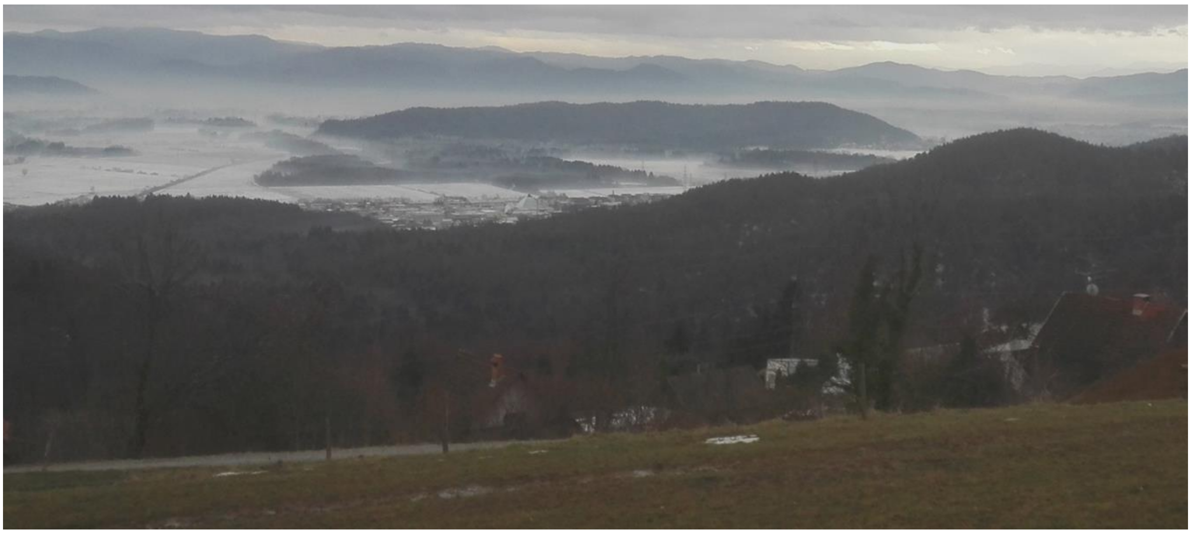
Synthesis centres on innovative wastewater treatment: feasibility studies in the Lower Danube

Lot 1: Slovenia, Slovakia, Czech Republic, Hungary, Bosnia-Herzegovina, Montenegro, Croatia

Summary of the Final Report of Activities



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1. Introduction

Water has been recognised as a central issue in the four vertical priorities of the "Scientific Support to the European Union Strategy for the Danube Region (EUSDR). One prominent issue is the enhancement and protection of water quality, which is the subject of the activities coordinated under Priority Area 4 of the EUSDR.

Among the threats to water quality, collected but untreated (or poorly treated) wastewater (WW) is a key problem in some countries, according to the International Commission for the Protection of the Danube River (ICPDR), as well as the River Basin Plan following the Water Framework Directive (WFD) 60/2000/EC. Often the capacity of communities to pay for water services (€/m^3 of treated water) is low compared to the cost of treatment. Thus, the scientific and policy aspects of the measures to be adopted for the implementation of the European Water Legislation need to be addressed by involving innovative WW treatment solutions that overcome the outlined limitations.

In support to the EUSDR, the Joint Research Centre (JRC) has involved expertise in the Danube region to gather and manage knowledge and know-how about possible alternatives by promoting capacity building through collaboration among research, industry and communities in the Lower Danube Region countries where this issue has been identified.

Three settlements (500-2000 PE - population equivalent) of Kamniška Bistrica Catchment, a small river basin in Slovenia in the lower Danube area, were selected as case studies. In this frame, decentralized approaches were compared to the option of collecting all WW in a centralized treatment plant. Several technologies were assessed considering the most recent systems to be applied in small settlements (in reference to the Sustainable Sanitation and Water Management Toolbox).

The overall aim of this project was to identify an affordable and sustainable solution for the WW treatment of small and medium settlements: 1) that can be replicable in the studied river basin, and 2) that can improve the capacity building of local companies which are involved in small WW treatment activities, since they can, in turn, facilitate the operation of the selected system and therefore help reducing the risks related to their improper management.

2. Objectives

In order to carry out this feasibility study, the following sub-objectives were addressed:

- Assessment of a complete range of WW treatment technologies appropriate for small settlements in the typical and widely spread conditions of the Lower Danube Region, analysing for each technology all relevant dimensions and highlighting advantages and disadvantages;
- Selection of appropriate technologies in three different contexts representing very widespread conditions;
- Detailed analysis of the selected solutions to extract technical and financial parametric data that allow to scale up the application of the selected alternative to the whole project area (Kamniška Bistrica catchment) and to other catchments in Lower Danube;
- Evaluation of possible financial schemes (considering taxes, costs, European Union funding and financing opportunities) that allow the realization of appropriate treatment facilities in the project area and in similar catchments;
- Elaboration of implementation program and schedule in the project area;
- Identification of the capacity building and training of operator needs in the project area.

3. Feasibility study

3.1 Task 1: Screening of technical alternatives

Location

In Slovenia, 98% of settlements have less than 2000 PE hosting 51% of the national population; around 2/3 of these 5.867 small settlements have no treatment facilities and discharge a significant pollution load into surface waters. In such isolated small villages, conventional treatment solutions, based on a large sewage network collecting WW to be treated in a centralized treatment plant, are technically difficult and very expensive so that alternative solutions must be identified.
Thus, the selected geographical area of the feasibility study was **Kamniška Bistrica Catchment**, a small basin in the lower Danube of Slovenia inhabited by more than 100.000 people. It is representative of Slovenia and other Lower Danube countries regarding its geographic characteristics and its environmental impacts of untreated WW on the water quality of receiving rivers/streams. The area presents a mountainous or hilly landscape with a huge number of small villages and settlements having no access to treatment facility.

In this area, the following three municipalities were selected as the most representative of settlements not equipped with WW treatment and complete sewer network:

- Case study 1: **Trojane** (municipality of Lukovica)
- Case study 2: **Dobeno** (municipality of Mengeš)
- Case study 3: **Vrhpolje pri Moravcah** (municipality of Kamnik)

Abatement targets

To define pollution abatement targets, the Slovenian legal framework, which is in the line with the Danube River Basin Management Plan and the most reliable international standards (WHO), was considered for the three possible final destinations of the outflows: 1) **discharge to water bodies**, 2) **discharge to the soil** and 3) **water reuse**. Further on, two different scenarios were considered: 1) **including nitrogen limits** (i.e. ammonium, nitrate) and 2) **no nitrogen limit**.

Identification of technical alternatives and screening of technology types

The possible technical options submitted to the multicriteria analysis were selected taking into account the peculiarity of the geographic conditions of the study area. The technology selection requirements were the following:

- robustness of the technology even with scarce and unskilled maintenance;
- low operation and maintenance (O&M) costs;
- appropriate treatment capacity relating to the local regulation framework;
- adaptability of the technology to decentralized treatment approach;
- acceptable integration in the surrounding landscape;
- resource recovery oriented approaches aimed to the development of circular economy;
- social acceptance of the treatment scheme.

The screened technical options were divided in three groups:

1. **Technological options:** WW treatment plants with a certain technological complexity, but in an acceptable level considering the local study area context. Such solutions generate the lowest area

footprint, but require significant O&M activities and therefore costs. Two technological options were selected for their acknowledged effectiveness and diffusion to serve small communities: **sequencing batch reactor (SBR)** and **membrane bioreactor (MBR).**

2. **Nature-based options:** solutions which allow the reduction of technological complexity and therefore of O&M activities, as well as costs with an increase of area footprint. The proposed alternatives are all based on constructed wetland (CW) technology. These treatment systems can be considered as the best management practices for the present case studies due to their capacity to guarantee a good treatment effectiveness with low investment and operational cost, as well as a high level of simplicity in the realization and maintenance activities. Five different nature-based options were selected to provide a full spectrum of technical possibilities: **horizontal subsurface flow (HF)**, **vertical subsurface flow (VF)**, **free water surface (FWS)**, **French reed bed (FRB)**, **forced bed aeration (FBATM)**. In addition, the possibility to combine the different CW technologies (the so called "hybrid CWs") was also considered to optimize the treatment performances and to reduce the total area footprint.
3. **Resource-oriented sanitation options:** solutions which aim to recover water and nutrients from WW to produce valuable products (e.g., biomass, fertilizers). Two options were proposed to investigate the potential benefits of these solutions in creating added-values from WW: **evapo-transpirative willow systems** and **algae-based technology**. Moreover, the possibility to recover nutrients by WW reuse was also considered.

Development of alternatives

The different technical options selected through the screening process could be implemented according to **centralized** or **decentralized** collection schemes. Eleven alternatives, within the three groups of technologies, were defined (**6 centralized**, and **5 decentralized**) in order to cover the different aspects regarding the WW treatment for the three case studies.

For each alternative and case study, a parametric approach was followed to design the treatment solutions that would guarantee the quality standard required in the two scenarios (with and without nitrogen limits). The preliminary design allowed to estimate investment and O&M costs, energy requirements, other technical requirements for operation, environmental impacts (including GHG emissions, and potential nutrient recovery). Socio-economic aspects were also considered, such as acceptability and opportunity for local employment.

3.2 Task 2: Selection of the preferred alternative

Socioeconomic analysis

This analysis was carried out by involving national and local stakeholders, as well as representatives of the local communities of the case study areas. Different meetings were organized to present the initiative to the different actors involved and questionnaires were distributed. The analysis allowed understanding the acceptability of the different solutions and the willingness/capacity to pay of the final users.

Multicriteria analysis (MCA) of alternatives and selection of the best alternative

MCA1:
For all three case studies, each technical alternative was subjected to a multicriteria analysis including four evaluation criteria: 1) costs, 2) environment and ecosystem service, 3) social acceptability, and 4) technical issues. Each criterion was based on different attributes and potentially sub-attributes that were measured through specific indicators.

According to the results of the MCA1 process, t**he best WW treatment solution** to be applied in small villages of Slovenian territory in the Lower Danube basin is a **decentralized nature-based solution (constructed wetland), allowing (where possible) the reuse of treated WW and its nutrients to irrigate fruit trees**.

Sensitivity analysis on MCA1:
To verify the robustness of the preferred solution, a sensitivity analysis was performed. The latter simulated what would have been the results of MCA1 if some attributes were measured through different indicators or the weights of the critical attributes were changed. The obtained result shows that **the preferred solution remains the same** whatever change is considered, even the costs of sewage (in favour of centralized solutions) or a drastic change of the weight of social acceptability.

MCA2:
To further corroborate the results of MCA1, a detailed analysis was performed for the Dobeno case study only in order to test the performance of the best-ranked previously- selected alternatives and of a decentralized approach. The results confirmed the **decentralized nature-based solution with WW reuse for irrigation (HF and irrigation in apple tree orchards)** as the best performing alternative, followed immediately by the same technical option without WW reuse (**HF**). The third on order of preference is the **centralized FRB** wetland and the last is the alternative envisaging **decentralized SBR** technology.

Generalizability of the alternative to similar situations in the Danube region

A parametric cost curve was elaborated, allowing to scale up the costs of WW treatment to the whole lower Danube basin for several of the alternatives: **3 nature-based centralized solutions** (hybrid, aerated and FRB wetlands, from 100 to 2000 PE) and for **2 decentralized solutions** (HF and VF wetlands, from 5 to 50 PE).
Discussion on the generalizability of the alternative to similar situations in the Danube region has been postponed in accordance with JRC. Iridra and the whole team working to the present study is committed to provide all the technical support needed for the upscaling of the results of the present study as a general solution for the lower Danube region.

3.3 Task 3: Technical and financial appraisal of the selected alternative

More detailed analysis of the selected alternative

Even though decentralized solutions appear clearly to be the most interesting regarding the local context, the occurrence of settlements that could be served by a centralized system cannot be excluded. Thus, a more detailed analysis was done for the 4 alternatives selected in the MCA2, allowing a **more reliable cost estimation** (both investment and O&M), as well as **an assessment of the activities and timing needed for the implementation** of the solution.

Project costs and financing

Considering the MCA results of private decentralized alternatives, the analysis of financing sources was focused on **public policies to support self-construction of treatment facilities**. A similar policy, with annual tenders, is already active in Slovenia where several municipalities are already subsidizing, through non-reimbursable funding, small, individual WWTPs. It could be noted that municipalities with predominantly urban settlement pattern (Ljubljana) are not providing co-financing schemes for the construction of individual WWTPs, as their main financial effort is focused towards the connection to the centralized systems.

The analysis shows that, in general, **small WWTPs are co-financed by the local community budget up to 1.000 Euro per singular individual WWTP, covering for 50% of the eligible costs**. The communities with dispersed settlement pattern decide for this financing mechanism because usually studies show that **the centralized solutions would be far more expensive for the budget of their municipality**.
Financial resources for co-financing are collected by local communities through the Decree on the environmental tax due for WW discharge. The tax is charged to end-users and can only be reduced to 10% of the original amount in the case of adequate WW treatment.
The income from this taxation goes to the local community, which usually uses this source either for the financing of the public WW collection and treatment systems or for the purpose of subsidies to individual WW treatment solutions.

Financial and economic analysis

The financial evaluation was based on the anticipated costs in the period of operation of WW collection and treatment for the three case studies. The financial analysis is related to actual costs incurred for the investment and operation of all the alternatives subject to the MCA. With respect to the long-term financial sustainability, the basic public WW collection and treatment systems in Slovenia are defined as a full cost-recovery service, following the general requirements of the Water Framework Directive, therefore all treatment costs have to be paid by the final users, either directly or through fees paid to the water managing body.
Two different approaches were compared:

- **Approach (1)** – **connection to the centralized WWTP** – connection fee as well as O&M costs are averaged on the level of local community or urban planning zone. Only the cost of connection pipe from the house to public sewerage collection system is directly covered by the individual owner.
- **Approach (2)** – **construction of individual WWTP** – all incurring costs are directly covered by the owner (investment and O&M).

This comparative analysis provided also a basic framework for the identified business model, differentiated for each approach: the individual solution (approach 2) has a lower annual cost compared to the public service one (approach 1); it allows saving for 129.84 €/year/household. Such an amount of savings – extended for the whole individual treatment plant lifespan (ranging between 20 and 30 years) – allows a positive balance of the investment costs: the payback time of investing 2500 euro to build a plant ranges between 11.5 and 19.2 years, depending on the possibility to access a construction subsidy of 1000 euro.

Identification of capacity building needs and plan for the training of plant operators

To support the capacity building and the training of plant operators (i.e. final users), two support manuals were provided: 1) **The sanitation safety planning: Manual for safe use and disposal of WW** provides guidelines to municipalities to promote sustainable WW and excreta management at settlement scale, 2) **The operation and maintenance manual for the case study of Dobeno** is a detailed user manual for the right management of CW treatment systems, which enables to enlarge the lifetime of the plant and promptly answers any functioning problem that may occur.

Implementation program and schedule

The duration of each activity, from the design to the realization, of the technical options proposed in the four alternatives selected in MCA1 analysis and further developed in more detailed analysis were estimated: the different solutions have a **realisation time ranging from 80 to more than 200 days** (only for the WWTP realisation).

4. Conclusions and analysis of the sustainability of the solution and possible risks

All the technical options proposed could be easily implemented in Slovenia and in the whole lower Danube area, to serve isolated communities. None of them have a significant negative environmental or social impact and all of them are "mature" technologies available on the market.

Nature-based solution proposed are **constructed wetlands**, a technology in use at market scale for 50 years and already in use in Slovenia at least since the 90's of the last century. The key aspect to guarantee effectiveness of CW is a proper, scientific based design, and a very wide scientific literature is available on the issue, together with several guidelines and manuals. Plant construction does not require expert technical labour, but just typical civil engineering works (e.g. excavation, waterproofing, etc.). If the CW is properly designed and is provided with a well-detailed O&M plan, we can assume a very low risk of not proper functioning in the future. Indeed, all the O&M general activities can be done by unskilled personnel; technical components are simple (e.g. pumps, valves) and can be repaired or substituted by local companies.

Regarding SBR solution – that could be used for decentralized treatment wherever lack of available space hinders the realisation of CW – several European producers of the technology exist, selling their products in Slovenia and in other countries of lower Danube basin; therefore, we can consider no limitation for the installation of small compact SBRs.

Among the possible risks of the proposed solutions it has to be considered that the recourse to a decentralized treatment system poses a problem in terms of monitoring the effluent quality: it is not possible to guarantee by the Environmental National Agencies a complete check of all the effluents. Therefore, malfunctioning of plants could be very difficult to be observed. The risk is considered acceptable for very simple and robust treatment systems, as HF wetlands, that require a very limited maintenance, and therefore, if properly designed, will guarantee a full secondary treatment. The risk, however, is not negligible for technological plants (such as SBR), that could present failures if not properly managed. Currently, small SBR for family use is a quite widespread technology in rural Slovenia. This technology is more diffused than CW because SBRs are better known by local technician and installers compared to CW, that are not so well known in the area. SBR could be an effective solution when wetlands could not be used for technical reason (e.g. lack of available area), but it is not comparable to wetlands in terms of robustness and reliability. As a result, it is highly recommendable that decentralized treatment systems make recourse mainly to nature-based solution, allowing the use of technological plants to a very limited number of users, able to demonstrate that nature-based solutions are not applicable in their properties.

In conclusion, a decentralized approach offers real advantages – economic, social and environmental – only if very robust and low-maintenance technologies are used. Thus, such aspects must be considered by the water policy at the basin scale.