOLUTIONS

# D 5.2.1 Strategies to increase DPs efficiency and testing photo disinfection process on fecal bacteria and emerging pathogens

# D 5.2.2 Feasibility assessment for implementation of selected novel technologies

# PROJECT AdSWiM

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|---|---|
| **Work Package:** | **5. Technologies and strategies for managing DPs guidelines definition and cross-borders strategies** |
| **Activity:** | **5.3 Joint and shared cross-border strategies of WWT plant management and legislative action proposals** |
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# PART 1: INTRODUCTION

Interreg CBC Italy-Croatia AdSWiM Project connects research institutions, municipalities and water utility companies in order to improve wastewater treatment processes and seawater quality. AdSWiM project is focused on Adriatic Sea, which is strongly exposed to anthropogenic impact coming from land, especially in urban areas and river mouths. Goals of AdSWiM project are related to enhancement of cross-border cooperation between Italy and Croatia considering Adriatic Sea and its marine eco-system preservation. This is related to fulfilment of European Water Framework Directive requirements which are related to nutrient balance in sea. Furthermore, bacterial pollution reduction and control is required by European Bathing Water Quality Directive. One of the strategies for achievement of these goals is through development and potential implementation of innovative wastewater treatment technologies. Sustainability of project results strongly depends on cross-border cooperation as well as future harmonized approach during implementation of measures for protection of Adriatic Sea, taking into consideration different coastal area particularities of each country.

Innovative technologies for wastewater treatment are developed within Work Package 4 of the AdSWiM project. In Work Package 5, project activities are, among others, oriented towards feasibility testing of innovative technologies on a real case study. In particular, Activity 5.2. of AdSWiM projects considers feasibility assessment for implementation of innovative wastewater technologies in new wastewater treatment plants (WWTP) Split, Ploče and Komin. This considers technical analysis for potential implementation in wastewater treatment facilities based on the research data. Results of the analysis are primarily focused on reduction of wastewater parameters concentration. Innovative wastewater treatment technologies are related to: granular biomass technology, which consists of aerobic granulation process in order to reduce chemical oxygen demand (COD), biological oxygen demand (BOD) and nutrients; and photo disinfection which is based on wastewater exposure to incandescent lamps on a photoactive material sheet.

# PART 2: SELECTED STRATEGIES TO INCREASE DPs EFFICIENCY

Based on the analysis performed within D.5.1.1, there is a difference between the quality status of marine waters at the Italian and Croatian sides. On the Italian side, due to the strong influence of the river Po and WWTPs with biological and tertiary treatment, there is a nutrient limitation in the coastal area. Responsible institutions are conducting different activities to mediate this situation. Two activities were delineated: phosphorous recovery methodology (Ref) and usage of submerged artificial reefs.

On the other hand, on the Croatian side, the quality status of marine waters is closely related to the wastewater discharges from the WWTP or untreated discharge for the population not connected to the public sewer yet. This results in the elevated nutrient presence in the coastal waters and also impacts the potential for the production of phytoplankton biomass. However, quite different hydrodynamic and atmospheric conditions create stronger mixing processes along the Croatian coastline, which results in predominantly oligotrophic conditions for the majority of marine waters.

The AdSWiM project proposed to analyze the granular biomass technology and innovative photo disinfection procedure. Since the WWTP development is in quite a different status between the Italian and Croatian coastline, the direct development of a strategy for potential improvements of WWTP efficiency on the Croatian side is currently premature. However, in the following, we will demonstrate the potential applicability of granular biomass and photo disinfection technology on the future planned wastewater treatment facilities.

# PART 3: GRANULAR BIOMASS TECHNOLOGY

Granular biomass technology (ARGUS) has been developed as a bio-augmentation-granulation procedure with aerobic granules with designed composition, instead of spontaneously developed activated sludge flocks. Main goal of granular biomass technology is to enhance nitrification by nitrifying bacteria granulation, which is related to the creation of granulated micro-colonies[1]. New

[1] (ARGUS AeRobic Granular Upgrade System) Data provided by contractor from the original developer

bioprocesses for treatment of complex wastewater are developed in granular biomass technology as well as for upgrading of the existing wastewater treatment plants, using selected microbial cultures in free or granular form (Figure 1.).

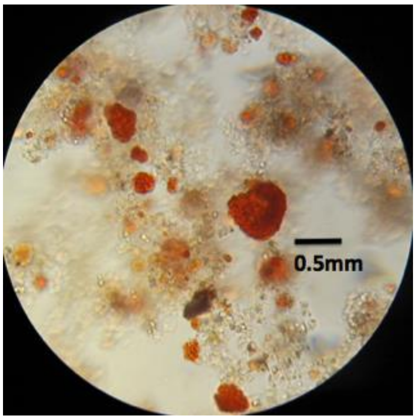


Figure 1. Light microscope image of the ARGUS granular sludge 400x

Granular biomass technology is suitable for implementation in existing wastewater treatment facilities as well as in new ones. This technology requires biological treatment with activated sludge, and it is developed for continuously stirred tank reactor systems (CSTR) as well as sequencing batch reactor systems (SBR). It is suitable for wastewater treatment facilities with high chemical oxygen demand (COD) and high nitrogen concentrations. Benefits of this technology is related to enhancement of settling properties, nitrification rates, lower sludge production, resistance to toxicity and steady state stability. Application of granular biomass technology is suitable for pharmaceuticals, chemical industry, food and beverage, leachate wastewater, sludge treatment residual water, overloaded communal wastewater treatment plants.

Table 1. Granular biomass technology efficiency at OLAZ WWTP

| **COD** | **N-tot** | **$NH_4$** | **$NO_3$** | **P-tot** |
|---|---|---|---|---|
| 59% | 89% | 100% | > 90% | 100% |

Granular biomass technology is designed to enhance the wastewater treatment processes, especially in facilities with high COD and nitrogen concentrations. Benefits of this technology are visible through significant cost reduction for new facilities through optimization of reactor size and energy consumption, as well as for existing facilities.

Technological requirements in wastewater treatment plants for implementation of granular biomass are primarily related to biological treatment with activated sludge. In a biological treatment tank, the propagator with aerobic granules cultivation is installed for preparation of the substrate and dosing to activated sludge tank (Figure 2.).

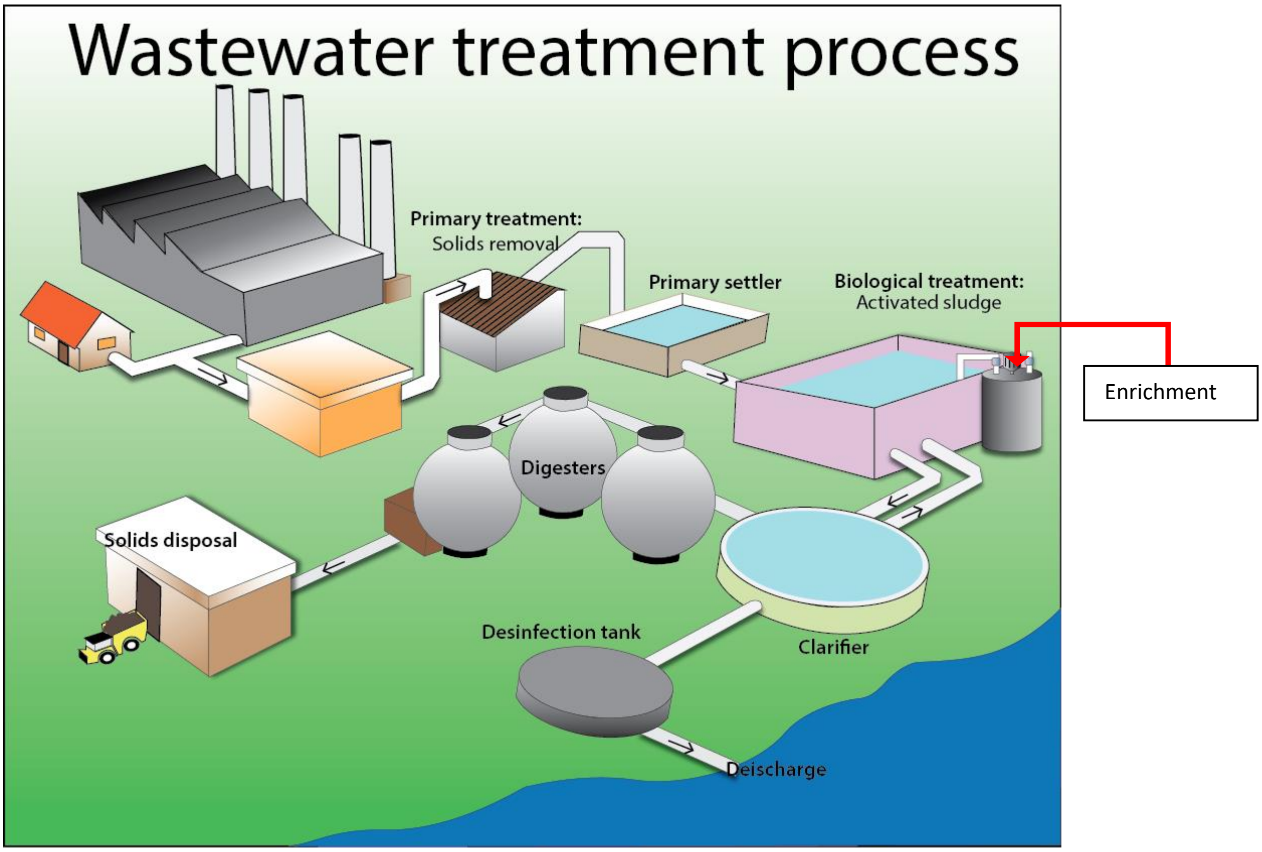


Figure 2. Technological scheme of wastewater treatment process with granular biomass enrichment[2]

Main investment considering granular biomass instalment is related to propagator installation for substrate preparation, whose dimensions are based on wastewater population equivalent number (Table 2.).

The first step is to evaluate the wastewater characteristics for side stream granular biomass preparation. The composition of granules depends on the characteristics of the water in which they are grown, and for each wastewater treatment, plant a custom solution is developed. Once granular

[2] Courtesy of PURATIS presentation of ARGUS (aerobic granular process for industrial and municipal WWTP applications)

biomass is prepared, it is implemented into a propagator where aerobic granules are cultivated and prepared for dosing into activated sludge reactor (Figure 3.).

Table 2. Granular biomass propagator size depending on wastewater population equivalent number

| **Wastewater treatment plant population equivalent PE** | **Propagator V/m$^3$** |
|---|---|
| 500 – 5.000 | 25 – 50 |
| 5.000 – 20.000 | 50 – 100 |
| 20.000 – 50.000 | 100 – 200 |
| > 50.000 | >200m$^3$ (2-5% of main system) |

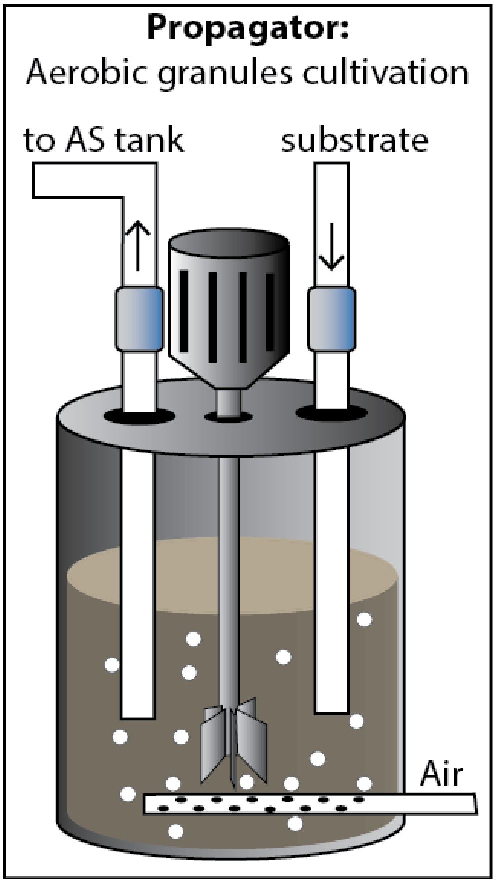


Figure 3. Propagator for aerobic granules cultivation

# PART 4: PHOTODISINFECTION TECHNOLOGY

Photo disinfection innovative technology has been developed in order to control and reduce bacterial and pathogen concentrations in wastewater. It is produced by experts from University of Udine, Italy and consists of photosensitive material and set of lamps. The concept is based on the composite of polyvinyl chloride (PVC)-based materials with blends of PVC, plasticizer, and photosensitizer materials. This photo disinfection concept is based on procedure where bacterial solution flows over the composite photosensitive material and being exposed to a light source. The main technological specifications of photo disinfection on a laboratory scale are summarized in Table 3.

The photo killing ability of this concept has been tested on a laboratory scale versus *Staphylococcus aureus*, showing efficient results in bacterial reduction. Bacterial solution with $10^7$ CFU/100 ml concentration has been used for testing, and after being exposed 60 minutes to blue light source with a radiance of 50 W/m$^2$ the bacterial concentration has been almost completely reduced. Similarly, the experiment was performed using incandescent lamps at 200 W/m$^2$, causing complete abatement of the initial bacterial solution after 180 minutes.

Photo sensible material consists of PVC, octyl Adipate and 4-py-P, and one sample of 125 mg is used for 30 cm$^2$ sheet. Approximately 1 cm$^2$ is required for 1 ml bacterial solution treatment. The durability of this material is not limited in particular; if it is conserved in the dark at -40 degrees Celsius, and the same material can be used at least four times. Required radiation for activation of the material is at least 50 W/m$^2$.

Table 3. Photo disinfection technology specifications[3]

| INDEX | UNIT VALUE | AMOUNT/QUANTITY |
|---|---|---|
| **Photo sensible material cost €/g** | • PVC: 0.127 €/g<br>• octyl Adipate: 39.1 €/g<br>• 4-py-P: 27 €/g | Sample composition:<br>• PVC: 100 mg<br>• Octyl adipate: 20 mg<br>• 4-py-P: 5 mg<br>*Sample cost: 0.93 € / 125 mg* |
| **Material quantity on the substrate surface** | $[Kg_{material}/m^2_{surface\ substrate}]$ | Sheet of 30 $cm^2$ can be made with a 125 mg sample,<br>*1 kg = 240.000 $cm^2$ = 24 $m^2$* |
| **Material quantity per volume of treated wastewater** | $[kg_{material}/l_{wastewater}]$ | Approximately 1 $cm^2$ of material is used to treat 1 ml of solution;<br>*1 $kg_{material}$/240 $l_{wastewater}$*<br>The same material can be used for more than four times |
| **Durability of the material** | [time] | It is conserved in freezer at -40°C;<br>if it is conserved in the dark, decline in quality will not occur |
| **Required radiation to activate the material** | [W/$m^2$] | The test done by University of Udine has been carried out with a led blue light with a radiance of 50 W/$m^2$ and incandescent lamps at 200 W/$m^2$. |
| **Exposure time to cut down the pathogen load ($10^7$ CFU/100 ml)** | [min] | Using blue light at 50 W/$m^2$: between 60 and 90 min<br>Using incandescent lamps at 200 W/$m^2$: between 150 and 180 min |

[3] Technical specification provided by University of Udine experts

# PART 5: STUDY SITES DESCRIPTION

## WASTEWATER TREATMENT PLAN SPLIT

Wastewater treatment facility in City of Split is designed as a part of a major infrastructure project, Agglomeration Split-Solin, and it is designed as a part of the existing wastewater treatment facility. Current facility consists of mechanical treatment (coarse and fine grid) and oil and grit removal. The wastewater treatment in new facility[4] is upgraded with biological treatment where organic and inorganic matter is dissolved. As a result, primary and secondary sludge is produced and treated in facility for sludge thickening and drying. Wastewater treatment plant Split is designed for 275.000 population equivalents (PE) with maximum hydraulic load of 1.278 litres per second (l/sec) during rain periods. Wastewater loading is estimated as:

- BOD (kg/d) = 16.500
- BOD (mg/l) = 271,8
- Suspended solids (kg/d) = 19.250
- Suspended solids (mg/l) = 544
- COD (kg/d) = 33.000
- COD (mg/l) = 546,53

The new wastewater treatment facility consists of (see Appendix for graphical details):

- Mechanical treatment with fine and coarse grid
- Primary settling tanks
- Biological reactors
- Sludge thickener
- Sludge stabilization
- Sludge dehydration and drying
- Biogas tank

[4] Conceptual design of wastewater treatment plant Stupe-Split, Hidroprojekt Consult d.o.o. Zagreb, 2016.

- Septic tanks collection

Mechanical treatment is related to coarse and fine grid, and aerated grit and oil removal units. After mechanical treatment, wastewater flows into primary settler unit. In this unit, remaining grit and oil is removed, and primary sludge is removed and transferred into sludge processing units. Biological treatment of wastewater is performed in biological reactors, with aerobic bacteria and compressed oxygen. In this unit, activated sludge is produced and transferred to secondary settlers. In this unit, activated sludge is settled on the bottom of the secondary settler tanks and transferred back into the biological treatment unit for additional treatment or into sludge processing unit. From the secondary settlers, clarified water is discharged into the sea by marine outfall pipe and diffuser with total length of 1.500 meters. In the sludge processing unit, collected sludge is thickened, heated and dried, and during this process the biogas is produced.

## WASTEWATER TREATMENT PLAN PLOČE

Wastewater treatment plant Ploče is designed for 9.000 PE, with maximum hydraulic load $Q_{max}$ = 39,8 l/s[5]. Wastewater loading concentrations for WWTP design are estimated as:

- BOD (mg/l) = 302,00
- COD (mg/l) = 657,30
- Suspended solids (mg/l) = 362,54
- Total Nitrogen (mg/l) = 61,92
- Total phosphorus (mg/l) = 7,22

Wastewater treatment plant Ploče is designed with mechanical treatment only consisting of:

- Fine grid
- Grit and oil removal
- Waste rinsing
- Waste air treatment
- Septic tanks collection

[5] Conceptual design of wastewater treatment plant Ploče, Akvaprojekt d.o.o. Split, 2017.

Mechanical treatment considers automatic fine grid with waste rinsing for separation of solids and waste, where wastewater flows under pressure eliminating the coarse grid requirement. After mechanical treatment, wastewater flows into aerated oil and grit removal unit. In the first part of the unit, grit and oil is broken down into smaller particles by using compressed air. Particles with specific weight less than water flow onto the surface where they are mechanically removed. Particles with specific weight greater than water are settled on the bottom of the unit tank and removed mechanically as well. Furthermore, a septic tank collection and treatment unit is design in WWTP Ploče as well. It is designed for collection and treatment of septic tanks wastewater, before being released into mechanical treatment unit of WWTP Ploče. Since there is no biological treatment, there is no activated sludge production. Treated wastewater is discharged into sea by 1800 m long marine outfall.

## WASTEWATER TREATMENT PLAN KOMIN

Wastewater treatment plant Komin[6] is designed for 1.650 population equivalents with maximum inflow of 5,78 l/s, and consists of:

- Mechanical treatment
- Biological treatment
- Secondary settler
- Sludge thickener

Wastewater treatment plant Komin is designed as a biological treatment facility with activated sludge production. Effluent concentrations considering BOD are less than 20 mg BOD/l, which is achieved by dimensioning the aeration tank to less than 0,2 kg of BOD/m3 with retention time of 4 hours at least. At first stage, wastewater influent flows through a 6 mm fine grid, where solids and waste are removed. In the next phase, wastewater flows into the biological reactor for biological treatment of wastewater. In the secondary settler, wastewater is separated between clarified water and activated sludge which is partially returned into the biological reactor. Treated wastewater is discharged into River Neretva using 111 m long outlet. Wastewater concentrations used for calculations are equal to:

- BOD 98,70 kg/day
- COD 197,40 kg/day

[6] Conceptual design of wastewater treatment plant Komin, Hidrotech d.o.o. Rijeka, 2020.

- SS 115,15 kg/day

Excess sludge is transferred into a thickening unit with two chambers separated. Sludge is transferred in the first chamber, where it is additionally separated to sludge and clarified water. The clarified water is transferred to the second chamber and from there it is returned to the aeration tank. Specific sludge production is equal to 0,8 kg of dry matter per kg of BOD.

# PART 6: TECHNICAL FEASIBILITY ASSESSMENT OF SELECTED TECHNOLOGIES

## WASTEWATER TREATMENT GRANULAR BIOMASS TECHNOLOGY

Possibility for application of granular biomass is associated with the existence of the biological reactor so the technological feasibility is performed for wastewater treatment plants Split and Komin, since wastewater treatment plant Ploče is designed with mechanical treatment only. Although granular biomass technology is originally developed for wastewater treatment facilities with high COD and nitrogen rate, potential benefits considering granular biomass could be related to optimization of biological reactor dimensions through lowering activated (secondary) sludge production. This can be achieved based on improvement of nitrogen removal and BOD reduction, respectively. Nitrogen share in BOD concentration is equal to 15-20%[7]. Consequently, increase of nitrogen removal efficiency in biological reactor could cause BOD reduction as well. It should be noted that urban wastewater has much lower concentrations in comparison to, for instance, industrial wastewater where granual biomass has been already successfully implemented.

Preliminary calculations for wastewater treatment plants Split and Komin dimensioning of the biological reactor are performed based on the ATV A 131 standards[8]. Volume of the biological reactor is calculated based on the *Equation 5-16*:

$$V_{AT} = \frac{M_{SS,AT}}{SS_{AT}} \qquad [m^3]$$

Where $SS_{AT}$ is equal to suspended solids concentration, $M_{SS,AT}$ is equal to mass of the suspended solids in the biological reactor and it is calculated based on *Equation 5-15*:

$$M_{SS,AT} = t_{SS,Dim} \cdot SP_d \quad [kg]$$

[7] Stanislav Tedeschi, Zaštita vodnih sustava i pročišćavanje otpadnih voda, Građevinski institut - Zagreb, 1983.
[8] German ATV-DVWK Rules and Standards A 131E Dimensioning of Single-Stage Activated Sludge Plants

And $t_{SS,Dim}$ is equal to sludge age upon which dimensioning is based and $SP_d$ is equal to daily waste activated sludge production. Using these expressions, a calculation considering suspended solids mass in biological reactor, volume of the biological reactor and sludge production is performed.

Considering WWTP Split, wastewater type and composition is related to urban or municipal wastewater with lower COD concentrations than industrial wastewater. Furthermore, nitrogen level is slightly lower and there is almost no phosphorus in wastewater (Figure 4.). BOD concentration presents a key parameter for activated sludge reactor dimensioning.

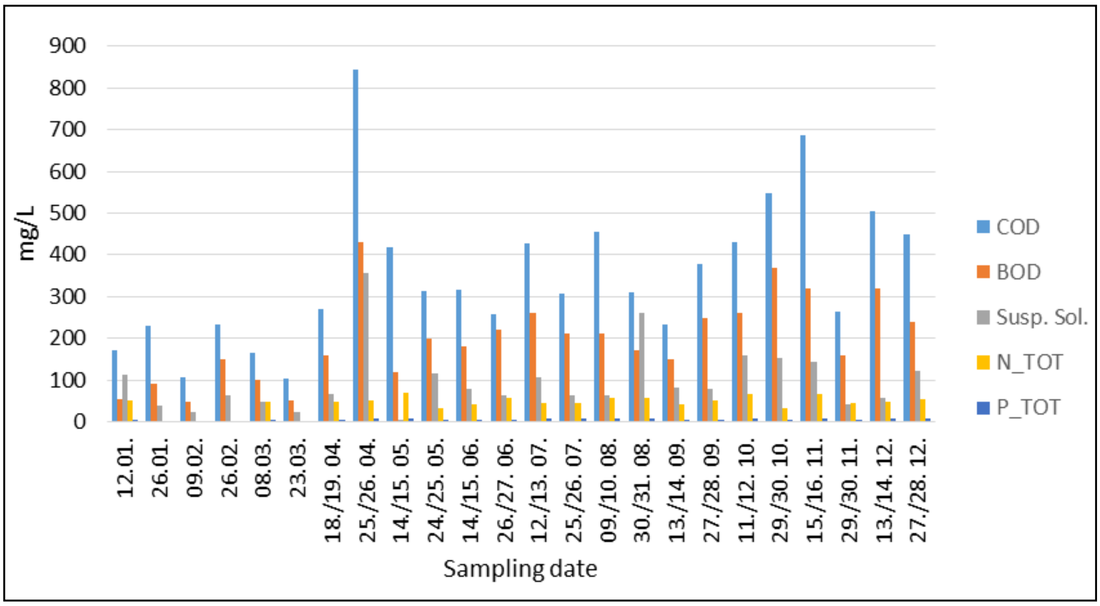


Figure 4. Wastewater concentrations in wastewater treatment plant Split

Table 4. Biological reactor design values for wastewater treatment plant Split

| PARAMETER | | DESIGN VALUE |
|---|---|---|
| Hydraulic load | $m^3$/day | 60.699 |
| | $m^3$/h | 3.148 |
| | l/sec | 875 |
| BOD input concentration kg/day | | 12.375 |
| Suspended solids concentration (kg/$m^3$) | | 3,3 |

| | |
|---|---|
| Daily waste activated sludge production (kg/day) | 12.499 |
| Sludge age (days) | 4 |
| Suspended solids mass (kg) | 49.995 |
| Biological reactor volume ($m^3$) | 15.150 |
| Primary sludge (kg/day) | 14.850 |
| Secondary sludge (kg/day) | 12.499 |
| Total sludge (kg/day) | 27.349 |

Design values for WWTP Split biological reactor are presented in Table 4. Estimated daily waste activated sludge production is equal to 12.499 kg per day, and with sludge age of minimum 4 days the suspended solids mass is equal to 49.995 kg. Considering the suspended solids concentration of 3,3 kg per $m^3$, the biological reactor volume is equal to 15.150 $m^3$.

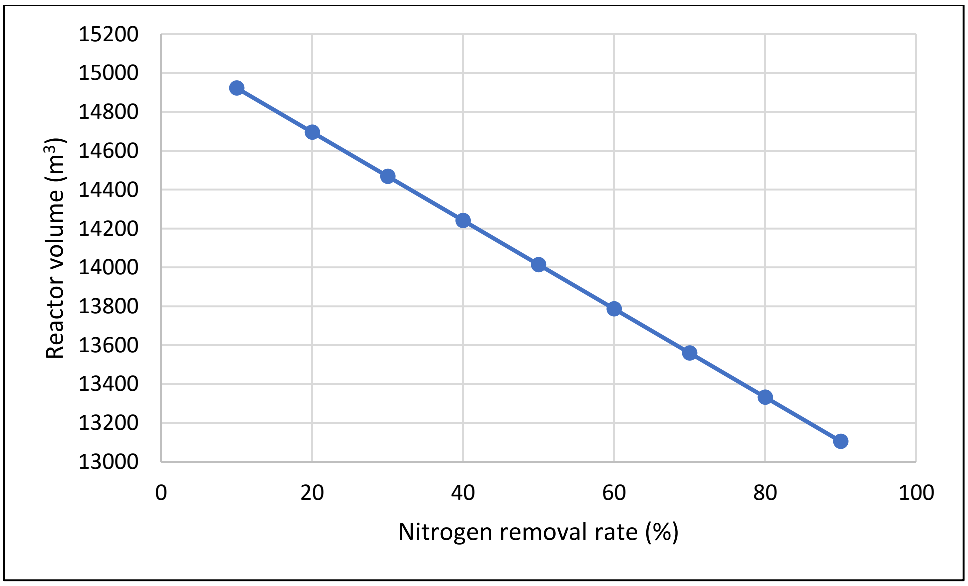


Figure 5. Nitrogen removal and reactor volume ratio for WWTP Split

Potential application of granular biomass is evaluated through nitrogen removal rate (from 10 – 90%). As shown in Figure 5., by additionally removing nitrogen the reactor volume is decreased to 14.900 m$^3$ and up to 13.100 m$^3$ (90%) approximately. Similarly, sludge production also decreases from 12.300 kg/day to 10.800 kg/day (Figure 6.).

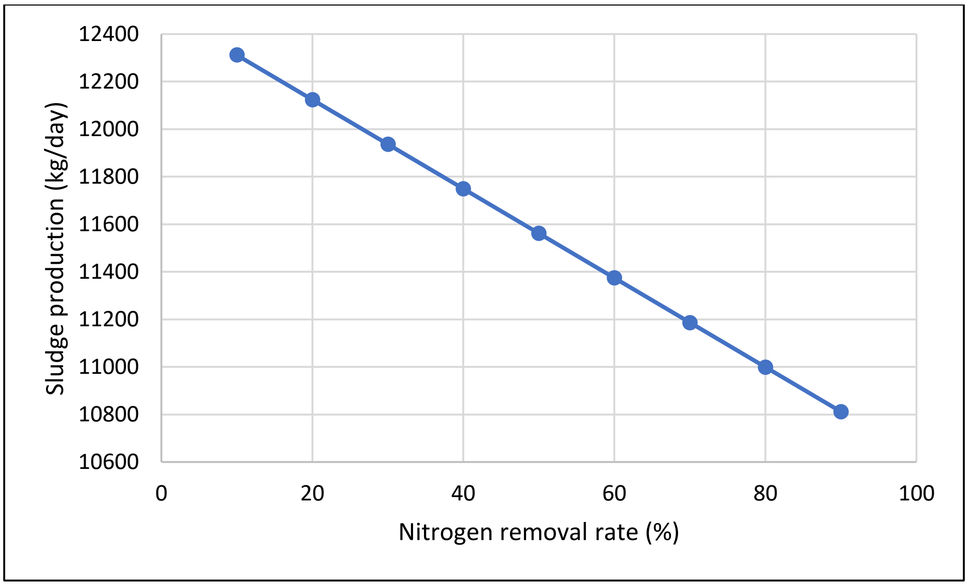


Figure 6. Nitrogen removal and sludge production ratio for WWTP Split

Considering the wastewater treatment plant Komin, the wastewater composition is similar as in WWTP Split (municipal wastewater), with lower COD concentrations and no phosphorus present. Design values for WWTP Komin biological reactor are presented in Table 5. Estimated daily waste activated sludge production is equal to 79,2 kg per day, and the biological reactor volume is equal to 504 m$^3$. By removing nitrogen for additional 10 – 90%, reactor volume can be decreased from 8 m$^3$ to 68 m$^3$, respectively (Figure 7.).

Table 5. Biological reactor design values for wastewater treatment plant Komin

| PARAMETER | | DESIGN VALUE |
|---|---|---|
| Hydraulic load | m$^3$/day | 499,39 |
| | m$^3$/h | 20,81 |

| | | |
|---|---|---|
| | l/sec | 5,78 |
| BOD input concentration kg/day | | 12.375 |
| Suspended solids concentration (kg/$m^3$) | | 3,93 |
| Daily waste activated sludge production | | 79,2 |
| Sludge age (days) | | 25 |
| Suspended solids mass (kg) | | 1.980 |
| Biological reactor volume ($m^3$) | | 504,00 |

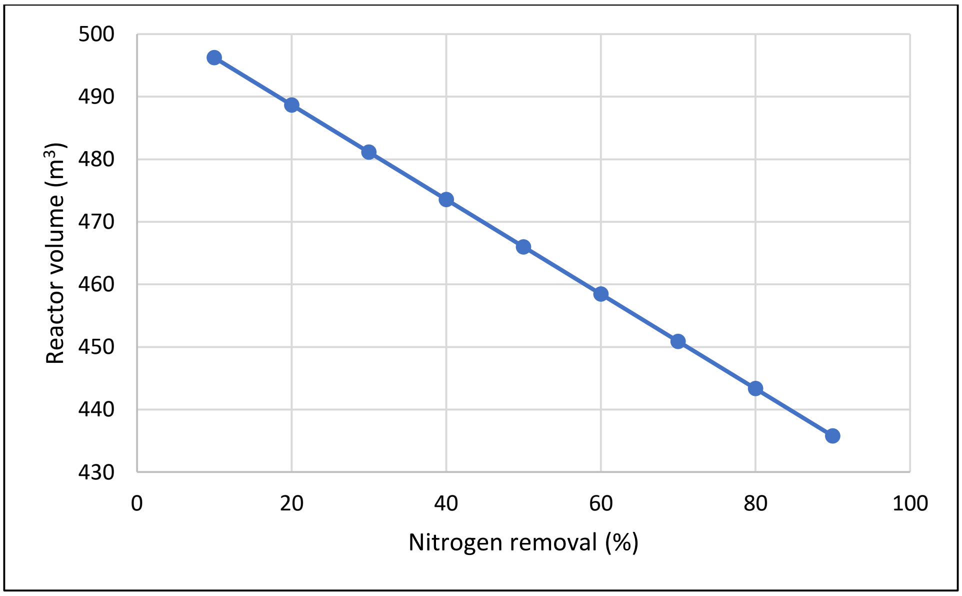


Figure 7. Nitrogen removal and reactor volume ratio for WWTP Komin

## WASTEWATER TREATMENT PHOTODISINFECTION TECHNOLOGY

Photo disinfection innovative technology has been developed by experts from University of Udine in order to control and reduce bacterial and pathogen concentrations in wastewater. In particular, this technology is designed to support the conventional wastewater treatment processes through removal of bacteria and pathogens from treated wastewater before discharging into sea or another recipient. Since there are no specific technological requirements or conditions for potential implementation, the technical feasibility of photodisinfection technology is tested on newly designed wastewater treatment facilities in Split, Ploče and Komin.

Considering wastewater treatment plant Split, estimated faecal concentration in the effluent is equal to 5,04 x $10^6$ CFU/100 ml[9]. Retention time is taken 60 min, as initial faecal concentration is approximately 10 times lower than the experimental one. Given the inflow of 1.278 l/sec and the required retention time, required volume is equal to 4.600 $m^3$. Since the thickens of the water layer is recommended to be up to 1 cm, required area is calculated as 460.080 $m^2$, with material quantity of 19.170 kg and total price of photo sensible material equal to 142.624.800 € (Table 6.).

Table 6. Photo disinfection technology calculation for wastewater treatment plant Split

| | |
|---|---|
| Maximum hydraulic load - Q (l/sec) | 1.278 l/sec |
| Faecal coliform concentration (CFU/100 ml) | 5,04 x $10^6$ CFU/100 ml |
| Total faecal coliform load (CFU/sec) | 64 x $10^9$ CFU/sec |
| Retention time (min): | 60 min |
| Required volume ($m^3$): $V = \int Q\,dt$ | 4.600,80 $m^3$ |

[9] Environmental impact assessment study for Split-Solin Agglomeration, Dvokut Ecro, Zagreb, 2016.

| | |
|---|---|
| Required area ($m^2$):<br><br>1 $cm^2$ = 1 ml | 460.080 $m^2$ |
| Material quantity (kg):<br><br>1 kg = 240.000 $cm^2$ = 24 $m^2$ | 19.170 kg |
| Photo sensible material cost (€):<br><br>Unit price: 0,93 € / 125 mg composite material | 142.624.800 € |

In the wastewater treatment plant Ploče, estimated faecal concentration in the effluent is equal to 6 x $10^7$ CFU/100 ml since there is no biological treatment. Retention time is taken 90 min, same as the experimental one. Given the inflow of 39,82 l/sec and the required retention time, required volume is equal to 215,03 $m^3$. Required area is equal to 21.503 $m^2$, material quantity of 895,96 kg and total price of photo sensible material is equal to 6.665.940 € (Table 7.).

Table 7. Photo disinfection technology calculation for wastewater treatment plant Ploče

| | |
|---|---|
| Maximum hydraulic load - Q (l/sec) | 39,82 l/sec |
| Faecal coliform concentration (CFU/100 ml) | 6 x $10^7$ CFU/100 ml |
| Total faecal coliform load (CFU/sec) | 2,39 x $10^9$ CFU/sec |
| Retention time (min): | 90 min |
| Required volume ($m^3$):<br><br>$V = \int Q\, dt$ | 215,03 $m^3$ |
| Required area ($m^2$):<br><br>1 $cm^2$ = 1 ml | 21.503 $m^2$ |
| Material quantity (kg): | 895,96 kg |

| | |
|---|---|
| 1 kg = 240.000 $cm^2$ = 24 $m^2$ | |
| Photo sensible material cost (€):<br><br>Unit price: 0,93 € / 125 mg composite material | 6.665.940 € |

In the wastewater treatment plant Komin, estimated faecal concentration in the effluent is equal to 5 x $10^6$ CFU/100 ml given that there exists a biological treatment. Retention time is taken 60 min, since the initial faecal concentration is lower Given the inflow of 5,78 l/sec and the required retention time, required volume is equal to 20,81 $m^3$. Required area is equal to 2.081 $m^2$, material quantity of 86,71 kg and total price of photo sensible material is equal to 645.122 €.

Table 8. Photo disinfection technology calculation for wastewater treatment plant Komin

| | |
|---|---|
| Maximum hydraulic load - Q (l/sec) | 5,78 l/sec |
| Faecal coliform concentration (CFU/100 ml) | 5 x $10^6$ CFU/100 ml |
| Total faecal coliform load (CFU/sec) | 2,89 x $10^8$ CFU/sec |
| Retention time (min): | 60 min |
| Required volume ($m^3$):<br><br>$V = \int Q \, dt$ | 20,81 $m^3$ |
| Required area ($m^2$):<br><br>1 $cm^2$ = 1 ml | 2.081 $m^2$ |
| Material quantity (kg):<br><br>1 kg = 240.000 $cm^2$ = 24 $m^2$ | 86,71 kg |
| Photo sensible material cost (€):<br><br>Unit price: 0,93 € / 125 mg composite material | 645.122 € |

# PART 7: CONCLUSIONS

In this study, a technical feasibility assessment of innovative wastewater treatment technologies developed within Interreg CBC Italy-Croatia AdSWiM project is performed. In particular, these technologies are related to granular biomass technology and photo disinfection technology. Granular biomass technology is based on bio-augmentation-granulation procedure with aerobic granules with designed composition instead of spontaneously developed activated sludge flocks. These aerobic granules are designed to improve nitrogen and COD removal as well as decrease of sludge production in comparison to conventional activated sludge flocs. On the other hand, photo disinfection technology is developed in order to control and reduce bacterial and pathogen concentrations in wastewater. Bacterial removal is based on wastewater flowing over the composite photosensitive material and being exposed to a light source.

Technical feasibility of granular biomass technology is performed for wastewater treatment plants in Split and Komin. Technical requirements are related to existence of biological reactor with activated sludge production. Since wastewater treatment plant Ploče is designed for mechanical treatment only it’s not taken into consideration. The efficiency of granular biomass is taken from the available literature, focusing mostly on nitrogen removal since COD concentrations are relatively low on both wastewater treatment plants. Technical feasibility is based on the hypothesis of high nitrogen removal rate (up to 90%) in comparison to conventional technologies, which is directly related to BOD reduction and sludge production. As a result, for both wastewater treatment plants the sludge production could be potentially decreased, which may result in a reduction of biological reactor dimensions together with sludge treatment facilities. However, this calculation is based on rough assumptions regarding the considered technologies and much more technical details and batch experimental validation is needed before assessing the feasibility of implementation.

Individual approach for each wastewater treatment facility is required in order to calculate the applicability of granular biomass technology correctly. This considers analysis of operational mode, wastewater quantity and concentrations as well as other particularities. Regarding the photo disinfection technology, there are no DP's technical constraints presented by the developers. However, unlike granular biomass this technology is currently developed on the laboratory scale only. This corresponds to the TRL 4 and requires the critical additional steps from TRL 5 and 6 before even considering possible validation and demonstration in the relevant environment. Although the photo disinfection technology is showing solid results on the laboratory scale considering bacterial removal, the estimated area required for full-scale implementation has shown that current technical feasibility is highly unreasonable at this moment. Furthermore, calculation of material cost has shown some irrational values that could certainly be the main constraint for implementation of this technology. Furthermore, the description of photosensitive material by the developer is doubtful and its long-term application is questionable at this moment. The photo disinfection technology clearly needs to undertake development of TRL 5 and 6 before any meaningful feasibility assessment can be performed.

Benefits of photo disinfections technology are in total bacterial removal, which can contribute to reduction of marine outlet length and provides the possibility of water reuse. Unfortunately, information about bacterial decay in relation to exposure time is not available. One of the possibilities could be in developing a device for partial bacterial removal, with shorter retention time required. This way, bacterial concentration could be decreased to a certain level and in combination with other processes such as dilution and decay provide bacterial levels below acceptable threshold.