LIFE-Okolje demonstracijski projekt
LIFE-Environment Demonstration Project

LAYMAN REPORT
LIFE 03 ENV/SL/000577-LIMNOTOP

Trajnostna sanacija odlagališča odpadkov

Sustainable Rehabilitation of the Landfill Site

Sanacija in zaprtje odlagališča komunalnih odpadkov Dobrava pri Ormožu z uporabo zaprtega krogotoka vode in onesnaženja

Rehabilitation and closure of Dobrava at Ormož municipal landfill site with the application of closed hydraulic and pollution cycle

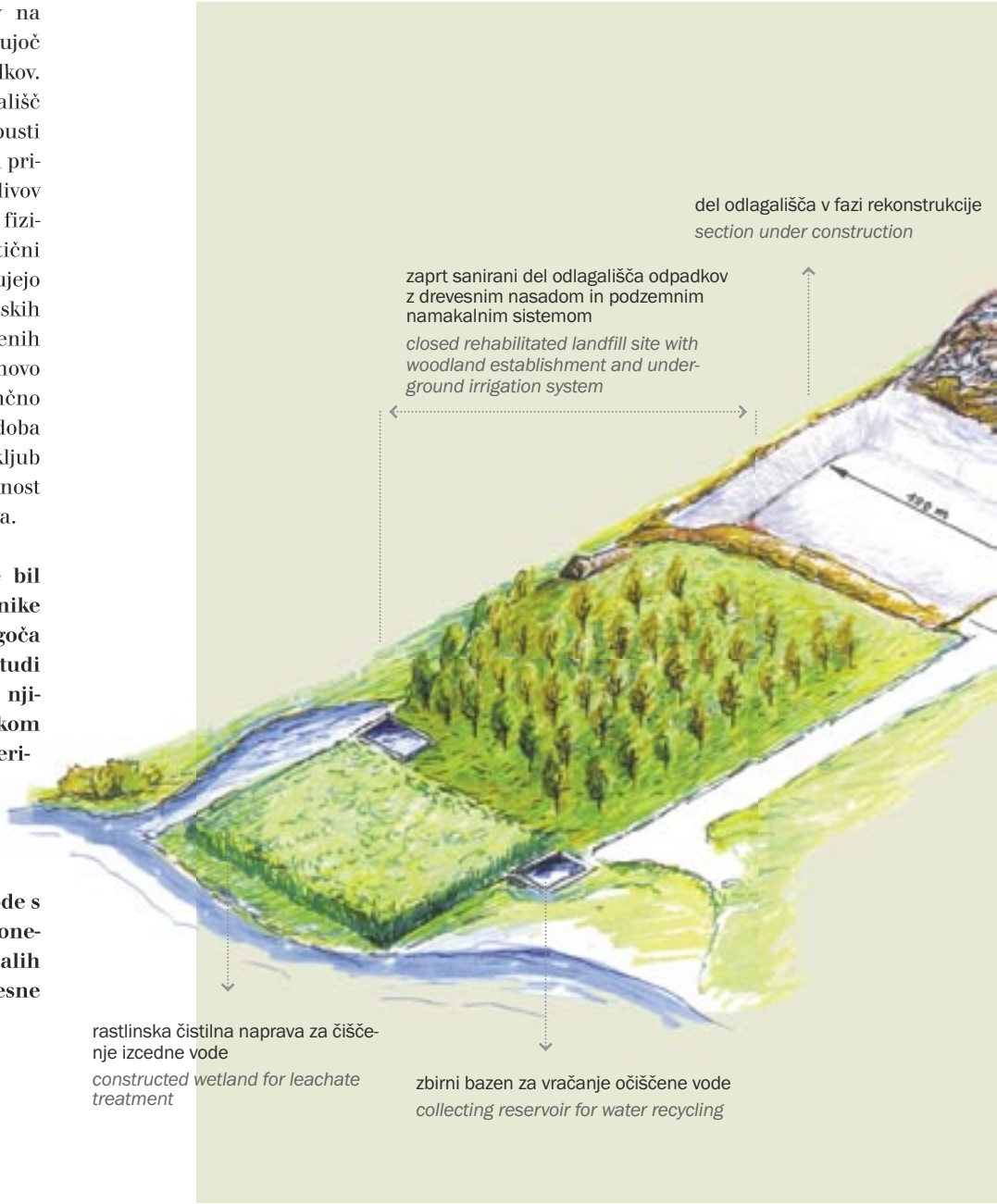
Limnotop

Usmeritev projekta

Scope of the Project

Odlaganje komunalnih odpadkov na odlagališča je še vedno prevladujoč način končne odstranitve odpadkov. Glavni okoljski problem odlagališč predstavlja trajni nadzor nad izpusti izcedne vode in bioplinov. Običajni pristop k preprečevanju negativnih vplivov odlagališča na okolje je uporaba fizikalnih pregrad (mineralni, sintetični izolacijski materiali), ki preprečujejo nastajanje izcedne vode in deponijskih plinov. Površinska izolacija odloženih odpadkov hkrati preprečuje njihovo nadaljno razgradnjo in s tem dokončno stabilizacijo. Ker je življenska doba izolacijskih materialov omejena, kljub njihovi visoki kvaliteti, je dolgoročnost obstoječih rešitev okoljsko vprašljiva.

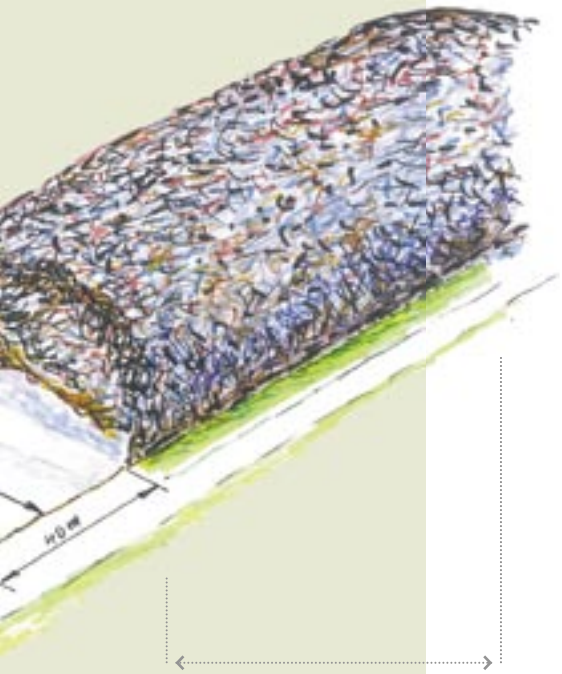
Namen projekta LIMNOTOP je bil prikaz uporabe inovativne tehnike sanacije odlagališča, ki omogoča nadaljno razgradnjo odpadkov tudi po zaprtju odlagališča in s tem njihovo stabilizacijo, še pred iztekom življenske dobe izolacijskih materialov. V sistemu odlagališča je uporabljen zaprt krogotok vode in onesnaževal. V proces sanacije so vključeni naravni sistemi, ki omogočajo čiščenje izcedne vode s stabilizacijo in razstrupljanjem onesnaževal, kot tudi izrabo preostalih hranil iz izcedne vode za rast lesne biomase.



Landfilling is still the most common form of final waste disposal. The permanent control of emission of leachate and biogas presents a major environmental problem of the landfills. The common approach toward elimination of the negative emissions from landfills on the environment is the use of physical barriers (mineral, synthetic liners), which prevents the formation of landfill leachate and gasses. Surface isolation of the deposited wastes at the same time prevents their further degradation and disables their final stabilisation. As the duration of the isolation materials is limited, in spite of their high quality, the long-term solution of these existing techniques is environmentally questionable.

The purpose of the LIMNOTOP project was to demonstrate an innovative techniqueof landfill rehabilitation which enables further waste degradation after the landfill closure, thus attaining stabilisation of waste before the end of the useful life of liner materials. A closed hydraulic and pollution cycle was applied in the system of the landfill. The rehabilitation process includes natural systems which enable leachate treatment with stabilisation and detoxification of pollutants, as well as extraction of residual nutrients in leachate for the growth of the wood biomass.

Cilji projekta
Project Objectives



obstoječi odpadki starega odlagališča
existing wastes of the old landfill site

Strokovnjaki iz različnih področij so združili svoje znanje v izgradnji in oceni delovanja prototipa s cilji doseči zahteve trajnostnega upravljanja z vodami in izpolnitvijo kriterijev evropske zakonodaje na področju odlaganja in ravnanja z odpadki, ki so:

1. Demonstracija trajnostne, zanesljive, cenovno učinkovite sanacije odlagališča.
2. Vzpostavitev zaprtega krogotoka vode in onesnaževal v okviru odlagališča brez izpustov izcedne vode v okolje.
3. Delno očiščenje izcedne vode v rastlinski čistilni napravi.
4. Dokončna odstranitev hranil in onesnaževal iz izcedne vode z vegetacijo prekrivnega sloja odlagališča.
5. Zmanjšanje onesnaženja okoliških voda s hranili in strupenimi snovmi.
6. Odstranitev neprijetnih vonjav.
7. Zmanjšanje emisije plinov.
8. Dokončna razgradnja odpadkov z nadzorovanim vstopom vode v telo odlagališča.
9. Vzpostavitev novega krajinsko sprejemljivega ekosistema na prekritem odlagališču z zasadnjo dreves.
10. Zmanjšanje nevarnosti za zdravje ljudi.
11. Omogočanje hitrejše sekundarne rabe revitaliziranega območja.
12. Doseči večjo sprejemljivost odlagališča s strani javnosti.

Experts from different fields joined their knowledge to construct and evaluate the performance of the prototype with the goals of meeting the requirements of sustainable water management and fulfilling the criteria stated in the EU, which were:

1. *Demonstration of sustainable, reliable, cost-effective rehabilitation of landfills.*
2. *Establishment of a closed water and pollution cycle within the landfill site with no leachate outflow into the environment.*
3. *Partial leachate treatment in constructed wetland.*
4. *Final removal of nutrients and pollutants from leachate with the vegetation of the landfill cover.*
5. *Reduction of the contamination of surrounding waters with nutrients and toxic compounds.*
6. *Elimination of offensive odours.*
7. *Reduction of uncontrolled emission of gasses.*
8. *Final degradation of wastes with controlled infiltration of water into the landfill body.*
9. *Establishment of an acceptable landscape ecosystem on closed landfill with the plantation of trees.*
10. *Reduction of health risk.*
11. *Enabling rapid secondary use of revitalised site.*
12. *Reaching higher public acceptance of landfills.*

Opis uporabljene tehnike
Description of the Technique Applied

Izgradnja prototipa sanacije odlagališča odpadkov se je odvijala na komunalnem odlagališču odpadkov Dobrava pri Ormožu, Slovenija. Sanacija v okviru projekta LIFE LIMNOTOP je obsegala celotno rekonstrukcijo 4 ha odlagališča z recirkulacijo izcedne vode na vegetativno prekritje odlagališča, prekritega s plastmi zemlje, ki dopuščajo infiltracijo vode v deponijsko telo. Predčiščenje izcedne vode se je odvijalo na rastlinski čistilni napravi velikosti 1000 m^2, od koder se je voda črpala preko podzemnega namakalnega sistema na prekriti del odlagališča. Prikazan pristop omogoča odlagališču, da postane bioreaktor, saj kontrolirana infiltracija izcedne vode omogoča nadaljno razgradnjo razgradljivega dela odpadkov. Rezultat tega je hitrejša stabilizacija odlagališča, saj voda v bioreaktorju stimulira anaerobne mikrobe k mineralizaciji organske snovi. Uporabljene so hitrorastoče drevesne vrste z visoko evapotranspiracijo, ki dodatno prispevajo k čiščenju izcedne vode in evapotranspiraciji viškov vode v atmosfero. Zaradi zaprtega hidravličnega in polucijskega kroga je zmanjšan negativni vpliv odlagališča na okolje, sanacija odlagališča pa je trajnostna.

The construction of the prototype of the landfill site rehabilitation took place on the municipal solid waste landfill site Dobrava at Ormož in Slovenia. The reclamation under the LIFE LIMNOTOP project comprised complete reconstruction of 4 ha of the landfill with the leachate recirculation to the landfill vegetative cover, with soil layers permitting infiltration of water into the landfill body. The pre-treatment of the leachate took place in a constructed wetland of 1,000 m^2, from where water was pumped through an underground irrigation system to the covered part of the landfill. The demonstrated approach allows a landfill site to become a bioreactor by permitting controlled infiltration and consequently further decomposition of the degradable part of the waste. This results in a quicker stabilisation of a landfill site as the water in the bioreactor stimulates anaerobic microbes to mineralise organic waste. Fast growing trees with high evapotranspiration are used, which additionally contributes to leachate treatment and evapotranspiration of excess water to the atmosphere. Due to the closed hydrological and pollution cycle, the negative impact on the environment is reduced and the landfill site is lastingly rehabilitated.

Projektne naloge | *Project tasks*

Delovanje prototipa smo spremljali skozi dvo in pol letno obdobje. Spremljali smo sestavo izcedne vode in ugotavljali prispevek rastlinske čistilne naprave k čiščenju izcedne vode. Sledili smo akumulaciji posameznih onesnaževal iz izcedne vode v podenotah celotnega remediacijskega sistema, v rastlinskem materialu in zemljinah.
The performance of a prototype was monitored throughout a two and a half year period. Monitoring of leachate composition was performed and the contribution of constructed wetland to leachate purification was evaluated. The accumulation of leachate contaminants was followed in all of the subunits of the remediation system; in plant and soil material.

Terensko vzorčenje
Field sampling

Odvzem vzorcev rastlinskega materiala
Sampling of plant material

Odvzem vzorcev izcedne vode
Sampling of leachate

Odvzem vzorcev tal
Sampling of soil material

Koraki sanacije | *Rehabilitation steps*

Izgradnja rastlinske čistilne naprave s črpališčem za predčiščenje izcedne vode in vračanje na zasajeni del odlagališča
Construction of constructed wetland with pump station for pre-treatment of leachate and recycling on planted parts of the landfill

Izkop starih odpadkov in onesnaženih zemljin
Excavation of old wastes and contaminated soils

Izolacija dna odlagališča, postavitev drenažnih sistemov za zbiranje in odvajanje izcedne vode
Isolation of landfill bottom, installation of drainage system for collection of leachate

Zapolnitev odlagališča s starimi in novimi odpadki, kompakcija
Filling up of landfill with old and new waste, compaction

Prekritje zapolnjenega odlagališča z zemeljskimi sloji in vgradnja podzemnega namakalnega sistema
Covering of the filled landfill with soil layers and installation of underground irrigation system

Zasadnja prekritega odlagališča z vrbami in travniškimi vrstami za vzpostavitev evapotranspiracijskega sloja
Planting of closed landfill with willow and grass species for establishment of the evapotranspirative layer

Laboratorijska analiza vzorcev
Laboratory analyses of the samples

Priprava vzorcev tal
Soil samples preparation

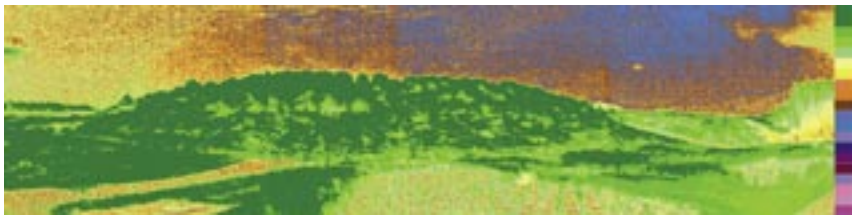
Analiza BPK vzorcev izcedne vode
BOD analysis of leachate

ICP-MS analiza vzorcev izcedne vode in tal
ICP-MS analiysis of leachate and soil samples

Rezultati projekta in njegov okoljski vpliv

Project Results and its Environmental Impact

1. Demonstracijski projekt je prikazal učinkovito zaščito okoja pred vplivom odlagališča s hkratno vzpostavitvijo pestre biološke združbe s krajinsko sprejemljivim izgledom.
2. Velike količine in visoke temperature izcedne vode so bile dokaz za to, da so se v telesu odlagališča intenzivno odvijali procesi razgradnje, ki so prispevali k stabilizaciji odloženih odpadkov. S tem je bil dokazan trajnostni sistem sanacije odlagališča.
3. Učinkovitost čiščenja izcedne vode v rastlinski čistilni napravi je bila s stališča varovanja rastlin in tal zadovoljiva.
4. Rast rastlin (vrbe, mešanica trav z belo deteljo) namakanih z izcedno vodo, je bila na prekrivnem sloju odlagališča boljša v primerjavi z okoliško vegetacijo. Rastline so imele zaradi hranilnih komponent izcedne vode (N, K, Mg, elementi v sledovih) na razpolago večje količine hranilnih snovi in vode za svojo rast kot okoliška vegetacija.
5. Dobra rast vegetacije prekrivnega sloja je omogočala velik privzem viškov vode in snovi iz izcedne vode, zaradi česar je sistem deloval kot »čiščenje s koristno ponovno uporabo odpadne snovi«, ki je bila v tem primeru izcedna voda.
6. Predstavljen način sanacije odlagališča in gospodarjenja z izcedno vodo je pokazal spodbudne rezultate, ki kažejo na to, da bi bilo smiselno v nadaljevanju razmišljati o izcedni vodi kot uporabnem viru hranil za vzgojo lesne biomase za energetske namene.
7. Izcedna voda ni vsebovala povišanih koncentracij težkih kovin, zato ni prišlo do akumulacije le-teh v prekrivnem sloju tal. Kovine se zadržujejo v anaerobnem telesu odlagališča, del pa se jih iz sistema izloči s privzemom z rastlinami, kjer se kaže največji potencial za Cd in Zn.
8. Kljub povišani slanosti izcedne vode ni prišlo do strupenega povišanja soli v tleh. V obravnavanem klimatskem območju demonstracijskega projekta je količina padavin in vračanje vode v zimskem obdobju omogočilo zadostno spiranje soli iz tal.
9. Izgradnja in prikaz delovanja prototipa v okviru projekta LIFE OKOLJE – LIMNOTOP je omogočila učinkovito predstavitev tehnologije potencialnim končnim uporabnikom in razširitev pomena uporabe trajnostnih pristopov sanacije odlagališča širom v Sloveniji in drugih državah.



Fotografija in posnetek fotosintetske aktivnosti vegetacije prekritega odlagališča namakanega z izcedno vodo in sestoja ruderalne vegetacije na desni strani slike, junij 2005. Temnozelena barva posnetka kaže na boljše stanje vegetacije namakane z izcedno vodo v primerjavi z ruderalno vegetacijo.

Photo and image of photosynthetic activity of landfill cover vegetation irrigated with leachate and ruderal vegetation on the right side of the pictures, June 2005. The dark green colour of the image indicates better plant vigour of the vegetation irrigated with leachate compared to ruderal vegetation.

1. *The demonstrated project presented an efficient environmental protection from the negative impacts of the landfill with simultaneous restoration of a diverse biological community and pleasant landscape appearance.*
2. *High quantity and high temperatures of leachate were the proof of the intensive degradation processes going on in the landfill body, which contributed to the stabilisation of the deposited wastes. This was proof of the sustainable landfill rehabilitation system.*
3. *The efficiency of leachate treatment in constructed wetland was efficient from the point of view of plant and soil protection.*
4. *The growth of plants (willow, grass and white clover mix) on the landfill cover, irrigated with leachate, was better in comparison with the surrounding vegetation. Due to leachate nutrient components (N, K, Mg, trace elements), there were more nutrients, and more water was available for the growth of those plants than for the surrounding vegetation.*
5. *Good growth of the landfill cover vegetation enabled a significant uptake of water and substances from the leachate. The system acted therefore as »a treatment with a useful reuse of waste substances«, which in this case was leachate.*
6. *The presented way of landfill rehabilitation and management with leachate showed stimulating results indicating that in the future work it would be sensible to consider leachate as a useful plant nutrient source for the cultivation of energy crops.*
7. *The leachate did not contain high concentrations of heavy metals, therefore no accumulation of them was found in the landfill cover material. The metals were therefore retained in the anaerobic landfill body and a part of them was eliminated from the system through plant uptake, which proved most efficient in the case of Cd and Zn.*
8. *In spite of high salinity of the leachate no toxic accumulation of salts in the*

landfill cover layer was found. The amount of precipitations and leachate recirculation during the winter period enabled efficient leaching of salts from the soil layer in the studied climatic region of the project.

9. *Construction and demonstration of the prototype functioning in the frame of the LIFE ENVIRONMENT – LIMNOTOP project enabled efficient demonstration of the technology to the potential end-users and dissemination of the meaning of the application of sustainable approaches toward landfill rehabilitation to a wide audience in Slovenia and other countries.*

Neposredni prispevek sistema LIMNOTOP k varovanju okolja	**Izboljšanje** *Improvement*	***Direct benefit of LIMNOTOP system to environmental protection***
zaščita podtalnice (vodni viri)	**70–90 %**	*ground water protection (drinking water sources)*
odstranjevanje N	**70–90 %**	*N elimination*
odstranjevanje P	**70–90 %**	*P elimination*
odstranjevanje težkih kovin in drugih strupenih spojin	**70–90 %**	*heavy metals and other toxic compounds elimination*
stopnja ponora CO_2 v lokalnem okolju	**40–50 %**	*CO_2 sinking rate in the local area*
vzpostavitev novega ekosistema	**10–80 %**	*new ecosystem creation*
povečanje biodiverzitete	**50–80 %**	*wildlife-biodiversity increase*
obnovljiva energija (lesna biomasa)	**10–25 %**	*renewable energy (wood biomass)*
zmanjšanje vetra, erozije	**60–90 %**	*reduced wind, erosion*
zmanjšanje emisij neprijetnih vonjav	**60–90 %**	*reduced odours*

Rastlinska čistilna naprava s polno vzpostavljeno vegetacijo
Constructed wetland with fully established vegetation

Vegetacija v prvi rastni sezoni
Vegetation in the first growing season

Nasad vrb v tretji rastni sezoni
Willow plantation in the third growing season

Prenosljivost rezultatov projekta
Transferability of the Project Results

Glede na stanje odlagališč v Sloveniji se kažejo mnoge možnosti uporabe predstavljenega pristopa zapiranja odlagališča in ravnanja z izcedno vodo. Sistem LIMNOTOP je v enaki obliki prenosljiv na druga območja v svetu s podobnim klimatskim režimom. Velike možnosti se kažejo v uporabi tehnologije za sanacijo nelegalnih odlagališč odpadkov.

Rezultati pridobljeni v okviru naših raziskav kažejo na smiselnost zapiranja odlagališča na način, ki pospeši stabilizacijo odloženih odpadkov, kar skrajša potreben čas vzdrževanja in varovanja zaprtega odlagališča ter izvajanja potrebnega monitoringa vplivov na okolje. Iz prikazanih dejstev sledi, da lahko uporabljeni sistem LIMNOTOP predstavlja ekonomsko konkurenčno izbiro v okviru različnih sistemov čiščenja in upravljanja z izcedno vodo in hkratno možnost pridobivanja obnovljivih virov energije.

With regard to the state of landfill sites in Slovenia, there are numerous possibilities for the application of the demonstrated approach toward landfill closure and leachate management. The LIMNOTOP system is in the same form transferable to other parts of the world with a similar climatic regime. There are high possibilities opened up with the demonstrated technology for illegal dump sites. The acquired results show the reasonableness of closing the landfill site in a way which accelerates stabilisation of deposited wastes, thus shortening the time needed for maintenance and protection of the closed landfill and for the necessary monitoring of the environmental impacts.

The demonstrated results show that the LIMNOTOP system represents an economically competitive choice among different leachate treatment and management systems. At the same time it offers the possibility to acquire renewable energy sources.

Stroškovna primerjava projekta

Cost-benefit Analysis of the Results

Ekonomska prednost projekta se kaže v uporabi rastlinske čistilne naprave za čiščenje izcedne vode, ki predstavlja cenejši sistem čiščenja v primerjavi z odvozom na čistilno napravo ali s postavitvijo druge čistilne naprave na odlagališču (biološka ČN, membranska filtracija, reverzna osmoza, itd.).
Zaradi dopuščanja pronicanja vode v telo odlagališča ni potrebnih vzdrževalnih del v okviru vzdrževanja integritete nepredušnega prekrivnega sloja odlagališča. S hitrejšim doseganjem končne stabilizacije odpadkov se skrajša potreben čas nadzora in s tem stroški po zaprtju odlagališča. Z nadgradnjo vegetativnega prekritja v smeri gostejših nasadov lesnih rastlin pa se izkazuje potencial pridobivanja lesne biomase v energetske namene, s čimer lahko pokrijemo del vzdrževalnih stroškov vegetativnega prekritja.

The economic advantage of the project is shown from the use of constructed wetland for the treatment of leachate, as it is cost-efficient compared to leachate transportation to the remote treatment plant or to construction of a technical treatment device on the landfill site (biological treatment plant, membrane filtration, reverse osmosis, etc). By permitting the infiltration of water into the landfill body, there is no need for the maintenance of airtight landfill cover integrity. With the faster achievement of waste stabilisation the aftercare period for landfill is shorter, thus lowering maintenance costs after landfill closure. With the upgrade of vegetative cover into dense woodland plantation there is a potential for energy crops production and a possibility for covering maintenance costs of the vegetative cover with income from energy crops.

NAPRAVE ZA ČIŠČENJE ODPADNE VODE | ***WASTE WATER TREATMENT PLANTS***				
za | *for* 500 PE	CW[1] (1000 m^2)	WWTP[2]	prihranek | *savings* EUR	%
Projektna dokumentacija *Project documentation*	7.000	9.700	2.700	28
Stroški izgradnje *Construction costs*	120.000	200.000	80.000	40
Vzdrževalni/operativni letni stroški *Maintenance/operation costs per year*	500	51.100	50.600	99
Vsota | ***Total***	**127.500**	**260.800**	**133.300**	**51**
PREKRITJA ODLAGALIŠČ ODPADKOV | ***LANDFILL SITE COVERS***				
za | *for* 10 000 m^2	WE[4]	FCSL[3]	prihranek | *savings* EUR	%
Projektna dokumentacija *Project documentation*	16.200	16.200	0	0
Stroški izgradnje *Construction costs*	262.500	389.200	126.700	33
Vzdrževalni/operativni letni stroški *Maintenance/operation costs per year*	1.400	700	–700	–50
Vsota | ***Total***	**280.100**	**406.100**	**126.000**	**31**

Prikaz stroškov in prihrankov
The List of Costs and Savings

Primerjava je narejena za čiščenje izcedne vode z obremenitvijo 500 populacijskih ekvivalentov (PE) in prekritja 1 ha odlagališča.

Comparison is done for leachate load of approx. 500 population equivalents (PE) and 1 ha of landfill site.

[1]CW .....rastlinska čistilna naprava | *constructed wetland*
[2]WWTP ..naprava za čiščenja odpadne vode | *waste water treatment plant*
[3]FCSL ....prekritje s sintetično plastjo | *cover with synthetic liner*
[4]WE .....vzpostavitev lesnega nasada | *wood establishment*

Partnerji | *Partners*

Nosilec projekta / ***Project beneficiary***
Občina Ormož, Slovenija
Municipality Ormož, Slovenia

Partner / ***Partner***
Univerza v Ljubljani, Fakulteta za kemijo in kemijsko tehnologijo, oddelek za kemijo in biokemijo, laboratorij za anorgansko kemijo
University of Ljubljana, Faculty for Chemistry and Chemical Technology, Department for chemistry and biochemistry, Laboratory for inorganic chemistry

Podizvajalec / ***Subcontractor***
Inštitut za fizikalno biologijo
Institute for physical biology

Podizvajalec / ***Subcontractor***
Komunalno podjetje Ormož
Communal company Ormož

Podizvajalec / ***Subcontractor***
LIMNOS, Podjetje za aplikativno ekologijo
LIMNOS, Company for applied Ecology

Internetna stran projekta
Project web page
www1.ormoz.si

Kontakt / ***Contact***

Prof. Dr. Danijel Vrhovšek
dani@limnos.si
LIMNOS d.o.o.
Company for Applied Ecology
Požarnice 41
1351 Brezovica pri Ljubljani
tel. +386 1 505 74 72
fax +386 1 505 73 86