



LIFE Project Number  
**LIFE12 ENV/SI/000443**

**FINAL Report**  
**Covering the project activities from 01/07/2013 to 30/09/2017**

Reporting Date  
**31/01/2018**

LIFE PROJECT NAME or Acronym  
**LIFE RusaLCA "Nanoremediation of water from small waste  
water treatment plants and reuse of water and solid remains for  
local needs"**

Project Data

<b>Project location</b>	Slovenia
<b>Project start date:</b>	01/07/2013
<b>Project end date:</b>	31/12/2016 <b>Extension date:</b> 30/09/2017
<b>Total Project duration (in months)</b>	51 months (including <b>Extension of 9 months</b> )
<b>Total budget</b>	€ 852,388
<b>Total eligible budget</b>	€ 852,388
<b>EU contribution:</b>	€ 426,192
<b>(%) of total costs</b>	50 %
<b>(%) of eligible costs</b>	50 %

Beneficiary Data

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## List of key words and abbreviations

**Nanoscale zero-valent iron particles (nZVI)** – This term denotes a nanomaterial which is used in the nanoremediation process of the pilot remediation system

**SWTP Poštaje** – This term denotes a small biological wastewater treatment plant (of the moving bed biofilm reactor type), which was constructed at the village of Poštaje (part of the small town of Šentrupert).

**Pilot remediation system** – This term denotes a multi-stage device which was constructed within the scope of the LIFE RusaLCA. It utilizes nZVI, oxidation, ion exchange, and filtration processes in order to remediate the wastewater water from SWTP Poštaje so that it meets the quality standards for drinking water.

**Remediation Protocol** – This term refers to the list of pre-determined parameters which were specified within the scope of Actions B.1 and B.2. These parameters were determined based on the results of experimental work or theoretical knowledge. They include: the optimal concentration of the added nZVI, the duration of the mixing, and of the settling, during nanoremediation process, and the concentration of the added oxidant. These parameters were further modified within the scope of Action B.5 in order to achieve effective and efficient operation of the pilot remediation system.

**Organic sludge** – This term refers to the organic waste material obtained from the small wastewater treatment plan, as a solid residue that settles after microbiological purification of municipal wastewater.

**Sediment from nanoremediation** – This term is used for inorganic waste, i.e. sediment, consisting of spent iron particles, which is produced during the nanoremediation of the wastewater within the scope of pilot remediation system of the LIFE RusaLCA project.

### List of abbreviations:

BOD – Biochemical oxygen demand

COD – Chemical oxygen demand

LCA – Life Cycle Assessment

LCCA – Life Cycle Cost Assessment

nZVI – nanoscale zero-valent iron particles

PE – population equivalent

S-LCA – Social Life Cycle Assessment

SLTO – Social licence to operate

SWTP – small wastewater treatment plant

## 2. Executive Summary

### **Project objectives and main results**

The LIFE RusaLCA project attempts to make a contribution to the mitigation of the problems caused by climate changes in Europe, which has been already affected by water scarcity and drought due to global warming. The project demonstrates an active approach towards the development, at both the local and the regional level, of a water-efficient and water-saving society. This approach can be used anywhere in Europe the local conditions have similar characteristics.

The first and primary objective of the project was the reduction of the consumption of drinking water by up to 30 % through the reuse of municipal wastewater in the Municipality of Šentrupert, which is located in south-eastern Slovenia. This was achieved through the reuse of remediated municipal wastewater originating in the drainage system of the village of Poštaje. The wastewater is first conventionally purified in a small wastewater treatment plant (SWTP). The wastewater leaving the SWTP contains different amounts of various pollutants, but these amounts, i.e. concentrations are, according to the relevant Slovenian legislation, suitable for release into surface waters. The wastewater water from the SWTP is then purified by means of a pilot remediation system, which was developed within the scope of the LIFE RusaLCA project, using a combined process consisting of nanoremediation (with the use of zero-valent iron nanoparticles), oxidation, filtration, and ion exchange. The purified water is stored in an underground storage tank, which is connected to a tap which members of the public can access it. A secondary water pipeline was also constructed in order to bring the purified water to a nearby concrete production plant. Additionally, 25 temporary storage containers, each with a volume of 1 m<sup>3</sup>, were distributed among the householders of Poštaje. These containers are regularly filled with purified water, according to people's needs, by the Municipal Public Services of Trebnje. The purified water is used, instead of drinking water, for people's secondary water consumption needs (e.g. the watering of gardens and vegetable gardens), as well as for the washing down of roads and the washing of cars, and for the needs of fire-fighters. In this way the consumption of drinking water in the village of Poštaje was indirectly reduced by 30 %, as was proved by the following calculation. The total amount of drinking water consumed in 2017 by 92 villagers of Poštaje, who are connected to the SWTP and thus also to the pilot remediation system, was 3200 m<sup>3</sup>, and 30 % of this amount corresponds to 960 m<sup>3</sup>. Within the scope of the LIFE RusaLCA project and taking into account 6 months of the above-mentioned year, half of this amount (i.e. 480 m<sup>3</sup>) was purified and reused, instead of taking the same amount of drinking water from natural sources.

The second objective of the project was to use the organic sludge from the SWTP, and the sediment from nanoremediation tank, in different types of composites. The sludge was used as a resource for the production of geotechnical composites, whereas the sediment was used in cementitious composites. This means that, due to this recycling of waste, natural resources were preserved, and simultaneous less waste was disposed of at landfill sites. In this way a zero-waste management system was established. Beneficial use of the organic sludge and of the sediment in composites is related to a low impact on the environment, especially when compared with traditional sludge treatment scenarios. For example, the incineration of organic sludge with heat recovery generates around 750 kg CO<sub>2</sub> equivalents, whereas the beneficial use of organic sludge in geotechnical composite generates only around 10 kg CO<sub>2</sub> equivalents. Moreover, the composites which make use of sludge and sediment result in a smaller environmental footprint than traditional composites, and thus fulfil the requirements for sustainability.

The third objective of the project was to disseminate the demonstrated pilot remediation system and its consequent benefits both in Slovenia and in other regions with similar geographic, climatic, settlement, and social characteristics. Dissemination was, during the course of the project, performed at national and international conferences and workshops, where lectures and posters were presented. The International LIFE RusaLCA conference (which was held at ZAG on 03-04/10/2016) gained the attention of the international community, since information about the benefits of the remediation of wastewater water by means of nZVI was disseminated internationally. In addition to Slovenian participants, stakeholders from Greece, Spain, Bosnia and Herzegovina, Montenegro and Macedonia participated at the conference. Participants at the conference also visited the pilot remediation system in the village of Poštaje, and were thus able to see the technology in operation, and obtain all other relevant information.

The LIFE RusaLCA project generated many interconnected results and effects which spanned such diverse areas as protection of the environment, the economy, social and community-related interactions, and science. The largest synergistic effect is reflected in the fact that the remediated water can be used to replace drinking water for a number of different purposes and needs in the Municipality of Šentrupert. The degree of nanoremediation of the wastewater water is sufficient to reduce the concentrations of pollutants at the baseline level which fulfils all the requirements for drinking water in accordance with the Slovenian national legislation.

### **Key deliverables and outputs**

The key deliverables and outputs of the project are the following:

#### The Initial Study

In this study the practical, scientific, and legislative aspects of wastewater treatment in SWTPs were explored, as well as the available options for the sustainable use of generated solid waste, as has been described in the literature. In the study, the focus was placed on the following subjects:

- The water situation in Slovenia and the cleaning/treatment of wastewater;
- The design of SWTPs and the current Slovenian legislation in this field;
- The nanoremediation of water by means of nZVI;
- The current management practices used in the treatment of organic sludge;
- Framework models for Life Cycle Assessments (LCA) and or Life Cycle Cost Assessments (LCCA);
- The reuse of treated wastewater obtained from SWTPs;
- The data on consumption of drinking water and the description of the characteristics of the urban wastewater drainage system in the Municipality of Šentrupert.

#### The optimized nanoremediation process

Comprehensive experimental work together with detailed chemical, microbiological, and physical analyses of water samples obtained from a SWTP at Hruševo (Slovenia) was conducted. Batch experiments were performed with the aim of optimizing the nanoremediation parameters (i.e. the necessary dosage of nanoparticles, the duration of the mixing and settling periods, the correct dispensing of remediation agents). Among the various available types of nZVI, the most appropriate were chosen. An effective multi-stage remediation protocol for the purification of wastewater from SWTP was developed which includes the use of iron nanoparticles, an oxidant, and an ion exchanger, as well as the use of a sand and activated charcoal filtration system. In a laboratory-scale simulation of the multi-

stage water remediation, sufficient purification of the wastewater of the SWTP was achieved, so that the remediated water fulfilled the criteria for drinking water quality.

#### The completed plans for the pilot remediation system

The pilot system was a complex multi-stage water remediation device which was connected to the SWTP. It has an electronic control system for the automated and autonomous operation of system. The necessary building permit was obtained in April 2014, for the construction of the proposed wastewater remediation plant for 100 population equivalents (PE).

#### The putting of the pilot remediation system into operation

The construction of the SWTP and the pilot remediation system was completed on 07/03/2015. A few days later, the trial period of operation of the system began. There were some delays achieving a fully functioning pilot remediation system, but the optimisation began in November 2015, and by March 2017 delivery of this system was achieved.

#### Optimization of the pilot remediation system

Modifications of the pilot remediation system were made on the basis of the results of monitoring of the treatment's efficiency and effectiveness, taking into account various experimental treatment procedures. Analyses of effectiveness were performed by means of chemical and microbiological characterization of water samples from each of the four stages of remediation. The remediation protocol obtained after optimization of the pilot remediation system formed the basis for preparation of a "Technical Operations Protocol" and for the training of the personnel needed to manage the pilot remediation system.

Technical improvements of the pilot remediation system were made, together with optimization of the remediation protocol. A new pumping station was installed in 2016, and forms a part of the pilot remediation system. It was needed in order to prevent any possible flooding of the system. Quite a lot of modifications were made to the control system in 2016 and 2017, both on the software and the hardware, in order to ensure a smooth, simple, and safe semi-automatic functioning of the pilot remediation system. An additional upgrade was made to the filtration units in 2017, which initially consisted of an activated carbon filter and ion exchanger. A sand filtration unit was added to ensure better removal of colloidal particles. Also, the regeneration system was improved for all three units.

#### Sludge and sediment recycling and evaluation of the final products (composites)

One of the main objectives of the project is to establish a zero-waste management system for the solid residues generated at the SWTP and by the pilot remediation system. This is because the treatment of municipal wastewater at the SWTP generates organic sludge, as the first type of waste. This is followed by treatment of the wastewater from the SWTP in the nanoremediation process, in which sediment consisting of spent iron particles is generated. The latter is collected and temporarily stored on site in a concrete underground tank. Both types of waste (i.e. the organic sludge and the sediment) have dissimilar properties, so they have to be treated separately.

The organic sludge is mixed with paper ash (which is generated during the combustion of biomass and waste from paper recycling processes) in order to produce geotechnical composites. Three recipes for composites were designed for different intended uses according to the complementary action of delivering a Slovenian Technical Approval. These geotechnical composites were designed for construction of impermeable sealing layers for non-hazardous waste landfill sites, as well as for the construction of handling and service areas, and transportation routes within the site. The properties of the composites were

examined in detail in order to make sure that they meet the corresponding technical and health regulations with regard to intended use.

Recipes for the use of the sediment in concrete were also prepared. Several tests were conducted in order to make sure that the concrete containing the waste iron would meet the specification standards, and to determine the optimal recipe for the concrete mixture.

For both types of waste, a protocol concerning the proper treatment and the possibility of further useful applications was defined. It was shown that both the organic sludge and the sediment can be used beneficially used in composites so that a zero-waste management system can be established in the case of the investigated SWTP and its pilot wastewater remediation system.

#### Feasibility study

A feasibility study was performed in order to examine the possibility of the implementation of nanoremediation of wastewater waters at SWTPs and the reuse of remediated water and solid-wastes (organic sludge, sediment) in the south-eastern part of Slovenia. The results of the study showed that the use of purified water for the people's secondary needs for water, for irrigation of farmland, gardens and vegetable gardens, for common public needs (e.g. firefighting), and for industry has great potential, which is particularly important in the light of increased fluctuations of temperatures and of more frequent periods of drought in recent years. In the above-mentioned region, it will possible to make use of the organic sludge from SWTPs, as well as the waste sediment of iron particles, since there are sufficient potential purchasers of such secondary raw materials in the regional construction sector.

#### Life Cycle Assessments (environmental related impacts)

The additional treatment of wastewater water with the use of nZVI shows two positive impacts on the environment: (i) there is a significant saving in the amount of consumed water (in the LCA calculations it was assumed that during a period of one year 960 m<sup>3</sup> of water from natural resources could be saved in the village of Poštaje, and (ii) the eutrophication of local streams can be reduced (in the discussed case the reduction of COD emissions amounts to 48.96 mg/L of O<sub>2</sub>, and that of BOD emissions to 7.2 mg/L O<sub>2</sub> per year). The environmental benefits for the local environment are thus significant. Another aspect is the recycling of the solid waste obtained from the SWTP and from the nanoremediation tank, i.e. organic sludge and sediment consisting of spent iron particles, respectively. The utilization of organic sludge from the SWTP for the production of geotechnical composites has only a low impact on the environment, especially when compared to traditional treatment methods (incineration with heat recovery, or use in agriculture). The ratio between the latter and the former impacts can be as high as 75 to 1. Moreover, composites in which organic sludge or sediment is used result in a smaller environmental footprint than traditional composites, thus fulfilling sustainability requirements.

#### Socio-economic impacts

At the present, the remediation of municipal wastewater by means of the use of nZVI, to the degree that it acquires the status of drinking water, is a relatively expensive. On average, the costs of purifying one cubic metre of wastewater amount to 13 EUR. The costs of purchasing the nZVI contribute a share of 91% of this price. The current cost of 1 kg of nZVI is 120 EUR, which has a significant impact on the results of the LCCA analysis. However, it is expected that price of nZVI become lower in the near future, taking into account the expansion of its use throughout the world.

With regard to organic sludge and sediment management, utilization of the sludge in a geotechnical composite and of the sediment in concrete is financially efficient treatment

methods. In comparison with traditional sludge management methods, such as sludge incineration, the costs are much lower. The estimated costs of sludge incineration in this specific case study amount to about 600 EUR per year, whereas the costs related to the use of the sludge in a geotechnical composite amount to only about 270 EUR per year.

The results of the performed Social Life Cycle Assessment (S-LCA) show that the LIFE RusaLCA project and new technology gained the approval of society and the local community, which is important in terms of the "social licence to operate". However, there are some internal and external restrictions, which currently prevent local inhabitants from fully adopting the proposed innovative technology as their own (i.e. co-ownership or a fully matured social licence to operate). These restrictions refer to the low level of recognition by individuals of the connection between climate change and their well-being, the lack of any carefully thought-out policy and/or legislative measures for the saving of water, side effects in agriculture and the food industry (compensation for drought damage), additional immediate costs for the operation of the new technology, and other reasons.

### Dissemination

Dissemination of information about the progress of the project began with the establishment of the official website [www.rusalca.si](http://www.rusalca.si) (on 25/10/2013), which was then continuously updated. This information was disseminated and presented within the scope of the following activities: public presentations (1 project presentation for the local community, and 2 for regional representatives, 1 final international conference, 11 lectures, 4 presentations at workshops, and the publication of 1 scientific paper, 9 technical papers, and 30 contributions intended for the general public), preparation of brochures and other promotional materials (e.g. posters), and preparation of a Layman's report.

### Networking

Based on networking, 510 potentially interested parties (people and companies) were identified (33 coordinators of various projects, 10 partners and customers of the consortium members, 80 municipal services companies and producers of SWTPs, 183 public agencies and ministries, and 204 researchers). Relations were also established with seven other LIFE projects, with similar topics. A Layman's Report has been sent to all potentially interested parties.

### The After-LIFE communication plan

The After-LIFE Communication Plan is focused on specific fields that were recognized as being important during the project, and describes the appropriate actions in each field. The After-LIFE plan is divided into two main set of activities:

- Technical and research activities, such as research on other promising remediation techniques, preparation of a proposal for the amendment of existing legislation in the field of sludge and water management, and the preparation of a business plan.
- Dissemination and communication activities (coordination of activities and the linking of partners, informing of experts, and monitoring/indicators).

### **Paragraph summarising each chapter of main report**

The Executive Summary gives an overview about the project aims, the key deliverables, and the outputs of the LIFE RusaLCA project.

The Introduction provides a description of the background and the addressed environmental problem, as well as a description of the applied technical solution, the aims of the project, and the achieved results.

The Technical Part contains detailed information about all the actions that were carried out within the scope of the project. The report corresponding to each action includes a description of the activities undertaken and the outputs achieved, and an evaluation of the Indicators of the performance of the action. The descriptions of the technical actions are followed by a description of the communication and dissemination actions, and of the project management and progress monitoring actions. The next section of the Technical Part is the Evaluation of the project implementation. In this section the achieved results are compared with the project's aims, in the form of a table. This part is concluded by an analysis of the long-term benefits.

The financial report includes a summary of the incurred costs, comments on the used accounting system, and the partnership agreement, followed by the auditor's report. This part ends with the summary of the costs per action.

The Annexes start with a list of the administrative Annexes already forwarded to the Commission, followed by the technical Annexes and the dissemination Annexes. The latter include the Layman's Report, the After-LIFE Communication plan, and other dissemination Annexes.

The Final Report of the LIFE RusaLCA project is completed by the financial report and its Annexes.

### 3. Introduction

#### ***Background***

The availability of drinking water of suitable quality and in sufficient amounts is the fundamental source of all ecological and sociological activities including food production, industrial activities, and the health and sanitary conditions of the population. One of the major global issues is water scarcity. Currently, one third of the global population suffers from insufficient availability of drinking water on a daily basis, and it is expected that this issue will become more severe in the future due to effects of various factors, including climate change, rapid population growth, the pollution of water sources, urbanisation, and changes in life style.

#### ***Hypothesis to be demonstrated by the project***

The LIFE RusaLCA project addresses the timely mitigation and adaptation to climate changes by means of innovative, feasible, efficient, and cost-effective solutions. This is achieved by confirming the validity of the hypotheses which refer to the main aims of the project. A 30 % saving in the consumption of drinking water from natural sources can be achieved through the reuse of municipal wastewater, which is additionally treated by an innovative nanoremediation process together with other complementary water purification methods. With the consumption of purified wastewater instead of drinking water obtained from natural sources, the consumption of the latter is indirectly reduced. The second hypothesis states that a zero-waste management system can be established, in the case of the proposed wastewater remediation system, by recycling all the solid wastes from the water purification processes in construction composites. The final hypothesis is that the proposed municipal wastewater remediation and reuse system can be beneficially used and transferred to any other region in the EU with similar characteristics and water scarcity problems.

#### ***Description of the technical solution***

Wastewater water from the SWTP located in the settlement of Poštaje in the Municipality of Šentrupert is additionally treated through an automated procedure by an innovative nanoremediation process which makes use of nZVI. Nanoparticles in the form of a suspension

are injected into the wastewater water, which is then purified during mixing through a variety of chemical reactions which are catalysed by the nZVI. A residue in the form of sediment is deposited at the bottom of the nanoremediation tank, after the settling of the spent iron particles. The sediment is later used as a raw material in the production of cementitious composites. The nanoremediation is further combined with multiple stages of conventional water purification processes (e.g. oxidation, sand and activated carbon filtration, ion exchange) in order to sufficiently reduce the concentrations of pollutants to the prescribed baseline levels so that the water fulfils all the requirements for safe reuse in accordance with the national and European Union's guidance document on the addressing of microbiological risks (Official Journal of the EU, 2017/C 163/01).

### ***Objectives and results achieved***

The primary aim of the project was a reduction in the consumption of drinking water by up to 30 % through reuse of treated municipal wastewater in the settlement of Poštaje in the Municipality of Šentrupert. This direct environmental benefit refers to a saving of natural drinking water resources through an indirect reduction in the consumption of drinking water. The consumption of drinking water was reduced by 30 % (which was demonstrated by reuse of 480 m<sup>3</sup> of purified wastewater in 6 months of the year 2017, including 92 inhabitants of Poštaje) through the use of purified water for people's secondary needs for water, as well as common public needs (e.g. firefighting) and in local industry.

The establishment of a zero waste system was also successfully demonstrated during the course of the LIFE RusaLCA project. The sediment of spent iron particles is, according to recipe designed within the scope of the project, admixed to concrete in which it partly replaces the needed mixing water and the fine-grained filler. The organic sludge from SWTP Poštaje is first processed at the Trebnje municipal wastewater treatment plant. The processed sludge is mixed with calcareous paper ash (e.g. fly ash and boiler slag from the incineration of deinking sludge and biomass) in predetermined proportions. The composite material, with an optimal content of water, is then compacted up to an optimum density for use in the placing of impermeable sealing layers.

### ***Expected longer term results***

The LIFE RusaLCA project can be replicated and transferred, as a whole (both the technology and the zero waste management system) to any region which intends to improve its water management system and is determined to fight against the effects of droughts and water shortage. In this way, longer term results will contribute to sustainability in the management of drinking water and water resources as a whole.

In the case of the Municipality of Šentrupert, the most important long term result of the LIFE RusaLCA project is the achieved greater resilience of the local community and industry to the effects of longer and ever more frequent periods of droughts due to climate changes. One of the important long term results of the project is also raised awareness among the local inhabitants about the importance of the preservation and sustainable management of drinking water resources.

## 4. Technical part

### 4.1. Technical progress, per task

#### 4.1.1 Action A.1 – Initial study

**Leader:** ZAG

**Other partners involved:** All other partners

**Actual start date:** 01/07/2013

**Actual end date:** 31/12/2013

***The activities undertaken and outputs achieved in quantifiable terms:***

General information about water supply and wastewater treatment was investigated, and the obtained data were critically evaluated in order to obtain a "bigger picture". In this study the practical, scientific, and legislative aspects of wastewater treatment in SWTPs was explored, as well as the options for the sustainable use of generated solid waste, as has been described in the literature. The Slovenian text of this report cites 77 important investigated sources. All the partners participated in the Initial Study, with contributions that focused on the following subjects:

- The water situation in Slovenia and the purification/treatment of wastewater (PKG);
- The design of SWTPs and the current Slovenian legislation in this field (IJS, NLZOH, Esplanada);
- The nanoremediation of water by means of nZVI (ZAG, IJS);
- The current management practices used in the treatment of organic sludge (ZAG, Structum);
- Framework models for LCA and or LCCA (ZAG);
- The reuse of purified wastewater water obtained from SWTPs (ZAG);
- The consumption of drinking water and the regulation system for public utilities in the Municipality of Šentrupert.

Below, some main points about the information gathered of the Initial Study are summarized in a few paragraphs.

1. Detailed information about return loop technologies was assembled in the form of different real cases, of which some are listed and described in the Initial Study Report, in Annex 7.2.1. In the majority of cases the focus was on the remediation technologies, and the reuse of water is described only as direct (when it is brought directly from the treatment facility to users for utilization) or indirectly (when intermediate stages of water use are included).

2. When studying good practices of water remediation in the field of nanoremediation, the focus was on the use of nZVI. From different sources at least 10 good practices of their use, mostly for the remediation of groundwater contaminated with organic pollutants, were identified. On the other hand, a number of scientific studies and laboratory simulations indicated the high efficiency of nZVI for wastewater remediation. The details about this are given in the Initial Study Report in Annex 7.2.1.

3. The Slovenian legislation in the field of SWTPs is covered by the following laws:

- The Construction Act (Official Gazette of RS, No. 110/2002 and its amendments: 97/2003 Odl.US: U-I-152/00-23, 41/2004-ZVO-1, 45/2004, 47/2004, 62/2004 Odl.US: U-I-1/03-15, 102/2004-UPB1 (14/2005 cor.), 92/2005-ZJC-B, 93/2005-ZVMS, 111/2005 Odl.US: U-I-

150/04-19, 120/2006 Odl.US: U-I-286/04-46, 126/2007, 57/2009 Skl.US: U-I-165/09-8, 108/2009, 61/2010-ZRud-1 (62/2010 cor.), 20/2011 Odl.US: U-I-165/09-34, 57/2012).

- The Environmental Protection Act (Official Gazette of RS, No. 41/04, 20/06, 39/06, 70/08, 108/09, 48/12, 57/12).

- The Water Act (Official Gazette of RS, No. 67/02, 110/02-ZGO-1, 2/04, 41/04-ZVO-1).

- The Regulations and other laws that cover the field of SWTPs are described and listed in the Initial Study Report in Annex 7.2.1.

4. The Municipality of Šentrupert gathered all necessary information about water consumption. The statistical data predicted a consumption rate of 97.7 L per person per day. However the figures which were obtained by actual measurements of water consumption showed that the consumption rate was even lower, and approximately equal to 81 L per person per day, which is lower than the average daily consumption in Slovenia (117 L per person per day). More details are given in the Initial Study Report in Annex 7.2.1.

5. According to the Slovenian legislation in a field of construction of SWTPs, the only permits needed are a Building Permit and a Permit for the start of the trial period.

6. One of the expected results of Action A.1 was the document: "Preparation of framework models for lifelong analyses". In order to achieve this expected result, a literature overview was carried out, with regard to the LCA of different wastewater treatment techniques and different procedures for the stabilization and treatment of organic sludge. These studies relate primarily to comparisons of energy consumption by wastewater and sludge treatments, and the associated emissions. Some of them also considered the financial aspect of different treatments. Based on the literature survey, LCA and LCCA models were prepared.

***Executed versus planned output and time schedule:***

Action A.1 was carried out during the period 01/07/2013 – 15/01/2013. The end of the Action was delayed by 15 days compared to the initial plan.

***Modification of Action:***

None.

***Indicators of the performance of the Action:***

The Initial Study was written in Slovenian. It has 67 pages and is entitled: "Začetna študija" (the "Initial Study Report"). It is the deliverable of Action A.1. The whole document written in Slovenian is presented in Annex 7.2.1. A summary in English forms part of the Inception Report.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

A slight delay occurred (the document was finished 15/01/2014), but this delay had no effect on the progress of the project as a whole.

***Complementary Action outside LIFE:***

None.

***Perspectives for continuing the action after the end of the project:***

Additional studies could be performed, with the purpose of gathering information about alternative technologies for wastewater reuse which have been developed and in some cases successfully applied worldwide. In Slovenia there is an important need to establish more specific and detailed guidelines or a policy in the field of water reuse which would define the monitoring of quality, possible types of use, and quality standards. Additional possible

improvements in water reuse policy, which have already been established in certain countries, could be beneficial for Decision Makers.

#### 4.1.2 Action B.1 – Initial parameters processing and nanoremediation optimization

**Leader:** IJS

**Other partners involved:** NLZOH, ZAG

**Actual start date:** 01/07/2013

**Actual end date:** 31/03/2015

***The activities undertaken and outputs achieved in quantifiable terms:***

All of the expected results of this Action were successfully achieved. The wastewater water for the experimental work was obtained from the SWTP at Hruševo (Figure 1). A good understanding of the processes which influence remediation efficiency was obtained through experiments and detailed chemical, microbiological, and physical analyses of the obtained water samples. More than 120 experiments were performed with the purpose of the optimization of the nanoremediation parameters (the amount of nZVI, the duration of the mixing and settling periods, the dispensing of remediation agents and oxidant). Among the various available types of nZVI, the most appropriate were chosen. An effective multi-stage remediation protocol for the purification of wastewater water from SWTPs was developed which includes the use of nZVI, an oxidizing agent, and ion exchange by zeolites, as well as the use of sand activated charcoal filtration. In a laboratory-scale simulation of the multi-stage water remediation, efficient purification of wastewater water from the SWTP at Hruševo was achieved, which fulfilled the criteria for drinking water quality.



Figure 1: Sampling of wastewater water at the SWTP, located at the village of Hruševo.

***Executed versus planned output and time schedule:***

The proposed duration of Action B.1 was 01/07/2013 – 30/09/2014. The Action was extended until 31/03/2015.

***Indicators of the performance of the Action:***

An optimized nanoremediation process report was prepared about the status and pollution of water from the SWTP located at Hruševó. This SWTP is comparable to the SWTP which was later constructed at Poštaje (in the Municipality of Šentrupert). The report also includes the data obtained from experimental work with the purpose of optimization and development of the remediation protocol.

***Modification of the Action:***

The Action was extended until 31/03/2015.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

None.

***Complementary Action outside LIFE:***

ZAG, as a partner of EIT Raw Materials, presented the outcomes and work on the LIFE RusaLCA project at a number of formal meetings. Within the scope of EIT RawMaterials, ZAG is connected to Bay Zoltán Nonprofit Ltd. for Applied Research. This Hungarian institute is involved in the development of nZVI for the remediation of water. Joint research in the field of water nanoremediation is planned, and the two above-mentioned organization intend to make a joint application for new research projects.

***Perspectives for continuing the Action after the end of the project:***

The remediation of wastewater water from SWTPs by means use of nZVI was successfully evaluated based on laboratory tests, with the aim that the remediated water would fulfil the criteria for drinking water quality. The water remediation process could be further developed with the use of nZVI by combining the latter with other complementary chemicals or methods. The possibility of remediation of other types of wastewater will be further investigated. The outlook for continuing the Action also refers to use of other nanoparticles, materials and processes for water purification in laboratory simulations.

### 4.1.3 Action B.2 – Pilot system planning and design

**Leader:** Esplanada

**Other partners involved:** The Municipality of Šentrupert

**Actual start date:** 01/07/2013

**Actual end date:** 30/06/2014

***The activities undertaken and outputs achieved in quantifiable terms:***

Based on the results obtained within the scope of Action B.1, a multi-stage remediation protocol based on the use of nanoremediation and complementary water purification methods (i.e. oxidation, sand and activated carbon filtration, ion exchange) was developed, which was the basis for the transfer of the knowledge obtained in the laboratory to the real case pilot application. According to this protocol, some complex technological solutions for the design of the pilot remediation system were developed. A simplified scheme of the pilot remediation system is presented in Figure 2, where the main components of system can be seen as they were designed by Esplanada.

In accordance with the currently valid legislation in the Republic of Slovenia, the pilot remediation system was classified as a "wastewater treatment plant", i.e. No. 22232, according to the "Unified classification of types of structures 2012" (Official Gazette of RS, No. 109/11). It was therefore necessary to prepare documentation in order to be able to apply for the necessary Building Permit ("PGD"), at the level corresponding to less demanding structures, which was obtained in April 2014 by the Municipality of Šentrupert. The Design for construction ("PZI") was prepared in September 2014 by Esplanada and the Municipality of Šentrupert.

***Executed versus planned output and time schedule:***

The proposed duration of Action B.2 was 01/07/2013 – 31/03/2014. This duration was extended until 30/06/2014.

***Indicators of the performance of the Action:***

The plans for the construction of the pilot remediation system were prepared, as well as all the technical documentation for the acquisition of the necessary building permit.

***Modification of Action:***

The Action was extended until 30/06/2014. The plans for the pilot remediation system proposed in the project description were improved and optimised. Taking into account the results of communication with the local inhabitants, it was estimated that the implementation of a return loop for the distribution of purified water would not be justifiable for a number of reasons. The main reason was that some other local inhabitants (living outside the village of Poštaje), together with local industry, expressed an interest in the use of the purified water. In order to ensure that the supply of purified water would be as easy and reliable as possible water, the proposed system with a return loop was replaced by the following solutions: (a) a tap for public access to the purified water was installed in the vicinity of the corresponding storage tank, (b) 25 temporary storage tanks (each with a volume of 1 m<sup>3</sup>) were handed over to individual households of the village of Poštaje, and were regularly, according to the user's

needs, filled with purified water, and (c) a secondary water pipeline was constructed in order to bring the purified water to the nearby concrete production plant, i.e. for industrial use.

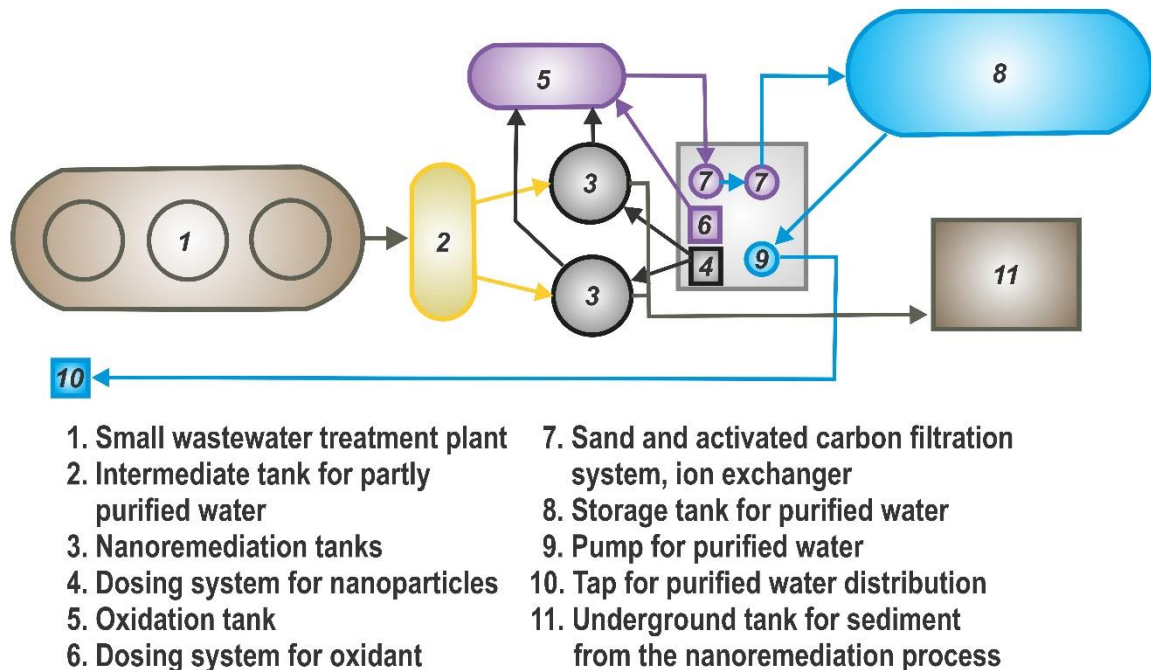


Figure 2: Schematic general arrangement of the SWTP and the pilot municipal wastewater remediation system.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

The Action was extended until 30/06/2015.

***Complementary Action outside LIFE:***

None.

***Perspectives for continuing the action after the end of the project:***

Technical improvements of the pilot wastewater remediation system will probably be made during future research and the further development of water remediation technology. ZAG and IJS are planning to exploit the potential of the system for further scientific work in the field of water remediation, which could lead to new technological solutions.

#### 4.1.4 Action B.3 – Construction of the pilot system for 100 PE

**Leader:** Municipality of Šentrupert

**Other partners involved:** Structum, Esplanada

**Actual start date:** 01/01/2014

**Actual end date:** 31/03/2015

***The activities undertaken and outputs achieved in quantifiable terms:***

Construction of the pilot wastewater remediation system for 100 PE was successfully completed. Immediately after the building permit was obtained, and the design for construction was prepared, the Municipality of Šentrupert carried out a public procurement procedure for the selection of a company for the construction of the SWTP and pilot remediation system. According to "lowest price" criterion, the tenderer Kostak PLC was chosen, and the contract for the implementation of the construction works was signed on 16/12/2014. The construction of the pilot remediation system was completed on 07/03/2015 (Figures 3 and 4). The trial period of use of the SWTP began on 19/03/2015.



Figure 3: Construction of the SWTP with its pilot wastewater remediation system.

***Executed versus planned output and time schedule:***

The proposed duration of the Action B.3 was 01/01/2014 – 31/12/2014. The Action was extended until 31/03/2015.



Figure 4: Meeting of the LIFE RusaLCA beneficiaries at the newly built SWTP and the pilot system for water remediation.

***Indicators of the performance of the Action:***

All the planned components of the pilot wastewater remediation system were installed. The system was to the SWTP, and during the next stages of the project it was prepared for implementation.

***Modification of Action:***

The Action was extended until 31/03/2015. The system was optimised. A storage tank was built, as well as a system for the more effective distribution of purified water at a publicly accessible tap. A water pipeline was built in order to bring the remediated water to the nearby concrete production plant.

***Major problems / drawbacks encountered delays and consequences for other tasks:***

Due to optimization and the development of a more complex design of the pilot wastewater remediation system than had at first been foreseen, the construction works were somewhat delayed.

***Complementary Actions outside LIFE:***

The technical solutions of the LIFE RusaLCA project were presented, by ZAG, to the Atlantic Copper Fundacion, which has shown interest in the field of industrial water remediation and reuse. Talks about the submission of a joint project, which could include the construction of a similar LIFE RusaLCA pilot remediation system, took place. However, the company has chosen to work with another type of water remediation technology.

***Perspectives for continuing the action after the end of the project:***

None

#### 4.1.5 Action B.4 – Sludge and sediment processing and further utilisation

**Leader:** PKG

**Other partners:** Structum, ZAG

**Actual start date:** 01/04/2015

**Actual end date:** 31/03/2017

***The activities undertaken and outputs achieved in quantifiable terms:***

PKG prepared a proposal for the management of wastes resulting from the wastewater purification process at SWTP Poštaje and from the pilot remediation system, as required by regulatory compliance. This proposal represented a basis for further work on the development of a zero-waste management system.

The design and preparation of mixtures which included the utilization of organic sludge from SWTP Poštaje in building composites were investigated, and validated for beneficial use in civil engineering (see Figure 5). After treatment, the sludge was mixed with calcareous fly ash produced at the VIPAP VIDEM KRŠKO paper-mill company, in two different ratios. The geotechnical composites are intended to be used as geotechnical fill. The availability of inorganic pollutants in the raw materials and in the composites after mixing and ageing was determined, and bulk chemical and mineralogical analyses were performed.



Figure 5: Test sample of a geotechnical composite made from paper mill ash and organic sludge from a SWTP.

Structum prepared mixes of cementitious composites containing sediment from laboratory experiments of nanoremediation, which were performed within the scope of Action B.1. In 2016, concrete mixtures were also prepared using sediment from the nanoremediation process which was performed during the pilot wastewater remediation system at Poštaje. The sediment was used as an aqueous suspension of iron particles which is partly able to replace some of the mixing water which is needed for the preparation of concrete. Due to the difference in the composition of sediment from the laboratory experiments to that from Action B.1 and the pilot remediation system, a slight modification of the mixtures was needed. In the addition to tests of the mechanical properties of the hardened concrete mixes, chemical tests

of leachate from the concrete were conducted. The results of the tests showed that the use of waste sediment from nanoremediation process is possible, and does not severely affect the concrete's properties. Since the sediment may be used as a suspension, the need for drying is eliminated.

***Executed versus planned output and time schedule:***

The proposed duration of Action B.4 was from 01/10/2014 to 31/12/2015. However, the Action was postponed due to the delay which occurred in Action B.3, and its actual duration was from 01/04/2015 to 31/03/2017.

***Indicators of the performance of the Action:***

The Report on sludge and sediment recycling and evaluation of the final products (composites) contains a report on the results of tests performed in connection with the geotechnical composites and the cementitious composites from recycled materials, as well as report on the treatment of wastes, as required by regulatory compliance.

The zero waste management system for SWTP Poštaje and the pilot remediation system was developed and successfully demonstrated.

***Modification of Action:***

Vekton resigned from the project as an Associated Beneficiary. Structum, ZAG, and PKG took over responsibility for the implementation of the activities foreseen in Action B.4.

***Major problems / drawbacks encountered delays and consequences for other tasks:***

Because of the delay in the start of the full operation of the SWTP at Poštaje, a significant delay occurred in Action B.4. However, the Action was successfully concluded and its delay had no significant effect on the progress of other tasks.

***Complementary Actions outside LIFE:***

The designed mixtures for geotechnical composites within the scope of this Action were initially prepared within the scope of a Slovenian Technical Approval for the company CEROP, and were modified in the LIFE RusaLCA project with the use of organic sludge from the SWTP at Poštaje.

In the project CINDERELA (this is a H2020 project, which is led by ZAG, and currently at the stage in which a grant agreement is being prepared), the problem about sustainable management with waste sludge will also be addressed. Contact has been established with other Municipal Public Services in Slovenia, and some of them have begun to use organic sludge in the production of geotechnical composites.

***Perspectives for continuing the Action after the end of the project:***

It is planned that applications will be made by ZAG for the approval of new projects on the topic of resource efficiency, circular economy, and zero-waste management systems. In 2017 ZAG applied for approval of the following projects, which are directly or indirectly connected with the outcomes of B.4 Action: LIFE HIDAQUA - Sustainable water supply in automotive and industrial technologies (the LIFE 2017 call), CRESSIDA - Promotion and Strengthening of Excellence in Urban Circular Economy and Remediation in Slovenia: Closing Soil, Sediment and Water Cycles (H2020H2020-WIDESPREAD-05-2017-Twinning), and GO CIRCLE! - Boosting eco-innovation and the regional circular economy by targeted capacity building (Interreg Danube call 2).

#### 4.1.6 Action B.5 – Operational monitoring and optimisation

**Leader:** Structum

**Other partners involved:** All other partners

**Actual start date:** 01/04/2015

**Actual end date:** 30/09/2017

***The activities undertaken and outputs achieved in quantifiable terms:***

The main achieved output of Action B.5 was that the SWTP and its pilot wastewater remediation system at Poštaje should operate properly and efficiently. Multiple test runs were performed, in which the relevant microbiological, organic and inorganic parameters were analysed for all stages of the treatment. Emphasis was placed on the optimization of the nanoremediation process. Along with the optimization of the Remediation Protocol, several technical improvements were made to the pilot wastewater remediation system.

Representatives of the Municipal Public Services of Trebnje, which is the company that is responsible for the management of the pilot wastewater remediation system, were involved in the optimization activities. In this way they were able to get acquainted with the basic functioning of the system, and were trained to operate it, including management of the stock of suspensions of nZVI. A training and educational meeting was organized by ZAG on 01/06/2017 (Figure 6), at the premises of the Municipality of Šentrupert, and at the location of the pilot wastewater remediation system. A Technical Operations Manual was prepared and presented to the managers of this system.



Figure 6: Training of managers for operation of the pilot wastewater remediation system.

Using the optimized remediation procedure, during 6 months of the year 2017 a total quantity of 480 m<sup>3</sup> of purified water was produced, which was of appropriate quality for use by local industry and inhabitants. The nearby concrete production factory and the municipality together constructed a secondary water pipeline which runs from the pilot wastewater remediation system to the concrete production facility, and currently consumes most of the

remediated water (around 90%). The Municipality of Šentrupert also distributed a total of 25 temporary storage tanks, each with a capacity of 1 m<sup>3</sup>, among the local inhabitants, so that they were able to temporarily store the purified water at their homes.

***Executed versus planned output and time schedule:***

Major delays occurred during this Action, which were caused by the many technical issues with SWTP Poštaje (which served for the biological treatment of the municipal wastewater), and were due to more time-consuming optimization of the pilot wastewater remediation system than had been predicted. The Action was extended up to the end of the project (30/09/2017), in order to supervise, fully evaluate and study the remediation processes during full-scale operation.

***Indicators of the performance of the Action:***

The deliverable of the Action was the Report on the optimized system, which included a Technical Operations Protocol and a User's Manual for the operation of the pilot wastewater remediation system. The latter contained instructions for the safe handling of the nZVI material and the oxidant, and for the proper management of the filtration system and ion exchanger. It was used for the training of the operatives who will be in charge of the implementation of the remediation, i.e. personnel from the Municipal Public Services of Trebnje.

***Modification of Action:***

The start of the implementation of Action B.5 was postponed by 6 months. The action was also extended to the new end date of the project, i.e. 30/09/2017.

***Major problems / drawbacks encountered delays and consequences for other tasks:***

Initially it was estimated that the activities planned to be performed within the scope of Action B.5 would start after the construction of the pilot wastewater remediation system on 07/03/2015. However, unexpected technical issues caused some malfunctions of SWTP Poštaje, which is intrinsically connected to the pilot wastewater remediation system. Major problems were caused by the inappropriate construction of sewerage connections from some houses to the central sewerage system, which is connected to SWTP Poštaje. Although residents received exact instructions from personnel employed at the Municipality of Šentrupert, they made some mistakes. Before all the errors were rectified it was not possible to start the operation of the pilot wastewater remediation system. Another problem was the result of a flooding event, which caused technical damage to SWTP Poštaje and to one part of the pilot wastewater remediation system in January 2016. Because of these reasons, additional time was needed to establish optimal processes for wastewater purification at SWTP Poštaje. In the meantime, it was decided that wastewater water from the nearby municipal wastewater treatment plant at Trebnje be imported in order to start the implementation of Action B.5.

***Complementary Actions outside LIFE:***

None.

***Perspectives for continuing the Action after the end of the project:***

Further optimisation of the wastewater remediation procedure is still possible, taking into account the replacement some of the required chemicals with possibly more efficient analogous chemicals. It is possible that the consumption of nZVI and chemicals could be reduced by further optimisation of the remediation procedure, which requires additional time.

#### 4.1.7 Action B.6 – Regional network feasibility study

**Leader:** Esplanada

**Other partners involved:** All other partners

**Actual start date:** 01/09/2015

**Actual end date:** 30/06/2017

***The activities undertaken and outputs achieved in quantifiable terms:***

In the Feasibility study, the possibilities for replicating the findings of the LIFE RusaLCA project in the south-eastern part of Slovenia were examined. Most of this region is characterized by a fairly rugged and forested terrain, i.e. a Karstic landscape. There is, in general, a lack of communal infrastructure, and of some of its parts are at considerable distances from main traffic routes. Due to the dispersed nature of the settlements in the region, the construction of SWTPs is the only realistic option for the treatment of municipal wastewater.

The geographical characteristics of the region are described in the introductory part of the study, where there is also additional information, e.g. about the region's hydrogeological and geological structure, as well as about its water balance, main industrial sectors, and socio-economic situation.

The results of an analysis of the possibilities for the reuse of wastewater water, and of the waste sludge generated by the other existing wastewater treatment plants in the region, are presented in the next part of the Feasibility study. The region has a total of 38 wastewater treatment plants, which are operated by publicly owned corporations. The results of the study showed that the use of purified water for the irrigation of farmland and gardens has great potential, which is particularly important in the light of increased fluctuations of temperatures and longer and more frequent summer droughts in recent years (e.g. 2017 was the third warmest year in the history of weather records in Slovenia, with summer heat waves lasting up to 8 days, with the largest temperature changes being characteristic for South Eastern Europe and Slovenia). Organic sludge from SWTPs, as well as the waste suspension of iron from the remediation process, both of which can be recycled into geotechnical / construction composites, can be used in the region since there are enough consumers of such composites for construction purposes.

In the final part of the study, comparisons were made, in terms of both environmental impacts, and sociological/economic impacts on the local community, between currently used systems for the treatment of municipal wastewater and the LIFE RusaLCA water and sludge/sediment remediation system. The greatest interest in the use of purified water from the pilot remediation system was demonstrated by local inhabitants and the local industry, and by voluntary communities such as firefighting organizations.

***Executed versus planned output and time schedule:***

The proposed duration of Action B.6 was 01/01/2014 – 31/06/2016, but the Action was prolonged until 30/06/2017. The Action is harmonized with some other Actions, so this is why its duration was prolonged.

***Indicators of the performance of the Action:***

The deliverable of the Action, i.e. the Feasibility Study, was prepared for direct implementation.

***Modification of Action:***

The Action was extended for one year, until 30/06/2017.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

None.

***Complementary Actions outside LIFE:***

ZAG has also established cooperation with the Municipal Public Services of Vrhnika, in order to verify the possibility of the use of the LIFE RusaLCA pilot remediation system, for the remediation of leachates from a landfill site for non-hazardous waste located at Vrhnika. The results of the already performed preliminary tests are very promising for the removal of problematic heavy metals.

***Perspectives for continuing the Action after the end of the project:***

This Action has great potential to be continued after end of the project. In general, people are increasingly aware of the need for the preservation of natural resources (through the recycling of organic sludge from the municipal wastewater remediation process), and of the problems associated with summer droughts in some parts of the Slovenia, so that interest in the remediation of wastewater water at SWTPs will increase, particularly in the south-eastern part of Slovenia, which is often affected by summer droughts.

#### 4.1.8 Action C.1 – Assessment of project Action impact on the environmental issue

**Leader:** ZAG

**Other partners involved:** All other partners

**Actual start date:** 01/01/2014

**Actual end date:** 30/09/2017

***The activities undertaken and outputs achieved in quantifiable terms:***

All the results of Action C.1 are described in the Report on Life Cycle Assessment (LCA) of the SWTP and the pilot remediation system at Poštaje. In this report, we evaluated the environmental burdens caused by construction processes and the operational stage of the SWTP with its pilot remediation system in quantifiable terms. Taking into account the operation stage, the functional unit was the operation time of the system over a period of one year. Findings about the burdens of sludge treatment, in accordance with the zero-waste paradigm, were also included in report about the performed LCA.

The results confirmed the validity of the assumption that the reuse of municipal wastewater on the one hand yields a significant saving in the amount of blue water (i.e. surface waters and groundwater) saving. In fact in the local community around 960 m<sup>3</sup> of water from natural resources is saved per year, although, viewed globally, the saving of blue water is somewhat smaller and amounts to 884 m<sup>3</sup>. On the other hand this reuse also causes some additional environmental burdens. The latter mostly relate to the production of the chemicals (the selected nZVI and oxidant) which are required for the operation of the processes of the pilot remediation system. The production of nZVI, which is consumed during the remediation process, is responsible for a relatively high impact on global warming (865 kg CO<sub>2</sub> equivalents out of a total of 4690 kg CO<sub>2</sub> equivalents), taking into account the LCA of the SWTP with its pilot remediation system. However, when the scale of water scarcity problems around the world is considered, the pilot remediation system is expected to contribute to environmental sustainability. In general, it was found that the additional treatment of wastewater water by means of nZVI results in significant water savings (i.e. a saving in groundwater reserves), and in reduction in the eutrophication in local streams (which is expressed as a credit of 1.13 kg PO<sub>4</sub> equivalents). The environmental benefit for the local environment is thus significant. On the other hand, globally related impacts (such as global warming, acidification, photochemical ozone creation, etc.) increase by 70 – 160% (taking into account the LCA of the SWTP with its pilot remediation system, compared to the same SWTP without such a system). However, such an increase in emissions from the SWTP with its pilot remediation system is still negligible when compared to the total emissions released to the environment throughout the world from various industries and other anthropogenic activities. From the global point of view, the discussed method of treatment of wastewater is environmentally more efficient in those countries which face a lack of drinking water, than in those which are rich with water resources. The different amounts of greenhouse emissions related to the operational stage of the SWTP its pilot remediation system over a period of one year are shown in Figure 7.

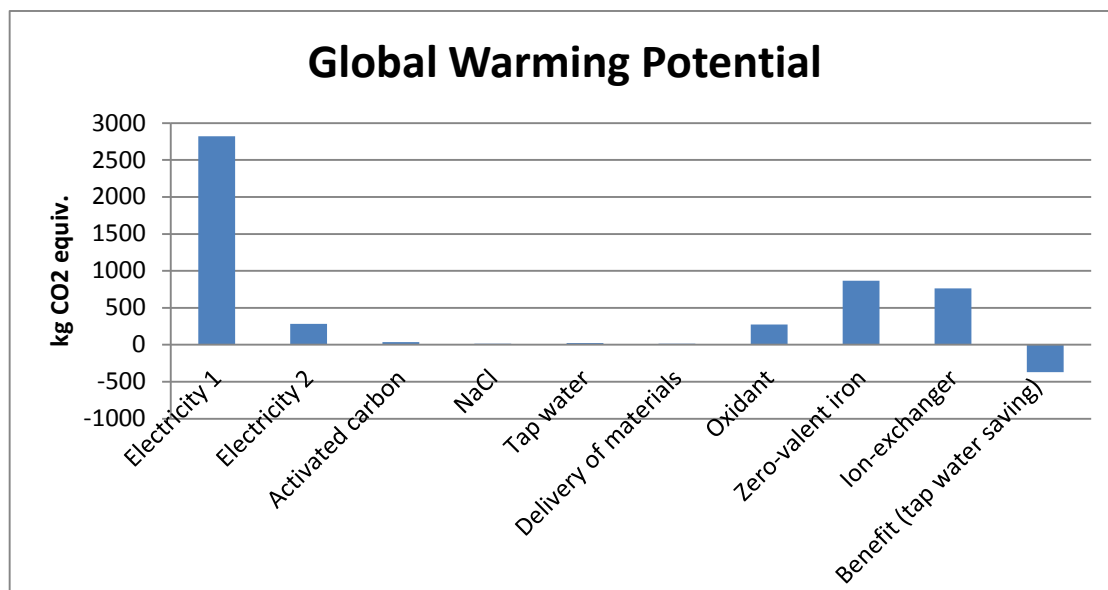


Figure 7: The impact on Global Warming as related to the operation of the SWTP and its pilot remediation system over a period of one year. The different amounts of greenhouse gas emissions associated with the corresponding processes are shown, as well as the amounts associated with the use of different consumables.

The innovative method for the recycling of organic sludge, which was developed within the scope of the LIFE RusaLCA project, was compared by means of LCA to the methods which are traditionally used for the treatment of sludge. The sludge from SWTP Poštaje is used as a raw material for the production of geotechnical composites. This use yields a low impact on the environment, especially when compared to traditional sludge treatment scenarios such as the incineration of sludge with heat recovery (in the former case the impact on global warming amounts to around 10.5 kg CO<sub>2</sub> equivalents, and in the latter to around 747 kg CO<sub>2</sub> equivalents). Considering the performed LCA of the sediment generated in the nanoremediation tank of the pilot remediation system, there are no environmental burdens except those related to the delivery of the sediment to the concrete production plant at Laže. The delivery distance from SWTP Poštaje to Laže is relatively long (120 km), so that the transport related burdens are relatively high (the impact on global warming amounts to around 150 kg CO<sub>2</sub> equivalents yearly). This situation might change in the near future, taking into account the utilization of this sediment at the concrete production plant located in the vicinity of the SWTP and its pilot remediation system. From the point of view of the performed LCA, the use of the sediment in concrete production process yields environmental benefits which are associated with a reduction in drinking water consumption for the production of concrete. Almost 9200 litres of drinking water (from natural resources) can be saved in the concrete production plant per year through the recycling of sediment for the production of concrete. It was demonstrated that the newly developed waste management system is a more friendly option, from the environmental point of view, than traditional sludge management scenarios. Moreover, composites in which organic sludge and sediment are utilized show a smaller environmental footprint than that of traditional composites, so that they fulfil sustainability requirements.

Detailed results and quantified values of the impacts related to the construction of the SWTP and its pilot remediation system at Poštaje, its use stage, and the sludge treatment are presented in the Report on Life Cycle Assessment.

***Executed versus planned output and time schedule:***

The proposed duration of Action C.1 was 01/01/2014 – 30/06/2016, but the Action was prolonged until 30/09/2017. All the LCA models were finished before the end of the last reporting period. The LCA model of the SWTP and its pilot remediation system at Poštaje was upgraded using the latest available data (in order to meet the needs of the last of the indicators of progress: "LCA of the optimised pilot system"). The optimised model included both the construction and the operation stages. Use of organic sludge from the SWTP (i.e. the sludge generated during the biological treatment of the municipal wastewater) as a raw material for the production of geotechnical composites was also evaluated by means of LCA. This type of use was compared with traditional sludge treatment methods (e.g. incineration). Utilization of the sediment from the nanoremediation tank in the production of cementitious composites (i.e. concrete) was also evaluated by means of LCA.

***Indicators of the performance of the Action:***

The deliverable for this Action consisted of 4 LCA studies, as follows:

- An LCA of the generic conventional system, which refers to the LCA model of SWTP Poštaje.
- An LCA model of the pilot remediation system (Action B.3), which refers to a LCA model of the pilot remediation system, which was added as an upgrade to SWTP Poštaje.
- An LCA of the optimized pilot remediation system (Action B.5), in which all the optimization processes of the pilot remediation system were taken into account. The corresponding data were included in the LCA model of the operation stage of the SWTP with its pilot remediation system.
- An LCA model of the new composites. See the summary of the results in the text above (Section: activities undertaken and outputs achieved).

***Modification of Action:***

No modifications, except that the Action was prolonged for nine months.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

None

***Complementary Actions outside LIFE:***

LCA was also used as a tool for the environmental assessment of remediation techniques in other remediation case studies.

***Perspectives for continuing the Action after the end of the project:***

Further optimisation of the pilot remediation process is still possible (improvement with regard to the consumption of chemicals, the replacement of some chemicals with "greener" ones), so that the environmental performance of the system could be further improved. Progress on further optimisation will be monitored and any improvement will be taken accordingly in order to update the LCA model of the pilot remediation system.

#### 4.1.9 Action C.2 – Socio-economic impacts of the project Actions on the local economy and population

**Leader:** ZAG

**Other partners involved:** All other partners

**Actual start date:** 01/01/2014

**Actual end date:** 30/09/2017

***The activities undertaken and outputs achieved in quantifiable terms:***

LCCA analysis of the construction process and operation stage of the SWTP, with its pilot remediation system, was performed by ZAG, with the support of the Municipality of Šentrupert, which delivered the needed data. It includes the costs related to: (i) the construction of SWTP Poštaje, which is a biological treatment facility (i.e. a conventional treatment system), and of the pilot remediation system, (ii) the costs related to the operation of the SWTP and the pilot remediation system, and (iii) the costs related to the management of organic sludge and sediment (different scenarios were considered). The total costs of the materials included in the LCCA analysis of the construction stage amount to 62,674 EUR, whereas the costs related to the delivery of the needed materials amount to 667 EUR.

In order to evaluate the costs related to the operation of the SWTP and the pilot remediation system, an operation period of one year was taken into account in the LCCA analysis. Electrical power is the only energy source which is needed for the operation of the SWTP's conventional system. For this reason the price of electrical power was taken into account in the LCCA. Around 6083 kWh of electricity is consumed over a period of one year, which costs around 430 EUR. With regard to the treatment of wastewater water by means of the pilot remediation system, the costs refer to additional electricity consumption (around 600 kWh per year), and especially to the cost of the chemicals which are needed as consumables. The former costs are relatively low (44 EUR per year), but 1 kg of nZVI costs 120 EUR. Taking into account an annual consumption of nZVI of 96 kg, the costs of purchasing this material represents the main hot spot from the financial point of view (11,520 EUR per year). The annual costs of the consumable oxidant used in the oxidation process are 505.50 EUR. For more details, see the Report on the Socio-economic impact of the project Actions on the local economy and population.

Taking into account the current market situation (i.e. the cost of chemicals and other materials required for nanoremediation), the remediation of wastewater water by means of nZVI to the level required to achieve drinking quality was found to be a relatively expensive process. On average, the costs for the purification of one cubic metre of wastewater amount to 13 EUR. 91% of these costs refer to the costs of the purchase of the nZVI. The current price of nZVI (120 EUR per kg) has a significant impact on the results of the LCCA analysis. However, it is expected that price of nZVI will decrease in the near future, taking into account its increasing use worldwide. In this case, the remediation of wastewater water by means of nZVI would become a more cost-effective process.

The LCCA of the solid-waste treatment process refers to the treatment of organic sludge and of the sediment generated in the nanoremediation tank of the pilot remediation system. Taking into account the use of this organic sludge as a raw material for the production of geotechnical composites, the costs are related to (i) the transport of the organic sludge from SWTP Poštaje to the central waste water treatment plant located near Trebnje), (ii) treatment of the sludge at the central waste water treatment plant, (iii) transport of the treated sludge to the composite

production plant, (iv) the production of the electricity required for the production of the composite, and (v) the amount of water consumed for cleaning the mixer. Altogether these costs amount to around 270 EUR per year. It should be emphasized that the costs for electricity and water were partitioned between the sludge and ash, as two different raw materials of the composites.

Around 9000 kg of sediment is generated per year in the nanoremediation tank of SWTP Poštaje. In the LCCA analysis, transport of the sediment to a concrete production plant over a distance of 120 km was taken into account. There are no other costs with regard to the management of the sediment. However, as the sediment, in the form of a suspension of spent iron particles, replaces some of the mixing water used in the concrete production process, the benefits associated with the saving of drinking water were evaluated. The direct costs related to the use of sediment in the concrete production plant amount to around 140 EUR per year. The costs of transport could be substantially lowered if the concrete production plant which is located in the vicinity of SWTP Poštaje were to be involved in the recycling of the sediment.

A Social Life Cycle Assessment (S-LCA) was performed by ZAG with the support of the Municipality of Šentrupert. The initial questionnaire was distributed during the initial stakeholder workshop, whereas a separate assessment was made during the final phase of the project. For the latter assessment the methodology was adopted from the UNEP Guidelines and UNEP Methodological Sheets and other relevant literature. Four groups of stakeholders were involved, with whom interviews were carried out either over the phone or through personal meetings, as follows: (i) Community and Society (37 interviews); (ii) Workers (4 interviews); (iii) Consumers (16 interviews), and (iv) the Supply Chain (4 interviews). The results show that the LIFE RusaLCA project and the new nanoremediation technology has gained acceptance in society as a whole and among the local community. In most cases the new purification technology achieved approval, which is important in terms of the "social licence to operate". However, there are some internal and external restrictions, which currently prevent local inhabitants from adopting the innovative technology as their own (in co-ownership, or with a full matured social license to operate). These restrictions are the following: a low level of recognition by individuals of the connection between climate change and their well-being, the lack of any carefully thought-out policy and/or legislative measures for the saving of water, side effects in agriculture and the food industry (compensation for drought damage), the additional immediate costs for the operation of the new technology, and other reasons.

#### ***Executed versus planned output and time schedule:***

The duration of Action C.2 was: 01/01/2014 – 30/09/2017 (taking into account a modification of the duration due to prolongation of the project). LCCA models of the construction works and of the operation of the pilot remediation system at SWTP Poštaje were performed. Conventional water treatment was compared to the pilot wastewater remediation system by means of LCCA. An LCCA comparison, using reverse osmosis as an alternative remediation technique, was also performed, taking into account available data from the literature. LCCA of the conventional and innovative sludge treatments were also performed, as well as a cost-benefits study of the latter treatment technique (the utilization of sludge in composites versus the latter's incineration). An S-LCA, which was linked to the full operation of SWTP Poštaje and its pilot remediation system, was also performed.

#### ***Indicators of the performance of the Action:***

The deliverable for this Action consisted of two S-LCA studies and two LCCA studies, as follows:

The S-LCA and LCCA of conventional SWTPs refer to SWTP Poštaje. Some data from a similar SWTP at Hruševo were also taken into account for the purpose of LCCA. The LCCA and S-LCA of the LIFE RusaLCA pilot remediation system refer to SWTP Poštaje with its pilot remediation system.

***Modification of Action:***

An extension of Action C.2 by nine months was approved.

***Major problems / drawbacks encountered, delays and consequences for other tasks:***

None

***Complementary Actions outside LIFE:***

None

***Perspectives for continuing the Action after the end of the project:***

Further monitoring of the operation costs related to the pilot remediation system will be carried out. The results of the LCCA analysis could be improved by taking into account all relevant data from a longer period. In such calculations the lifespan of some materials (e.g. filters), which directly affect the outcomes of the LCCA analysis, refer to data given in the literature. Based on the on-site observed life span of these materials, the accuracy of the LCCA analysis could be improved. Any further costs related to maintenance could also be taken into account, based on further experience at the site.

The Social licence to operate (SLTO) will be considered in future replications of the pilot remediation system in order to ensure acceptance of the technology before it is installed, and to monitor any change in acceptance due to changes in the external conditions (e.g. changes in the legislation, an increase in climate change, etc.). The S-LCA and SLTO methodology which was established in the LIFE RusaLCA project will be further be adapted to similar environmental and innovative research projects, since it has been shown that this is an important factor for bringing such innovative technology to the market.

#### 4.1.10 Action E.2 – Networking

**Leader:** ZAG

**Other partners involved:** All other partners

**Actual start date:** 01/07/2013

**Actual end date:** 30/09/2017

***The following activities were undertaken and the following outputs were achieved in quantifiable terms:***

Networking was implemented throughout the whole course of the LIFE RusaLCA project, in order to establish a network of interested parties. Networking was performed at the international, national and regional level, among similar projects, including LIFE projects having a similar content, partners and clients of individual beneficiaries, the professional public, and various institutions of the European Union, as well as municipalities located in neighbouring European regions, and in regions with similar geographical, climatic, and sociological characteristics.

At the beginning of the project (in September 2013) an initial networking plan was prepared. The first six months of the project included networking activities which focused on the stakeholders and interested parties at a national level (municipalities, relevant ministries, agencies and institutes dealing with water protection/research/remediation). For this reason a web site was established (in both the English and the Slovenian language) as well as a promotional letter in the Slovene language. Networking was also established by means of e-mail contacts, as well as at the regional kick-off meeting which took place in Warsaw in November 2013, at meetings with individual stakeholders, through published papers, and with the activities of the LIFE Rebirth project (LIFE10 INF/SI/138), that was led by ZAG. For example, the LIFE RusaLCA project was promoted by ZAG through presentations that were made at the final LIFE ReBirth conference, which took place in Ljubljana in June 2014.

Networking with local community was a constant activity, and took place through the Municipality of Šentrupert. An example of such networking was the introductory round table meeting, which was organized at the premises of the Municipality of Šentrupert on 12/03/2014.

Networking was also established with other LIFE projects (Stop CyanoBloom, PharmDegrade, WATOP, LIFE-PURIWAT, LIFE Integral Carbon, and LIFE TL-BIOFER, ZELDA). A meeting with the company Arhel (a partner in the Stop CyanoBloom and PharmDegrade LIFE projects) was held on 04/03/2015, at ZAG. Cooperation was also established with the Slovenian Tourist Board, and with the non-governmental organization Planet Earth, with whom a meeting was held on 17/12/2015, at ZAG.

The project partners participated in an event organized by the LIFE Capacity Building project on 16/09/2016. A meeting with the LIFE-Photoscaling project leader Dr. Marto Castellote about connecting together the LIFE RusaLCA and Photoscaling technologies was held in Brussels on 17/11/2016, as well as a meeting with the ECCA (European Circular Construction Alliance) project leader Mr. Vladimir Gumilar in order to discuss the possible commercialization of the LIFE RusaLCA system (this took place on the same date). The Slovenian LIFE Contact Point delegation visited Poland in order to establish (among other activities) new connections for the future of the LIFE RusaLCA project on 24-28/10/2016. Transfer of the LIFE RusaLCA system to an industrial environment was discussed with the

CEO of the firm Atlantic Copper Fundacion, Gomez Pardo, and the firm's advisor Dr. Jose Luis Tejera Oliver, on 24/11/2016.

Considerable networking was performed at the conferences, which are listed in Action D.1 – Dissemination. The two-day LIFE RusaLCA conference was the most important one, since it attracted a large group of international and Slovenian experts. Other dissemination activities formed part of Action D.1, and are described there. An open-air exhibition was set up in cooperation with students from the Faculty of Natural Sciences and Engineering of the University of Ljubljana.

Information about the project was sent to different potentially interested parties. Based on all these networking activities, a total of 510 potential interested parties, out of the 500 planned, were identified and connections were established with them. They consisted of:

- 33 coordinators of different projects,
- 10 partners and customers of the consortium members,
- 80 municipal services companies and producers of SWTPs,
- 183 public agencies and ministries,
- 204 researchers.

All of the interested parties received the electronic version of the LIFE RusaLCA Layman's Report.

***Executed versus planned output and time schedule:***

The activities of Action E.2 were extended until 30/09/2017 in order to coincide with the extended duration of the LIFE RusaLCA project. The outputs of the project were in accordance with the time schedule. The duration of Action E.2 was 01/07/2013 –30/09/2017.

***Indicators of the performance of the Action:***

The deliverable of this Action was the Report on networking. A total of 510 contacts were successfully established with potentially interested parties. Networking was also established with partners working in projects with similar topics. Such partners were those working in the projects LIFE Pharmdegrade and LIFE Stopcyanobloom, and those working in the FP7 project GLOBAQUA.

***Modification of Action:***

None.

***Major problems / drawbacks encountered delays and consequences for other tasks:***

None.

***Complementary Actions outside LIFE:***

Application to other EU calls. For example, a new project with the title LIFE HIDAQUA "Sustainable water supply in automotive and industrial technologies" has been submitted for the LIFE 2017 call, and is currently in the evaluation phase.

***Perspectives for continuing the Action after the end of the project:***

It is assumed that the interest of stakeholders in the LIFE RusaLCA's innovative technology for the remediation of wastewater water will continue after the end of the project, and might even increase with the upscaling of this project. This would increase the market potential of this technology, and increase the readiness level of the technology to the state where some customers will already be already interested in its replication. For this reason networking activities will continue, in particular at various events (e.g. conferences and workshops) which are dedicated to the topics of water scarcity and water remediation, as well as at events which

may take place within the scope of other projects carried out at ZAG (several KIC projects dedicated to raw materials are currently in progress at ZAG, and ZAG has also applied also for several other projects related to water and/or remediation, which are still in the evaluation phase).

#### 4.1.11 Gantt diagram

LIFE12-ENV/SI/0004433

Annex 1: TIMETABLE – new plan, September 2016

Action		2013				2014				2015				2016				2017			
Action number	Name of the action	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
<b>A. Preparatory actions:</b>																					
A.1	INITIAL STUDY (ZAG)																				
<b>B. Implementation actions:</b>																					
B.1	INITIAL PARAMETERS PROCESSING AND NANOREMEDIATION OPTIMISATION (IJS)																				
B.2	PILOT SYSTEM PLANNING AND DESIGN (ESPLANADA)																				
B.3	CONSTRUCTION OF PILOT SYSTEM FOR 100 PE (The Municipality of Šentrupert)																				
B.4	SLUDGE AND SEDIMENT PROCESSING AND FURTHER UTILISATION (PKG-Mirko Šprinzer)																				
B.5	OPERATION MONITORING AND OPTIMISATION (STRUCTUM)																				
B.6	REGIONAL NETWORK FEASIBILITY STUDY (ESPLANADA)																				
<b>C. Monitoring of the impact of the project actions:</b>																					
C.1	ASSESSM. OF PROJECT ACTION IMPACT ON THE ENVIRONMENTAL ISSUE (ZAG)																				
C.2	SOCIO-ECONOMIC IMPACTS OF THE PROJECT ACTIONS ON THE LOCAL ECONOMY AND POPULATION (ZAG)																				
<b>D. Communication and dissemination actions:</b>																					
D.1	COMMUNICATION AND DISSEMINATION OF KNOWLEDGE (The Municipality of Šentrupert)																				
<b>E. Project management and monitoring of the project progress:</b>																					
E.1	MANAGEMENT AND MONITORING OF PROJECT PROGRESS (ZAG)																				
E.2	NETWORKING (ZAG)																				
E.3	POST-LIFE PROJECT (ZAG)																				
E.4	FINANCIAL AUDIT (ZAG)																				
<b>Overall project schedule:</b>																					
<b>Legend:</b>																					
■ Work done																					

The key deliverables and milestones that were prepared are given in Table 1 below.

*Table 1: The key deliverables and milestones.*

<b>Deliverables (Action)</b>	<b>Achieved</b>
Initial study report (A.1)	15/01/2015 (Midterm Report)
Complete pilot system plans (B.2)	27/05/2015 (Midterm Report)
Periodical report about dissemination (D.1)	27/05/2015 (Midterm Report)
Optimized nanoremediation process (B.1)	27/05/2015 (Midterm Report)
Operational pilot (prototype) system (B.3)	27/05/2015 (Midterm Report)
Periodical report about dissemination (D.1)	31/03/2016 (Progress Report 2016)
Report on optimized system (B.5)	30/09/2017 (end of the project) (see Final Report)
Report on sludge and sediment recycling and evaluation of final composites (B.4)	30/03/2017 (Progress Report 2017)
Feasibility study (B.6)	30/09/2017 (end of the project) (see Final Report)
Periodical report about dissemination (D.1)	30/09/2017 (end of the project) (see Final Report)
Report on life cycle assessment (C.1)	30/09/2017 (end of the project) (see Final Report)
Report on socio-economic impacts (C.2)	30/09/2017 (end of the project) (see Final Report)
Report on networking (E.2)	30/09/2017 (end of the project) (see Final Report)
PostLIFE plan (E.3)	30/09/2017 (end of the project) (see Final Report)
Financial audit report (E.4)	30/09/2017 (end of the project) (see Final Report)
<b>Milestones (Action)</b>	<b>Achieved</b>
Project web-site formulated (D.1)	26/02/2014 (Inception Report 2014)
Completed laboratory analyses (B.1)	15/01/2015 (Midterm Report)
LCA of the generic conventional system (C.1)	30/09/2014 (Progress Report 2015)
Development of protocols for nanoremediation at the optimized pilot treatment plant (B.5)	30/03/2017 (Progress Report 2017)
Established system for recycling and reuse of processed sludge from the small-scale urban wastewater treatment plant (B.4)	30/03/2017 (Progress Report 2017)
Established system for recycling and reuse of sediment from the nanoremediation tank (B.4)	30/03/2017 (Progress Report 2017)
Training of persons in charge of the implementation of nanoremediation (B.5)	30/09/2017 (end of the project) (see Final Report)
LCA model of new composites (Action B.4) and LCA model of the optimised pilot system (Action B.5)	30/03/2017 (Progress Report 2017)
LCA model of the pilot system (Action C.1)	30/03/2017 (Progress Reports 2016 and 2017)

## 4.2 Dissemination Action

### 4.2.1 Objectives

The main objective of dissemination actions was (1) to communicate with relevant stakeholders, end-users and all actors having an effect on the development and acceptance of the proposed innovative technology, (2) to disseminate project's results, and (3) to identify possible exploitation routes of the project results, especially of the innovative technology. By means of these Actions, the LIFE RusaLCA project aimed to raise awareness on the positive effects of the reuse of wastewater, from both the environmental and the sociological-economic perspective. Dissemination of the project results was carried out at the local, regional, national and international level, with the participation, and involvement, of all the project partners.

The main activities which took place within the scope of communication and the proliferation of knowledge were as the following:

- meetings, conferences and lectures;
- publication of articles (technical and non-technical);
- creation of a web-site, as well as the preparation of a brochure, info-boards and promotional materials;
- preparation of a Layman's Report.

### 4.2.2 Dissemination: overview per activity

#### **4.2.2.1 Meetings, conferences and lectures**

Individual meetings with interested parties at the national level (one meeting per year)

Individual meetings were held with number of interested parties (i.e. potential end-users of innovative water remediation techniques and innovative solid-wastes sinks).

The introductory round table meeting with the local community

An introductory round table meeting with the local community was organized at Šentrupert, on 12/03/2014. The Municipality of Šentrupert was responsible for the organisation of this event. Potential users of the recycled water in the local community were invited, and 53 people participated. Representatives of all the project partners also participated at the meeting. A group of experts working on the LIFE RusaLCA project presented the innovative technology for the nanoremediation of municipal wastewater. The importance of the project for local inhabitants as well as for the region as a whole was also emphasised. After the presentations, there was discussion about the project, which was beneficial for the local inhabitants and for the beneficiaries working on the project. Answers were obtained about questions regarding the management and use of the pilot wastewater remediation system. In personal contacts with members of the local community at the project site, their attitudes towards the project were checked, and they were acquainted with the project's content. At the end of the event a questionnaire about their viewpoints about water was handed to the participants. The results of an analysis of the data obtained from the questionnaires showed that the presentations at the round table meeting and during later discussion, had contributed significantly towards better understanding of the project by the local inhabitants. They recognized the project as important for the development of their municipality. They agreed with importance of the preservation of groundwater reserves through the reuse of wastewater. In general, a high level of awareness about environmental issues among the inhabitants was observed, so that they began to accept the project.

#### Educational activities for pupils and students

It was planned that three lectures should be given to students, and that there would also be three educational activities for pupils from the local elementary school, and three educational activities for pupils from secondary-level schools. In fact, altogether five lectures were given to students, and one educational activity was organized for pupils from the local elementary school.

- Two lectures were given to students currently studying at the University of Ljubljana. The first lecture was given to students of geology from the Faculty of Natural Sciences and Engineering who attended a lecture entitled "Research in the field of innovative technologies for water remediation" at ZAG on 10/12/2015. 27 students of geology attended the lecture.

- The second lecture that was organised at ZAG for students of the Faculty of Civil and Geodetic Engineering, on 14/01/2016, was entitled "RusaLCA – Nanoremediation of water from wastewater treatment plants". As can be seen from the photos, 30 students attended this lecture.

- Two lectures were given to students currently studying at the University in Nova Gorica, School for Environmental Studies, on 14/04/2016 and on 05/05/2017. The title of the lecture that was given on 14/04/2016 was "Life cycle assessment - methodology and examples from practice". The results of the LIFE RusaLCA project were shown as a case study. The title of lecture that was given on 05/05/2017 was "Eco-innovative technologies in the construction sector and quantification of their environmental impacts". Among other case studies, the results of the LIFE RusaLCA project were also shown.

- An international lecture for students of the Polytechnic University of Madrid was given in Madrid on 18/02/2017. The title of this lecture was "Recycling of ferrous slags for construction purposes". Among other case studies, the results of the LIFE RusaLCA project were also shown. This lecture was also connected to the meeting with Prof. Dr. Luis Tehera, who is the adviser to the company Atlantic Coper concerning the transfer of the LIFE RusaLCA technology to their industrial plants.

- On 16/10/2017 the LIFE Rusalca project was presented to 25 pupils from the elementary school at Šentrupert, who participated in a special group of pupils who were interested in the natural sciences. The members of this group learnt, from representatives of the Municipality of Šentrupert, about the significance of water recycling, the preservation of natural resources, and the principles of circular economy.

The aim of the above-described educational activities for students was to disseminate the good practices which were achieved within the scope of the LIFE RusaLCA project, and to educate them about new technologies for water cleaning. The feedback from the students was very positive, since they thought that the topic of water remediation and recycling is very important in order to cope with present and future environmental problems.

No educational activities were conducted for pupils of secondary-level schools. However, it was planned that at least 200 pupils and students will be informed about the good practices of the LIFE RusaLCA project. Taking into account the lectures given to students and the educational activities which were organized for the pupils of the local elementary school, around 200 students and pupils were informed about the good practices of the LIFE RusaLCA project.

#### Presentation of the demonstrated water treatment technology at international symposiums and conferences

The aim of this activity was to demonstrate the good practices which were achieved within the scope of the LIFE RusaLCA project among the expert public. It was planned that the results

should be presented at least at two international symposiums and conferences. This plan was significantly exceeded, as is described below:

Four presentations were made in a form of posters at scientific conferences:

- A poster entitled "LIFE RusaLCA - An advanced system for the nanoremediation of wastewaters for sustainable water management" was presented at the 22nd Conference of Slovenian Geologists (which was held at the Department of Geology of the Faculty of Natural Science and Engineering, University of Ljubljana on 30/11/2015).
- A poster entitled "LIFE RusaLCA – An innovative Prototype System for the remediation of Municipal Waste Water" was presented at the 23rd International Conference on Materials and Technology (which was held on 28/09/2016 in Portorož, Slovenia).
- Two posters with the content describing the expected outcomes of the project were presented at the LIFE Water Platform meeting which was held in Manchester, UK on 24-25/05/2016. The titles of the posters were: "Nanoremediation of water from small wastewater treatment plants and reuse of water and solids for local needs" and "Pilot water remediation plant".

Eight contributions were made at various scientific conferences and workshops:

- The activities of the project were presented at the workshop "Knowledge and activities for a sustainable future: the environmental aspect" on 03/06/2016.
- A contribution in the form of a short lecture was made at the International conference on materials and technology, which was held at Portorož, Slovenia, on 28-30/09/2016. The lecture was entitled "An advanced water purification method with the utilization of zero-valent iron nanoparticles" and contributed to the dissemination of the scientific background of the LIFE RusaLCA project and the optimization of the pilot remediation system in Poštaje.
- A lecture entitled "Closing the loops and use of secondary resources in the construction sector" was given at the workshop aRAWness, which was held at the Geological Survey of Slovenia on 20/10/2016. This lecture was an opportunity for the dissemination of the expected outcomes of the project LIFE RusaLCA from the point of view of the circular economy.
- The LCA aspects of the LIFE RusaLCA project were presented at a workshop which was organized within the scope of the CEL.KROG project at ZAG on 27/10/2016.
- An invited lecture with a presentation of the obtained scientific data and expected outcomes of the LIFE RusaLCA project was given at the concluding conference of the LIFE PharmDegrade project on 24-25/11/2016. This lecture was entitled "Nanoremediation of wastewater water from the SWTP and its challenges from the point of view of the treatment of micro-pollutants; the LIFE RusaLCA project".
- Ana Mladenovič gave a lecture at the Planet Earth conference which was held in Ljubljana on 22/04/2016. A photograph is attached in the Deliverable of Action D.1.
- Alenka Mauko Pranjić gave a lecture entitled "Closing the loops in the construction sector - LIFE ReBirth and RusaLCA projects" at the ECCE conference which was held in Ljubljana on 12/01/2017. See the 1<sup>st</sup> ECCA Conference programme <http://circularconstruction.eu/wp-content/uploads/2016/06/D3.2-1st-ECCA-conference-proceedings-v1.3a.pdf>

The LIFE RusaLCA project activities were also presented at the "Nature-Health" Fair, which took place in Ljubljana on 24-27/11/2016.

All the above-listed presentations gained positive feedback from the expert public. They found the innovative water treatment technology very interesting and useful for broad application.

### Two regional-level disseminations

The Municipality of Šentrupert and Structum were responsible for the organisation of two regional-level dissemination events.

- The first regional presentation of the project was held at Šentrupert on 09/06/2016. This was an event where the objectives, processes and technology of the project were presented to the general public. The mayors of municipalities from the wider Dolenjska region were invited to participate, as well as the representatives of companies for municipal services and experts in the field of water remediation. The agenda of the regional presentation was the following. The participants were first addressed by the Mayor of Šentrupert, Rupert Gole, who stressed his satisfaction with the fact that the municipality has demonstrated its progressiveness by participation in such projects, which are supported by the European Commission through the LIFE programme. At the presentation, the importance of the project and the technologies that have been developed for the treatment of municipal water, were presented by Ana Mladenović and Primož Oprčkal from ZAG, whereas Peter Geršič illustrated the importance of the project for the local community. In the second part of the meeting, the participants toured the SWTP Poštaje and inspected the nanoremediation wastewater purification process. The presentation of the project was a good opportunity to exchange experience in the management of similar projects and in water management in south-eastern Slovenia, as the presentation was intended primarily for municipalities, municipal companies, and the professional community in this region. The stakeholders and experts were informed about innovative approaches in the remediation of wastewater water and new possibilities about the beneficial use of the solid-wastes generated at the SWTP and of the nanoremediation system (with operates on the basis of the zero-waste management system).

- The second regional presentation of the project was held at Šentrupert on 04/10/2016. It was intended for participants of the International LIFE RusaLCA conference, which had been held one day earlier (i.e. on 03/10/2016) at ZAG, and also for others. Participants of the conference visited the pilot remediation system at Šentrupert, and its operation demonstrated. This second regional presentation had similar impacts to those of the first, above-mentioned regional presentation; however, the public which participated at these two events was different. In the second event, the public was more international in character, meaning that information obtained from the site was disseminated also to foreign stakeholders and experts. This event had several indirect impacts, e.g. new business and research opportunities were opened up with foreign partners in the fields of the environment, recycling and circular economy. New connections with some regions in the countries of the West Balkans were established, as foreign stakeholders were interested in transfer of good practices obtained within the scope of the LIFE RusaLCA project. One indirect impact of the regional presentation of the LIFE RusaLCA project on 04/10/2016 was that ZAG obtained some projects with other countries of the West Balkans (a RIS project with Macedonian partners within the scope of the EIT programme, and a bilateral project with Montenegro). Apart from this, an application for a twinning project was made together with Greek and Spanish partners.

It was planned that at least 20 participants members of the local public and decision-would attend each meeting. In fact more than 50 people participated at both events.

### The International LIFE RusaLCA conference (i.e. the conference which took place towards the end of the project)

The two-day International LIFE RusaLCA conference, which was held on 03-04/10/2016 at ZAG, Ljubljana, was the most important dissemination event. The organiser of the conference was ZAG. Power-point presentations were made, to 45 participants, by invited and registered

participants at the conference about the progress of the project, its objectives, and the innovative technology for the purification of municipal wastewater by means of the SWTP and its pilot remediation system, and about the use of water for the secondary needs of local inhabitants. This number of participants was slightly less than the planned number, which was 50. In addition to the above-mentioned power-point presentations, the different approaches to the management of wastewater which are used in Spain, Greece, Montenegro, Macedonia, and Bosnia and Herzegovina were presented.

Here is a list of the lecturers, along with the titles of their presentations:

- Ana Mladenovič, ZAG – Presentation of the LIFE RusaLCA project;
- Damia Barcelo Culleres, Spain – The EU GLOBAQUA project on Multiple Stressors on Aquatic Ecosystems under Water Scarcity and Global Change. A Reconnaissance Study in Selected European River Basins;
- Andreas Angelakis, Greece – Evolution of Water Supply and Waste- and Storm-Waters Management in Urban Areas Focusing on Hellenic Cities;
- Radmila Milačič, IJS – The use of different zero-valent iron nanoparticles for the remediation of wastewater water from a small biological wastewater treatment plant;
- Primož Oprčkal, ZAG – Water purification technology of a pilot remediation system with the utilization of nanoscale zero-valent iron;
- Alenka Mauko Pranjic, Janez Turk, ZAG – Life cycle analysis of the RusaLCA system;
- Anka Ilc, Structum – Use of sediment from the nanoremediation process in cement composites;
- Peter Geršič, RusaLCA – Challenges of water distribution and support to the project by the local community;
- Vesna Mislej, JP VODOVOD-KANALIZACIJA Ljubljana – Mission of the Central WWTP Ljubljana – the release of treated wastewater back into nature and on-site preparation of the excess sewage sludge for its final utilization;
- Snežana Didanović, Montenegro – Waste water treatment in Montenegro with focus on the use of aquatic plants for wastewater purification;
- Sanja Bosiljčić Pandur, Bosnia and Herzegovina – Small Waste Water Treatment Plants WWTP – Technical aspects and cost estimation of pilot plants;
- Janko Urbanc, GeoZS – Chemical status of Slovenian ground waters and drinking water resources;
- Kasam Zeqiri, Macedonia – Sector policy of water resources management in the Republic of Macedonia;
- Rupert Gole, Municipality of Šentrupert – Presentation of the Municipality of Šentrupert.

The meeting was also an opportunity to exchange knowledge and experience in the field of water management and between different projects (e.g. the FP 7 project GLOBAQUA). Participants visited the SWTP and its pilot remediation system at Poštaje. Practical demonstration of the water treatment technology was carried out.

#### Training of personnel responsible for operation of the SWTP with its pilot remediation system

During the experimental treatment of water at the pilot remediation system, experts from ZAG gave a tour and explanations of the system's functions to the attending representatives of the Municipality of Šentrupert and to operatives of the Municipal Public Services of Trebnje. In this way, all these participants were informed about the basic functioning of the system, and were trained to operate it, as well as managing the stock of suspensions of nZVI. IJS was responsible for the organisation of this official training and education program, which was carried out together with ZAG (the Coordinating Partner). On this occasion a Technical Operations Protocol and a User's Manual were handed over to the managers of the pilot remediation system.

Representatives from the Municipal Public Services of Trebnje were also present at the meetings which were held at the premises of the Municipality of Šentrupert on 15/04/2015 and 26/11/2015.

#### **4.2.2.2 Overview of published articles**

A table with the relevant data about all the published articles (i.e. (a) technical papers and (b) contributions to non-technical journals and the media) was provided in the Periodical report about dissemination 2017. By the end of the project a total of 40 lay and expert articles had been published in local, national, and international journals, and in the media.

Publications in the media followed the progress of the project, and were focused mainly on three important milestones of the project: the signing of the contract with the contractor for the construction of the SWTP, the obtaining of a building permit for the SWTP and the pilot remediation system of the LIFE RusaLCA project, and the commencement of trial operation of the SWTP together with its pilot remediation system.

Twenty-two non-technical articles were published at the local and regional level, and in the national media, about the LIFE RusaLCA project and its activities. For example, in December 2014 several media outlets (Dolenjski list, Novice24, and Mojaobcina.si) reported about the signing of the contract with the contractor for the construction of SWTP Poštaje.

Nine technical papers were published. These articles were published in proceedings of conferences, one in the Slovenian journal "Ekolist", which is dedicated to environmental problems, and two in the Slovenian journal "Mineral".

A news report about the LIFE RusaLCA project was submitted to The Green Network and published in Volume 107 (March 2016) of the periodical journal EOL (Packaging | Environment | Logistics).

#### **4.2.2.3 Publication of a scientific paper**

A scientific paper entitled "Critical evaluation of the use of different nanoscale zero-valent iron particles for the treatment of wastewater water from a small biological wastewater treatment plant" was published in the scientific journal: "The Chemical Engineering Journal").

#### **4.2.2.4 Creation of a web-site and preparation of a brochure, info-boards and promotional materials**

The dissemination tasks of the LIFE RusaLCA project began to be implemented with the establishing of the official website [www.rusalca.si](http://www.rusalca.si) on 25/10/2013 (it was translated into the English language on 07/03/2017). The project's website was regularly updated with information about the progress of the project. Maintenance and updating of the Project's website will continue for at least five years after the end of the project.

During first year of the project various flags, info-labels, and self-fixing stickers with LIFE and LIFE RusaLCA logos were prepared in order to disseminate the project at every step of the project, and to satisfy the requirements of the Grant Agreement. Roll-up posters were designed in the B.2 format and were delivered to the associated beneficiaries so that they could display them at their own premises. Roll-up posters were also designed and put on display at various events (e.g. conferences, networking, and dissemination activities) at ZAG and at the premises of the Municipality of Šentrupert. An information board was erected at the location of the SWTP and the pilot remediation system after they were erected in March 2015. This board contains the main information about the remediation system and all required elements of the LIFE project.

An important dissemination element was also the informational leaflet (printed in both the Slovenian and English language), which contains all the basic information about the project. It

was prepared in May 2016, and was distributed at different formal and informal events at ZAG and at the Municipality of Šentrupert.

#### **4.2.2.5 Layman's report**

At the end of the project, 500 copies of the 20-page Layman's Report describing the targeted problem and the results of the project, were printed, 250 in the Slovenian language and 250 in the English language. This Action was led by ZAG. All the project partners were involved in the preparation of the report. A Pdf version of the report was sent to those receiving the LIFE RusaLCA Newsletter, and it was also published on the LIFE RusaLCA web-sites.

#### **4.2.3. The dissemination deliverables and dissemination-related products**

The dissemination deliverables and dissemination-related products were the following:

- The LIFE RusaLCA website which can be accessed on <http://www.rusalca.si/si/> (in Slovenian) and <http://www.rusalca.si/en/> (in English)
- The leaflet about the project: 600 printed copies (350 in Slovenian and 250 in English)
- The Layman's Report: 500 printed copies (250 in Slovenian, and 250 in English)
- Two information boards: During the construction of the project an information board was put up, with details about the project. After completion of the construction works, an informative board with information on the project, a plan of the treatment plant, and information about the innovative method of wastewater remediation treatment. The board also contains a visual QR code for a quick link to the project website by means of smartphones.
- Flags: 10,
- Info-labels,
- Self-fixing stickers: 100
- Posters: 20 (in sizes: A2 and B2)
- Roll-up posters: 3 (size 100 x 200 cm)
- Photographs
- Overview of press cuttings
- Use of the LIFE logo on documents and durable goods.

### **4.3 Evaluation of Project Implementation**

#### **Methodology applied**

The applied methodology for the reuse of municipal wastewater, which is based on the additional multi-stage remediation of wastewater water from SWTPs, was successfully demonstrated. The parameters for nanoremediation by means of nZVI were optimised. Also, additional stages of water remediation (e.g. oxidation, sand and activated carbon filtration, ion exchange) were designed as complementary procedures to the nanoremediation, and for the effective purification of water to make it safe for reuse. The cost of such nanoremediation of wastewater water is still relatively high, taking into account the current price of the nanoparticles (nZVI). If the quantity of used chemicals could be further optimized then it would be possible to reduce the costs. The aim of reducing the consumption of drinking water by 30% through the reuse of municipal wastewater was achieved through cooperation with the local community, and especially with local industry. The nearby concrete production plant is currently the main user of purified water obtained from the pilot remediation system which is coupled to SWTP Poštaje. Approximately 10% of the water that was recycled in 2017 was used by the local inhabitants for the watering of their gardens and vegetable gardens. Thus the remediated water was mostly used for the needs of local industry, which needs this water throughout the year, in contrast to households whose needs for remediated water mostly refer

to the late spring and summer months of the year (taking into account the use of water for the watering of gardens and vegetable gardens).

The use of organic sludge from the SWTP and sediment from the nanoremediation tank in building composites was also successfully demonstrated. The sediment from the nanoremediation tank is currently delivered over a relatively long distance so that it can be used in the production of concrete. The use of this waste resource in the nearby local concrete production plant would improve the sustainability of this approach. This weakness could be solved in the After-LIFE period. The approach which was developed, within the scope of the LIFE RusaLCA, showed that a zero waste management system can be established both in the case of biological water treatment in the SWTP and in the case of water remediation by the pilot system.

The applicability of the developed pilot remediation system and its benefits was disseminated at multiple levels, from the lay public to water remediation professionals, to the industry which produces and has needs for water remediation technology and waste recycling, and to scientists who are concerned with waste recycling, "water research" and circular economy. The selected methods of dissemination were based on the organisation of conferences and dissemination events, as well as on participation at national/international workshops/conferences with the aim of the presentation of the results of the LIFE RusaLCA project, and on the publication of various articles. Positive feedback from the target public (i.e. scientists and stakeholders) was obtained and collaboration was established. Some of these collaborative links resulted in applications for new projects. The dissemination will also continue after the end of the project, according to the After-LIFE communication programme. The optimisation process of the nanoremediation of the wastewater water at the pilot remediation system resulted in a reduction in the costs of the nanoremediation, and also resulted in some simplifications of the process. Even if further optimisations are achieved, the current solutions already ensure the wide applicability of the proposed water remediation technology, as well as improved possibilities for the transfer of this technology to similar environments, especially to those which face water scarcity problems.

In *Table 2* the achieved results are presented in comparison with the defined objectives.

*Table 2: Achieved results against the objectives*

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
A.1 Initial Study	<ul style="list-style-type: none"> <li>– Detailed knowledge about return loop technologies in other parts of Europe.</li> <li>– Transfer of good practices in the field of nanoremediation.</li> <li>– A review of the national legislation and preparation of the necessary amendments.</li> <li>– A review of the status and consumption of waters in the selected area.</li> <li>– Acquisition of the permits required.</li> <li>– Preparation of framework models for lifelong analyses.</li> </ul>	<p>Yes.</p> <p>The Initial study was finalized by 15/01/2014 and covered all the objectives.</p> <p>The Initial Study Report is the Deliverable of Action A.1.</p>	The Initial Study is a comprehensive guide for the partners of the consortium and also wider, for the technical public, whose members are involved in water management.	44,080	37,663	The actual incurred costs were lower than those initially planned, with all the goals of the Action achieved.
B.1 Initial parameters processing and nanoremediation	<ul style="list-style-type: none"> <li>– A detailed understanding of the situation and the variations in the water</li> </ul>	<p>Yes.</p> <p>The document "Optimized nanoremediation</p>	Exhaustive research into this topic resulted in detailed knowledge about the remediation procedure and the corresponding	99,390	83,740	The actually incurred costs were lower than those initially planned.

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
optimisation	that has been treated in the SWTP. – The remediation protocol.	process" is the Deliverable of Action B.1.	mechanisms (agents, time, sludge properties). - A protocol for the managers of the pilot remediation system. - Benefits: basic and applicative knowledge about water remediation. - A Patent has been applied for.			
B.2 Pilot system planning and design	– Pilot system plans completed. – Permission from relevant authorities.	Yes. All the plans were completed. The document: "Completed pilot system plans" is the Deliverable of Action B.2. The necessary permissions were obtained on time.	All documents were successfully prepared, which was of crucial importance in order to obtain the required building permit from the competent authorities in time.	32,650	33,552	The actually incurred costs were only slightly higher than those initially planned.
B.3 Construction of a pilot system for 100 PE	– Operational pilot system.	Yes. The construction works were finished on 07/03/2015.	The construction of the pilot system was successfully completed. The works were somewhat delayed due to the development of a more complex design of the pilot remediation system. For this reason, a short extension of the	154,280	167,013	The actual incurred costs were higher than those initially planned. The reason for this was that a more complex design of the pilot

Task	Objectives foreseen in the revised proposal	Achieved	Evaluation	Budget foreseen (EUR)	Total costs (EUR)	Cost-efficiency
			Action was needed.			remediation system needed to be developed than had been initially planned.
B.4 Sludge and sediment processing and further utilisation	<ul style="list-style-type: none"> <li>– Established system for the recycling and reuse of processed sludge from the SWTP.</li> <li>– Established system for the recycling and reuse of sediment from the nanoremediation tank.</li> </ul>	Yes. All the plans were completed. The document "Report on sludge and sediment recycling and evaluation of final products" is the Deliverable of Action B.4.	<p>Recipes that included the utilization of organic sludge from SWTP Poštaje were validated for use in civil engineering. The organic sludge was mixed with calcareous fly ash generated at the VIPAP VIDEM KRŠKO paper-mill.</p> <p>Recipes for concrete containing sediment from the pilot remediation system were prepared. In 2016, the first concrete mixtures were also prepared using this sediment. The results of mechanical tests proved that the use of sediment from the nanoremediation process does not have any significant effect on the properties of the concrete. Furthermore, the sediment may be used as a solution, which eliminates the need for drying it.</p>	40,920	34,137	The actual incurred costs were lower than those initially planned, with all the goals of the Action achieved.
B.5 Operational monitoring and	– Detailed understanding of the situation and of	Yes. The document	A Remediation protocol (based on the laboratory results) was	99,768	119,422	The incurred costs were considerably

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
optimisation	<p>variations in the water that has been treated in the SWTP.</p> <ul style="list-style-type: none"> <li>– A custom-designed remediation protocol.</li> <li>– A Technical Operations Manual, which includes the requirements for the synthesis, storage and handling of nanoparticles.</li> <li>– The Remediation Protocol, which was developed within the scope of Action B.1, was adjusted for the optimal functioning of the Pilot Remediation System, and thus an Optimised Remediation Protocol was developed. The latter was the basis for the preparation of the Technical Operations Protocol for the management of the pilot system.</li> </ul>	<p>"Report on the optimised system" is the Deliverable of Action B.5.</p>	<p>successfully validated on the real case pilot remediation system.</p> <p>Official training of personnel from the Municipal Public Services of Trebnje was performed.</p> <p>The Technical Operations Protocol was prepared in a form of a manual for personnel from the Municipal Public Services of Trebnje, who manage the pilot remediation system.</p> <p>A User's Manual for the use of the pilot remediation system's electronic controls was prepared for the employees of the Municipal Public Services of Trebnje, who are responsible for the operation of the remediation.</p>			<p>higher than those initially planned. The optimisation of the pilot remediation system was a more demanding process than had been predicted.</p>

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
B.6 Regional network feasibility study	– Known possibilities for the development of a regional network of SWTPs using nanotechnology, recycled water return loops and zero-waste management system in Slovenia and in other parts of Europe with similar characteristics.	Yes. The Feasibility Study is the Deliverable of Action B.6.	A comprehensive document was prepared with a detailed overview of the hydrological and hydrogeological conditions in SE Slovenia, and an overview of current SWTPs in the region. The possibilities of water reuse and the recycling of organic sludge and sediment are discussed. Current systems for water remediation are compared with the LIFE RusaLCA system from different perspectives (environmental, social, and economic).	38,800	27,059	The incurred costs were lower than those initially planned. The goals of the Action were achieved.
C.1 Assessment of project Action impact on the environmental issues	– Proved environmental efficiency and sustainability of pilot systems through their life cycle in comparison with traditional systems for water treatment and traditional composites.	Yes. All the plans were completed. The document "Report on life cycle assessments" is the Deliverable of Action C.1.	The results of the LCA analysis showed the environmental benefits of the pilot remediation system for the local environment (benefits due to a reduction in eutrophication, and a saving of natural water resources). The pilot remediation system causes some increases in the impacts when reflected on a global scale (e.g. global warming). Despite the fact that the increase in some of the impacts is negligible for the global environment, the pilot	45,720	41,553	The incurred costs were lower than those initially planned. The goals of the Action were completed.

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
			remediation system is environmentally more efficient in those countries which face a lack of drinking water, than in those countries which are rich with water resources.			
C.2 Socio-economic impacts of the project Actions on the local economy and population	<ul style="list-style-type: none"> <li>– Proved social and economic efficiency of the pilot system through the whole life cycle in comparison with conventional water treatment systems, reverse osmosis and traditional composites.</li> </ul>	Yes. All the plans were completed. The document "Report on socio-economics impacts" is the Deliverable of Action C.2.	It was found that, taking into account the current situation, the pilot remediation system is economically relatively less efficient for wastewater treatment technology for Slovenian conditions, due to the high price of the nZVI. Slovenia is one of the richest countries in the world with water, so that the price of drinking water is relatively low. The pilot remediation system would be an economically more efficient wastewater treatment technology in those countries which face water scarcity and where the quality of drinking water does not meet all standards to be totally safe for drinking. These are countries, where the inhabitants are forced to buy and use bottled water.	22,880	18,645	The incurred costs were lower than those initially planned.

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
			Society as a whole and the local community in the Municipality of Šentrupert accepted and in most cases approved the need for the new water purification technology developed within the scope of the LIFE RusaLCA project.			
D.1 Communication and dissemination of knowledge	– Increase in awareness about the resolution of the environmental issues related to water scarcity and to increase awareness and inform the target groups	Yes. This Action has three deliverables (periodical reports about dissemination).	The project aimed to increase awareness among the local inhabitants of the need to treat fragile water sources with care, and to establish new methods of water management. Negative experience related to the non-cooperative behaviour of some local people showed us that this part of the project is very important. However, based on the results of the project, social cohesion did increase, as well as the confidence of the population that individuals and local communities can together contribute significantly towards the improvement and preservation of the environment for future generations. In conclusion, it can be said that	67,510	53,039	The incurred costs were lower than those initially planned. The goals of the Action were achieved.

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
			the project received positive attention from the media and target groups.			
E.1 Management and monitoring of project progress	– Administrative and financial activities related to the day-to-day project management	Yes.	The project management was conducted smoothly. The Coordinating Beneficiary performed continuous monitoring of the progress of the project.	96,200	112,625	The incurred costs were considerably higher than those initially planned. Personnel costs were are higher because of the larger number of meetings that were necessary for the optimisation of the pilot remediation system and for communication and coordination between the partners.
E.2 Networking	– A strong network of stakeholders and interested parties, which will ensure information and knowledge distribution and exchange.	Yes. The document “Report on Networking” is the Deliverable of Action E.2	510 contacts with interested parties were established. They were all informed about the LIFE RusaLCA project.	48,350	34,912	The incurred costs were lower than those initially planned. The goals of the Action were achieved.
E.3 Post-LIFE Project	– Agreed consensus between the partners	Yes	Achieved	0	0	

<b>Task</b>	<b>Objectives foreseen in the revised proposal</b>	<b>Achieved</b>	<b>Evaluation</b>	<b>Budget foreseen (EUR)</b>	<b>Total costs (EUR)</b>	<b>Cost-efficiency</b>
(designated: Post-LIFE Project in the proposal)	about their activities in the After-LIFE period					
E.4 Financial Audit	– Successful implementation of financial management of the project	Yes	Achieved	6,080	6,935	The incurred costs were slightly higher than those initially planned.

### **Visibility of the results**

The project results which are clearly visible are: (i) the observed reduction in the consumption of drinking water obtained from natural sources in the municipality of Šentrupert by 30% (due to the use of recycled water by local industry and the local inhabitants) and (ii) the achievement of a zero-waste management system (due to the use, in different types of composites, of the sludge from the SWTP, and of the sediment from the nanoremediation tank).

Awareness among local community about the fact that water is a fragile natural resource, and that novel methods based on sustainable management therefore need to be adopted, has been increased, but maybe not yet to the expected level. However, this kind of awareness can only be improved gradually, so it is expected that it will become even more apparent later, after a certain period of time. The recycled water has been fully available to the local community only for six months, so that people have not yet perceived all the benefits of using the recycled water for their needs. This may change in the next few years, as summer droughts are becoming ever more frequent.

### **Effectiveness of the dissemination**

All of the planned activities of Action D.1 were implemented according to the project plan. In the course of the project, communication with the local community was intensified since it was noted that some negative connotations about the project were growing due to a lack of understanding about the project goals and the used technology. There was observable opposition in part of the local community to the use of "nano-particles", and questions about safety of the procedures with regard to public health. Through intensified communication activities we managed to neutralize such trends, and thus were able to achieved almost unanimous support for the project in the local community. Residents also grasped the broad message of project about conservation of natural resources, since we received positive feedback about this.

From the general public there was favourable feedback regarding the project's goals and general message, since all the media outlets (both national and regional) reported favourably about the project's progress. No serious obstacles were encountered with regard to the gaining of media time and space regarding communication of project achievements. There is a strong connection between clear and strong communication of the project's message and favourable media coverage, which is also due to the hot topic of climate change, and the preservation of natural resources in connection with advanced technological solutions.

The professional public received plenty of information about the development of the project throughout the latter's duration. As has been noted above, several high-profile conferences and meetings with broad segments of the professional public were organized. This increased the visibility of the project and the LIFE programme, and also proved to be a platform for the exchange of knowledge.

## 4.4 Analysis of the long-term benefits

### 4.4.1 Environmental benefits

The project provides a number of direct benefits to the environment, which are related to the saving of water as a natural resource, the reducing of emissions of nutrients to surface streams (COD and BOD emissions), and of emissions related to organic sludge treatment, due to the application of the new alternative remediation procedure.

Around 960 m<sup>3</sup> of wastewater will be additionally purified annually by the pilot remediation system. This purified water is stored in a special tank so that it can be reused for different purposes instead of drinking water. An important consequence of the additional purification of the water is the reduction in the quantity of wastewater from the SWTP. In practice this also means that the emissions of nutrients, and of organic and inorganic contaminants, which are still to some degree present in the wastewater after its treatment at the SWTP (taking into account COD and BOD emissions), are reduced. The additional purification of 960 m<sup>3</sup> of wastewater (per year) means that 48.96 kg of COD emissions and 7.2 kg of BOD emissions can be avoided annually. These emissions would otherwise have an impact on eutrophication, but since they are reduced this is considered as a benefit. From the global point of view, the purification of 960 m<sup>3</sup> of wastewater by using the described technology results in the preservation of 884 m<sup>3</sup> of blue water.

The utilization of organic sludge in geotechnical composites is a low-level polluting option, especially when compared to other traditional treatment options such as incineration, use in agriculture, or at a biogas plant. The geotechnical composites are used for the construction of low permeability barriers at landfill sites instead of natural clay, which is typically used for this purpose. The need for clay extraction is therefore reduced (in the LCA analysis, the abiotic depletion of elements shows a credit equal to -1.19E-07 kg Sb equivalents). The avoided extraction of this natural resource is considered as a benefit from the point of view of the LCA.

Innovative organic sludge treatment techniques can contribute to more sustainable waste treatment, taking into account the fact that organic sludge is, worldwide, an important type of waste. The use of sludge and sediment in geotechnical/cementitious composites does not generate any significant environmental burdens, but instead it contributes to resource efficiency (e.g. by preserving resources of natural clay and water) and is in accordance with the requirements of circular economy. For example, considering the life cycle of the sediment generated in the nanoremediation tank, there are no environmental burdens except those related to the delivery of the sludge to the concrete production plant. Using the sediment from nanoremediation tank in the concrete production process, the amount of water required for the production of concrete is reduced, which is also an environmental benefit. Taking into account the results of the performed LCA, 8,890 litres of blue water is saved per year due to the use of sediment generated from the nanoremediation tank in a concrete production plant.

### 4.4.2 Relevance for environmentally significant issues or policy areas

The scope of the project is in accordance with the main priorities of the European Union: water protecting - Water Framework Directive (Directive 2000/60/EC), Groundwater directive 2006/118/EC (protection of groundwater against pollution) and waste prevention - Waste Framework Directive 2008/98/EC (in order to implement this hierarchical concept in practice, a significantly increased level of recycling and reuse is necessary). The project's results are therefore in line with zero-waste thinking, and as such promote the circular economy approach. The efficient use of materials is achieved, since the waste (organic sludge, and sediment from the nanoremediation tank) is considered as a raw material for different

composites (geotechnical, cementitious). The project is thus in line with the strategy for smart, sustainable, and inclusive growth (European Commission, EUROPE 2020), Roadmap to a Resource Efficient Europe and a Resource-Efficient Europe – Flagship initiative under the Europe 2020 Strategy.

#### **4.4.3 Long-term benefits and sustainability**

##### **- Long-term / qualitative environmental benefits**

Implementation of the project will continue after its formal conclusion, in accordance with the After-LIFE communication programme. The new business models for resource efficiency which were demonstrated through the use of the pilot remediation system will contribute towards increased resource efficiency in the Municipality of Šentrupert, as well as to the gradual establishing of a green and circular economy. The project activities were focused on the mitigation of and adaption to climatic change in Europe. The project demonstrated an active approach toward water-efficient and water-saving society at the local and regional level, which can be applied in other regions of Europe, or indeed worldwide. Based on the obtained experience, it was found that the efficiency of the pilot remediation system (considering it from just the environmental point of view) is more significant in those countries and regions which are faced by water scarcity problems. Considering the increasing concern about water scarcity around the world, the utilization of the pilot remediation system could contribute to the long-term sustainability in the reuse of wastewater. Moreover, newly developed innovative organic sludge treatment techniques can improve sustainability with regard to waste management, considering that organic sludge represents an important part of wastes on a global scale.

ZAG is currently preparing an upscaling project within the EIT Raw Materials programme about the nanoremediation of industrial water. In this way the knowledge and experience gained from the LIFE RusaLCA project could be partly transferred to the remediation of polluted waters arising from metallurgical and mining processes. ZAG has applied for another LIFE project, which is currently in the phase of evaluation. The topic of this project is sustainable water supply in automotive and industrial technologies, and it also refers to the technology developed within the scope of the LIFE RusaLCA project.

ZAG is an Associate Partner of the EIT Raw Materials consortium, which currently consists of around 60 Core Partners and 50 Associated Partners of leading business organizations, universities, and research institutes, with additional outreach to over 50 other organisations. Communication about the LIFE RusaLCA project within the scope of this consortium has already been initiated, and the good practices adopted in the LIFE RusaLCA project will be upgraded in new project ideas.

##### **- Long-term / qualitative economic benefits**

Taking into account the current economic situation, the remediation of wastewater with nZVI nanoparticles does not present an economic benefit, due to the relatively high costs of these nanoparticles. The situation will probably change in the near future, since the application of nanotechnologies is becoming ever more popular, so that the prices of nano-materials are gradually decreasing. From this point of view, it can be expected that, in the long term, the pilot remediation system will become economically more efficient.

On other hand, it is assumed that the used technology will provide good opportunities for commercialization (in the field of water purification technologies and nanoparticles production), thus generating economic income (i.e. profit), as well as opportunities for new

jobs. The Municipality of Šentrupert plans to construct a footpath for pedestrians and a cycling path past the pilot remediation system, thus presenting this point as an innovative technology attractive in the Municipality. This means a "push" for tourism, and as a result greater income from this field.

**- Long-term / qualitative social benefits**

Long-term qualitative social benefits are foreseen, taking into account the fact that the consumption of drinking water from natural sources is significantly reduced, and that the remediated water is available for local needs. The effects will be apparent through an improved quality of life, especially in the case of dry summers, when the obtaining of clean water from natural sources will be restricted due to drought conditions.

The project was developed in accordance with the vision of the Municipality of Šentrupert as an energy-wise independent community, in which this vision can be understood as an independent status in the field of all resources, not just energy. Šentrupert is a small municipality, which, from the point of view of its own promotion, has been able to achieve visibility, on a national level, through far-reaching and innovative projects (such as LIFE RusaLCA). The achievements of the LIFE RusaLCA project will, in the long term, benefit the municipality at several levels, i.e.: (i) visits of the expert public, which could result in direct income in the tourist business, and (ii) advanced thinking of the local community, which improves the attractiveness of the municipality for new investments. Also, in the light of the achievements of the LIFE RusaLCA project, the Municipality of Šentrupert can be considered as a modern and well-developed rural environment, which could be compared on an equal basis to any urban environment. Projects such as the LIFE RusaLCA help to keep young people in the countryside since in this way it can be demonstrated that innovations and modern technologies can be in compliance with life in a country environment.

It is intended that the innovative water remediation technology, which has been proposed and demonstrated within the scope of the LIFE RusaLCA project, will be applied especially in those regions which face the problems of water scarcity and droughts, and are the most affected by climate change (i.e. through global warming). If stakeholders from such regions apply the technology in order to remediate wastewater for drinking purposes, it can be expected that the exploitation of natural reserves of groundwater in such regions will be significantly reduced. The quality of life could be improved, considering better or even constant accessibility to water. What is important is that the population of these areas has access to clean (remediated water), without risking the consumption of chemically and/or biologically contaminated water. The proposed technology thus presents an important step towards environmental and social sustainability, since access to clean water is the most important need of the human race.

**- Continuation of the project Actions by the beneficiary or by other stakeholders**

The beneficiaries successfully transferred the results of laboratory tests into practice in the case of the pilot remediation system. This device will be used for the further development and optimisation of water treatment procedures. New ideas can be easily tested, and if they are found to be feasible, they can be further implemented in practice.

The beneficiaries will try to further optimize the recycling of organic sludge and sediment, by reducing the size of the environmental footprint of the recycling procedure. In this way, the environmental performance of new composites based on the beneficial use of organic sludge and sediment could be further improved. These are some of challenges that the beneficiaries can expect to encounter in the future.

As stated in the After-LIFE communication plan, the beneficiaries have committed themselves to further joint activities. Some of the partners have already initiated new activities, e.g. the preparation of joint project initiatives within the framework of the KICs call.

#### **4.4.4 Replicability, demonstration, transferability, cooperation**

The LIFE RusaLCA project could be replicated and transferred, as a whole (i.e. both the developed technology and the accompanying approach) to any country which needs to improve its water management system, while simultaneously fighting against the problems caused by climate change, droughts, and water shortage. The development of the pilot remediation system and of its technology was well planned and documented during its construction. The plans for the pilot remediation system can thus be replicated and used for the construction of similar devices anywhere in the world. The LCA/LCCA tools have shown that, at this point, more progress needs to be made in the field of the commercial availability of nZVI. The relatively high price of the nZVI is probably currently the only potentially "limiting factor" for the transferring of this remediation technique. However, it is expected that the price of nZVI will become substantially lower in the near future, which will be partly due to the rapid development of cheaper synthesis procedures.

The system's cost-effectiveness could also be enhanced after further development of the initial recipe in such a way that a lower concentration of nanoparticles would be needed. The cost efficiency of the presented good practices could be increased even further if regional or national decision-makers worked towards the stimulation of more sustainable solutions through, for instance, green public procurements.

#### **4.4.5 Best Practice lessons**

One of the best practices identified was the fruitful communication which was established with the local community with regard to their expectations and needs, and the social acceptance of the pilot remediation system. We learned how to communicate with the local community, and how to increase their awareness about an issue which is related to the reuse of wastewater. The perception of local communities in a rural environment is different, with regard to investments in innovative technology, from that of larger urban communities. The lesson learned and the experience obtained can be considered as a lesson in good practice. Another example of best practice was the fact that, due to the extension of Action B.3, a great deal of additional knowledge was obtained in the field of the remediation of water. A third example of best practice consists of the finding that, although the consortium was made up of some very different subjects, it acted coherently, which made possible the successful transfer of the results of scientific investigations into practice.

#### **4.4.6 Innovation and demonstration value**

The LIFE RusaLCA project involved both a novel approach to the management of wastewater and sludge from a SWTP, as well as an innovative technology for the implementation of these procedures. The innovative character of the project is proved by the fact that an international patent has been applied for.

The innovative aspect of the project is that it was based on the cross-sectoral recovery of waste materials (organic sludge and sediment generated in the nanoremediation tank), the involvement of different sectors (waste derived from one sector can become a valuable raw material for another sector), as well as the building of bridges between different legislations, which apply to such cross-sector recovery. The promotion of such cross-sectoral recovery and the taking into account of different legislative aspects has a direct impact on the boosting of a circular economy and on the long-term well-being of European citizens.

Both the innovative approach and the applied technology can help to tackle problems of a trans-national nature, as they demonstrate an active approach toward a water-efficient and water-saving society at the local and regional level. This approach can be applied to several other European regions and worldwide.

#### **4.4.7 Long term indicators of the project success**

Monitoring of the project's success, i.e. achieving a significant reduction in the consumption of drinking water, by 30%, through the reuse of municipal wastewater in the Municipality of Šentrupert, will continue after the end of project. Flow counters have been installed in the remediation unit, in order to obtain reliable data about how much water is remediated, and how much of this water is then consumed. Interest among the local inhabitants in the use of recycled water is expected to increase; especially in summer periods, for the watering of gardens and vegetable gardens (periods of drought in the summer are becoming more and more frequent). It is also expected that advantages of wastewater reuse instead of the consumption of drinking water from an aquifer will be recognized also for other purposes (e.g. fire-fighting), which means that the consumption of drinking water from natural resources could be reduced by even more than 30% in the future.

Project partners will further promote the remediation technology with publications in scientific journals, popular and professional magazines, and presentations at conferences:

- at least 3 published scientific articles in the next five years,
- at least 8 published popular/professional articles in the next five years,
- at least 10 oral or poster presentations on different events in the next five years.

We will continue organizing meetings with stakeholders, i.e. to represent them novel water remediation technology developed in the scope of RusaLCA project. We plan to conduct at least five such meetings in next five years.

The technology will be presented/promoted also in the fair and on different workshops organized by ZAG or other beneficiaries involved in RusaLCA project.

We will propose amendment of legislation in the field of sludge and waste water management.

Successfulness of the future promotion of the technology will be monitored through the visit of the RusaLCA website. Taking into account above mentioned promotion and dissemination activities, we plan to maintain visit of the website and especially to increase the visits of the website from foreign countries.

We will apply for new projects in the field of water remediation. In period 2018-2022, we plan to apply for one LIFE project, one HORIZON 2020 project, one KIC - EIT Raw Materials project and one post doc project.