Oznaka poročila: ARRS-RPROJ-ZP-2015/185

ZAKLJUČNO POROČILO RAZISKOVALNEGA PROJEKTA

A. PODATKI O RAZISKOVALNEM PROJEKTU

1.Osnovni podatki o raziskovalnem projektu

Šifra projekta	L1-4311	
Naslov projekta	Sedimenti v vodnih okoljih: geokemična in mineraloška karakterizacija, remediacija ter njihova uporabnost kot sekundarna surovina	
Vodja projekta	5930	Ana Mladenovič
Tip projekta	L	Aplikativni projekt
Obseg raziskovalnih ur	8430	
Cenovni razred	B	
Trajanje projekta	07.2011 - 06.2014	
Nosilna raziskovalna organizacija	1502	Zavod za gradbeništvo Slovenije
Raziskovalne organizacije - soizvajalke	104	Kemijski inštitut
	106	Institut "Jožef Stefan"
	738	SALONIT ANHOVO, Gradbeni materiali, d.d.
	792	Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo
	797	Univerza v Mariboru, Fakulteta za gradbeništvo
	1555	Univerza v Ljubljani, Naravoslovnotehniška fakulteta
	2316	Javni zavod Republike Slovenije za varstvo kulturne dediščine
Raziskovalno področje po šifrantu ARRS	1	NARAVOSLOVJE
	1.06	Geologija
	1.06.01	Mineralogija in petrologija
Družbeno-ekonomski cilj	02.	Okolje
Raziskovalno področje po šifrantu FOS	1	Naravoslovne vede
	1.05	Vede o zemlji in okolju

B. REZULTATI IN DOSEŽKI RAZISKOVALNEGA PROJEKTA

2.Povzetek raziskovalnega projekta[1]

SLO

Nalaganje sedimentov v celinskih vodnih telesih in obalnem morju in s tem zmanjševanju pomembnih funkcij, ki jih imajo ti objekti, predstavlja velik okoljski in inženirski problem. Pri

tem so še posebno kritične tiste lokacije, kjer je sedimentov količinsko veliko in so lahko tudi onesnaženi. Eden od takšnih je sediment v Luki Koper, kjer gre za mulj, ki je onesnažen s težkimi kovinami, sulfati in kloridi in kot takšen po statusu nenevaren odpadek, za katerega na Obali ni deponijskega prostora. Druga skupina so rečni sedimenti v akumulacijah hidroenergetskih objektov na reki Savi in reki Dravi. Tretja skupina sedimentov so sedimenti v zaprtih ali polzaprtih jezerih, kjer zaradi hidroloških razmer samih in zunanjega onesnaževanja s hranili prihaja do zamuljevanja, evtrofikacije in posledično do prekomernega razvoja alg (npr. Perniško jezero). Vsi opisani tipi sedimentov po načelu "Odpadek je surovina" predstavljajo potencialne surovine v gradbeništvu iz dveh razlogov – v tej panogi je možno porabiti velike količine sedimentov, poleg tega je različnimi postopki remediacije možno nevarne snovi v gradbenih kompozitih trajno imobilizirati. Na ta način ohranjamo naravne vire in z viri ravnamo gospodarno.
V raziskovalnem projektu smo izvedli interdisciplinarno in kompleksno raziskavo kemičnih, mineraloških in fizikalnih karakteristik materiala ter stopnje in vrste onesnaženja, zlasti glede vsebnosti biološko dostopnih težkih kovin. Izdelan je bil pregled sodobnih tehnologij za odstranjevanje različnih tipov sedimentov in preverjeni različni postopki odstranjevanja vode. Poudarek je bil na možnostih glede sekundarne izrabe odstranjenih sedimentov v gradbeništvu in njihova istočasna okoljska remediacija v skladu z načeli trajnostnega gradbeništva. Na enem od perspektivnih primerov uporabe (mulj v betonu) je bila izvedena analiza življenjskega s kvantifikacijo vplivov na okolje z uporabo LCA analize. Preverjeno je bilo tudi stanje glede obstoječe zakonodaje, dana bo pobuda na ustreznega zakonodajalca glede nujnosti sprejetja področne Uredbe o ravnanju z usedlinami.

ANG

The accumulation of sediments in inland water bodies and coastal waters, together with the reduction of the important functions provided by these facilities, is a major environmental and engineering problem. Those locations where the quantities of sediments are very large, and usually anthropogenically polluted, are of critical importance. In Slovenia one such case is represented by the sediments at the Port of Koper, where the mud is polluted with heavy metals, sulfates and chlorides, and as such, has the legal status of "non-hazardous waste", for which there is insufficient storage space for it along the Slovenian coast. Another problem is presented by the fluvial sediments which accumulate behind the dams of HE power plants on the Sava and Drava rivers, whereas the third group of sediments consists of those found in closed or semi-closed lakes, where, due to the hydrological conditions themselves as well as external pollution by nutrients, the silting-up of such lakes occurs, together with eutrophication and the growth of large quantities of algae (e.g. Perniško jezero). According to the slogan: "No waste here, just resources", all of the above-described types of sediments are potentially raw materials which could be used particularly in the building and civil engineering industry, for two reasons: firstly, because in this industry large quantities of sediments can be used, and, secondly, because various remediation methods are now available which can be used to immobilize the hazardous substances in the sediments when manufacturing different types of construction composites from them. In this way natural resources can be preserved, and resources can be handled more economically.

In the project interdisciplinary research was performed into the chemical, mineralogical, and physical characteristics of the sediments concerned, and into the degree and type of their pollution, in particular with regard to their content of biologically accessible heavy metals. An overview of modern technologies which can be used for the removal and dewatering of various types of sediments has been prepared. Emphasis was placed on the secondary use of the removed sediments in the construction industry, and on their simultaneous environmental remediation in accordance with the principles of sustainable construction. In one of the most promising applications (the use of sludge in concrete), LCA was used to evaluate and quantify the environmental impact of such procedures. The situation regarding the existing legislation was also examined, and an initiative will be prepared with regard to the urgency of the introduction of a sector-based regulation about the management of accumulated fluvial and marine sediments.

3.Poročilo o realizaciji predloženega programa dela na raziskovalnem projektu[2]

Raziskovalna hipoteza

Velike količine sedimentov, ki se akumulirajo v vodnih telesih, imajo številne škodljive posledice in vplivajo na njegovo funkcionalnost. Odstranjevanje se izvaja redko in še takrat se ta material praviloma odloži kot odpadek (takšen je trenutni legalni status v večini primerov). To je v nasprotju z aktualnimi EU in nacionalnimi strategijami, ki zahtevajo učinkovito rabo virov, vzpostavitev krožnega gospodarstva in zmanjševanje odlaganja odpadkov. Gradbeništvo je tisto področje, kjer se ti materiali lahko učinkoviti porabijo. Ključni pogoj za to je, da je na razpolago nekonfliktna, izvedljiva zakonodaja, da so znane karakteristike materialov kot potencialnih surovin (količina, lastnosti) in realistični načini njihove remediacije. Na podlagi teh podatkov je možno izvesti smiselno aplikacijo v gradbenih kompozitih in konstrukcijah, pri čemer je osnovni pogoj, da je aplikacija praktično izvedljiva tako s tehničnega stališča (z obstoječim znanjem osebja in z obstoječo gradbeniško mehanizacijo), komercialnega (koliko so stroški transporta do končnega uporabnika) in okoljskega (kakšen je vpliv teh aktivnosti na okolje).

Identifikacija problema

Sedimenti se glede na izvor razlikujejo po fizikalnih in tehničnih lastnosti ter po onesnaženosti. Da bi našli in validirali optimalno rabo posameznega tipa sedimenta v gradbeništvu, je najprej potrebna njihova natančna in celovita karakterizacija ter za sedimente ki so onesnaženi, raziskava možnosti učinkovite in dolgoročne remediacije. To je bilo vodilo raziskav, ki jih podrobneje opisujemo v nadaljevanju.

Potek projekta

Najprej je bila pregledana in primerjana zakonodaja na področju odpadkov, gredbenih proizvodov in voda, z namenom uporabiti rešitve, ki bodo možne in v skladu s strateškimi usmeritvami države. Stanje na področju zakonodaje in morebitne spremembe v leti 2011-2014 je bilo preverjeno tudi na koncu projekta. Ugotovljena je bila nujna potreba po sprejetju področne uredbe o ravnanju z odpadnimi naplavinami in usedlinami, ki bi določala naslednje: (a) njeno povezavo s krovno Uredbo o odpadkih, (b) zahteve za ravnanje z naplavinami, (c) obveznosti v zvezi z ravnanjem z naplavinam, še zlati zahteve za izdelavo načrta gospodarjenja z odpadnimi naplavinami (d) obveznosti izvajalca obdelave naplavin, (e) nadzor in (f) kazenske določbe. S tem v zvezi je pripravljen dopis za resorno ministrstvo (MO) za pripravo in izdajo »Uredbe o ravnanju z odpadnimi

naplavinami in usedlinami.«
Za lokacije vzorčevanj so bile skupaj s sofinancerji, ki so samo izvedbo tudi dejansko omogočili, izbrane naslednje lokacije: Luka Koper, akumulacija za HE Moste pri Žirovnici, akumulacija za HE Mariborski otok in Perniško jezero. Pri zadnjem gre za odmik od predvidene lokacije v prijavi projekta, kjer je bilo predlagano Blejsko ali Šmartinsko jezero (oba v primeru odobritve velikega projekta) in sicer na podlagi Ocene stanja jezer v Sloveniji v leti 2012 (ARSO). V tem poročilu je bilo navedeno, da je Perniško jezero močno evtroficirano, obremenjeno s hranili, povišani sta bili tudi koncentraciji pesticidov in metolaklora. V vseh primerih so sedimenti pretežno anorganski mulji. Ker se je v letu 2011 ponudila tudi možnost, da vzorčujemo peščeno-prodnati sediment Ljubljanice na področju Špice, smo v program raziskav vključili tudi tega. Za vsako lokacijo je bil izdelan načrt vzorčevanja in izveden v skladu s planom. Vzorci mulja so bili odvzeti s plovila s pomočjo jedrnika, vzorci proda in peska pa tako, da smo angažirali potapljača. Na lokaciji HE Moste, kjer je sediment na globini 40 m, klasično vzorčevanje ni bilo možno. Na tej lokaciji je bil sediment izčrpan na lokacijo začasnih bazenov in vzorčevan tam.
Nato je bila izvedena podrobna karakterizacija sedimentov: mineraloška sestava (tudi morebitne škodljive komponente, ki v gradbenih kompozitih lahko sprožijo patologijo), mehansko-fizikalni parametri, vsebnost organske snovi in ključna – kemijska sestava, s poudarkom na težkih kovinah in organokositrovih spojinah. Za določitev morebitne strupenosti sedimentov so bile izvedene sekvenčne ekstrakcije, s katerimi je bila raziskana njihova biološka dostopnost in toksičnost težkih kovin ter njihova vezava med posamezne lažje in težje topne faze v sedimentu. Ugotovljeno je bilo, da se klorid in sulfat po kriteriju inertnosti v mulju Luke Koper pojavljata v presežni koncentraciji, težke kovine in organokositrove spojine pa zadoščajo pogoju inertnih odpadnih materialov. Na vseh ostalih lokacijah, nepričakovano tudi v mulju akumulacije HE Moste, so vse te koncentracije pod mejo inertnosti. Tudi v sedimentu Perniškega jezera nismo zasledili povišanih koncentracij anorganskih ali organskih onesnaževal. Ti podatki sicer ne pomenijo odsotnosti onesnaženosti, temveč dejstvo, da topne snovi prehajajo v vodo, kar po eni strani sicer pomeni razredčenje in zmanjšanje nevarnosti za živa bitja, po drugi strani pa širitev onesnaženja s tokovi po vodnem telesu.
Glede na rezultate karakterizacije sedimentov s posameznih izbranih lokacij je bil izveden pregled aktualnih načinov odstranjevanja sedimentov. Tehnologija je odvisna predvsem od geomehanskih in geoloških lastnosti sedimenta ter od globine lokacije. Najbolj relevantne podatke pridobimo z intaktnim vzorčevanjem skozi skozi sediment in nato izvedbo laboratorijskih raziskav na teh vzorcih. Na podlagi izmerjenih lastnosti materiala (zlasti pomembna je nedrenirana trdnost) je po potrebi možno izvesti stabilnostno analizo brežine v sedimentu za različne globine izkopa v statičnih pogojih nad in pod vodo, vendar le v primeru, če med izvajanjem del ne pride do sukcesivnega rušenja strukture, kar pa je v rahlih sedimentih pogost slučaj. Za opisovanje dogajanj v izkopu med črpanjem rahlega drobnozrnatega sedimenta, ki se utekočinja, osnovne geomehanske relacije ne zadoščajo. V teh primerih je potrebno poznati tudi reološke parametre sedimenta in mešanice sedimenta in vode, ki nastane na mestu sesalne cevi, pri načrtovanju usedalnih bazenov pa filtrska pravila.
Z namenom aplikacije v gradbenih kompozitih so bile na podlagi rezultatov karakterizacije sedimenti smiselno ločeni v več skupin: (a) mulj Luka Koper – obravnavan posebej, zaradi slanosti in geomehanske specifike, (b) skupaj mulja iz HE Moste in HE Dravski otok, (c) mulj iz Perniškega jezera (zaradi visoke vsebnosti organskih snovi) in (d) prod iz Ljubljanice.
Največji obseg raziskav je bil izveden na mulju Luke Koper, ki je s stališča potencialne uporabe tudi najbolj problematičen (vsebnosti kloridov in sulfatov, visoka ozmotska sukcija, zaradi česar se po odlaganju zelo počasi sedimentira, konsolidira in suši). Zaradi sušenja se na površini napravijo suha skorja in krčitvene razpoke, vendar pa ostaja pod površino zasičen in v židkem stanju tudi več let. Material je izrazito slab za inženirske nasipe, saj v njem brez dodatnega ožemanja ni mogoče doseči optimalne vlage za vgradnjo. Naravno osušeni sediment ustreza le za namene zelo enostavnih gradenj. Izvedeni so bili obsežni poskusi izboljšanja mulja z dodajanjem veziv, vendar zaradi visoke vlažnosti in težke homogenizacije z vezivi ne dajejo najboljših rezultatov. Poskusni terenski nasip z mešanjem delno osušenega mulja in papirniškega pepela je bil

izveden v Celju, na delovišču podjetja Vekton. Ugotovljeno je bilo, da se z običajno gradbeniško mešalno tehniko razmeroma uspešno lahko oba materiala homogenizirata in kompozit doseže optimalno vlago. Material je bil vgrajen v nasip, ki je bil zgrajen po geotehničnih principih. Da bi potrdili, da so polutanti z vgradnjo v gradbene kompozite učinkovito in trajno remediirani in ne predstavljajo nevarnosti za okolje, so bili na laboratorijsko pripravljenih kompozitih izvedeni dolgoročni testi izluževanja (6 mesecev). V celotnem poteku teku preskusa so bile koncentracije strupenih snovi daleč po kriterijem za inertnost.
Izvedena je bila tudi raziskava, kako hitrejšo sedimentacijo mulja doseči s kemijskimi dodatki, zlasti z dvema, ki sta se v postopkih polielektrolitskih titracij od številnih analiziranih pokazala kot najbolj perspektivna (Drewfloc 410 in Drewfloc 488. D 488).
Na mulju Luke Koper je bil analiziran tudi okoljski vidik kalcinacije mulja pri izbranih temperaturah. Ugotovljeno je bilo, da se pri povišanih temperaturah (do 800 °C) iz kalcinirane matrice prične sproščanje primarno netopnih kovin in nekaterih anionov (zlasti kroma, ki je praktično ves pretvorjen v strupeno šestvalentno obliko, molibden, sulfat, klorid, fluorid). Nad 1000 °C se strupene komponete imobilizirajo, se je pa zaradi anoksičnega okolja sedimenta razvija močan smrad.
Mulja iz lokacij HE Moste in HE Dravski otok smo uporabili v nezahtevnih betonskih kompozitih, v katerih je bil del finozrnate frakcije nadomeščen z muljem. Pretežno karbonatni in karbonatno/silikatni material fine zrnavosti namreč predstavlja odličen nadomestek konvencionalnim polnilom. Projektirani in izdelani so bili trije betonski kompoziti (med njimi samozgoščevalni beton) z različno vsebnostjo mulja in različnimi kemičnimi dodatki za izboljšanje vgradljivosti in povečanje obstojnosti. Raziskave so potrdile, da je možno mulj v različnih masnih razmerjih uporabiti kot delno nadomestilo finozrnatemu naravnemu agregatu. V primerjavi z referenčnim vzorcem brez mulja sicer izkazujejo ti betoni nekoliko počasnejše vezanje in nekoliko nižje trdnosti, kljub temu pa so po svojih lastnostih primerni za določene namene v gradbeništvu (podložni betoni). Vsi proizvodi imajo zahtevano trajnost z okoljskega stališča so inertni in po končani življenjski dobi 100 % reciklabilni.
Na mulju iz Perniškega jezera je bila izvedena poskusna predelava v umetno zemljino in nato njen pilotni vnos v tla, z namenom zapolnitve tal po izkopu območja mineralnih surovin gramoznice Dogoše pri Mariboru. Mulj je bil odvzet s postopkom sesalnega črpanja v cisterno za prevoz gošč. Po prevozu v gramoznico je bil mulj dehidriran na mobilni tračni dehidracijski napravi in nato na deponiji obdelan z biološkim preparatom, ki pospešuje proces mineralizacije, dobro premešan, razgrnjen v plast debeline 30 cm in pokrit z PVC folijo. Po enem tednu zorenja je bil zmešan z neonesnaženim zemeljskim izkopom v razmerju 2 : 1 in na ta način predelan v umetno zemljino. Po opravljeni preiskavi kakovosti je bila ta vgrajena v tla na območju gramoznice Dogoše v debelini 50 cm.
Peščeno prodnati sediment iz Ljubljanice je klasičen agregat s širokim spektrom uporabnosti za različne gradbene kompozite in okoljsko inerten.
Na osnovi pridobljenih znanj in informacij je bila izbrana najustreznejša metodologija za ovrednotenje potenciala novih materialov z uporabo LCA analize (analize življenjskega cikla). Izdelan je bil dokument »Priročnik o vrednotenju okoljskih vplivov pri recikliranju sedimentov iz vodnih teles v gradbeništvu na podlagi LCA analize«. Konkreten primer analize je bil izveden na primeru proizvodnje betona, kjer smo ovrednotili proizvodnjo betona s tradicionalnimi surovinami in betona, v katerem je bil del finozrnatega naravnega agregata nadomeščen z muljem iz akumulacije HE Moste. Primerjalna LCA metoda je močno orodje za ocenjevanje okoljskih bremen in s tem kvantificirana osnova za odločevanje glede ustreznih metod ravnanja s sedimenti.
V skladu s programom je bil izdelan dokument z naslovom »Nacionalni priročnik za trajnostno ravnanje z onesnaženimi sedimenti iz vodnih okolij«, ki je namenjen strokovni javnosti, zlasti odločevalcem (investitorji, projektanti, nadzor, javna uprava) in s katerim želimo predstaviti osnovne module in možnosti ravnanja s sedimenti – glede na tip in na vrsto onesnaženja – na okoljsko, ekonomsko in sociološko odgovoren način. Rezultati in predvsem ideja projekta (sediment je materialni vir za gradbeništvo) so bili strokovni javnosti posredovani tudi na številnih seminarjih in delavnicah na temo o učinkoviti rabi virov, ki so bile v obdobju 2011-2014 izvedene v okviru LIFE projekta Rebirth (ZAG je bil koordinator projekta).

4.Ocena stopnje realizacije programa dela na raziskovalnem projektu in zastavljenih raziskovalnih ciljev[3]

Ocenjujemo, da so bili cilji projekta izpolnjeni. Ker smo med karakterizacijo odvzetih sedimentov ugotovili, da je z geotehničinega in okoljskega najbolj problematičen material mulj Luke Koper, smo največji del raziskav opravili na tem materialu. Sofinancerji so se s tem strinjali, saj se zavedajo, da je možno postopke, metode in tehnologije, ki so razvite na enem sedimentu, ekstrapolirati tudi na druge materiale. Drugi poudarek je bil namenjen razvoju postopkov remediacije onesnažene vode in onesnaženega sedimenta, pri čemer je bil pri zadnjem cilj, da se predela v gradbeni proizvod, ki je okoljsko inerten in ima ustrezne tehnične karakteristike za določen namen rabe. Ena od rešitev za remediacijo se že uporablja v praksi in je tudi v fazi prijave mednarodnega patenta. Raziskave so bile uspešne in so dale pričakovane rezultate, tako z vidika študija bazičnih raziskav mehanizma pretvorb strupenih snovi v postopkih remediacije, kot tudi konkretne uporabne rezultate in možnosti uporabe različnih tipov sedimentov v gradbeniških aplikacijah.

5.Utemeljitev morebitnih sprememb programa raziskovalnega projekta oziroma sprememb, povečanja ali zmanjšanja sestave projektne skupine[4]

V projektu ni bilo bistvenih odstopanj od predvidenega programa. Edina razlika je glede sofinancerjev. V prijavi so bili kot sofinancerji navedeni: Salonit Anhovo d.d., Ecologic d.o.o., Dravske elektrarne Maribor d.o.o., PKG ŠPRINZER MIRKO s.p. in Koto d.d. V fazi podpisa pogodb je podjetje Dravske elektrarne Maribor d.o.o. umaknilo interes. Namesto njega smo pridobili podjetja Vekton okoljski inženiring d.o.o., Hidrotehnik Vodnogospodarsko podjetje d.d. in Luka Koper d.d. Namesto podjetja Koto d.d. se je vključilo njegovo hčerinsko podjetje Ekosistemi d.o.o. Vsa nova podjetja se na različne načine ukvarjajo s problematiko sedimentov ali imajo kot dejavnost registrirano ravnanje z odpadki.

6.Najpomembnejši znanstveni rezultati projektne skupine[5]

	Znanstveni dosežek			
1.	COBISS ID		1176158	Vir: COBISS.SI
	Naslov	*SLO*	Mineraloške in geokemične raziskave sedimentov iz jezera Dojran (Republika Makedonija)	
		ANG	Mineralogical and geochemical study of Lake Dojran sediments (Republic of Macedonia)	
	Opis	*SLO*	V študiji smo raziskovali mineraloške in geokemične značilnosti površinskih (0-5, 5-10, 10-15 cm) sedimentov Dojranskega jezera, z namenom, da bi določili njihovo primernost v balneoterapevtske namene. Mineraloško sestavo smo določili s pomočjo rentgenske praškovne difrakcije (XRD) in rezultate elementne sestave pa smo pridobili s pomočjo induktivno vezane plazemske spektrometrije (ICP-MS). Rezultati mineraloške sestave so pokazali, da je mineralna asociacija močno povezana z geološkim zaledjem metamorfnih in magmatskih kamnin iz okolice jezera Dojran. Izračunali smo tudi kemijski indeks sprememb (CIA), ki je z vrednostjo 67 % nakazal srednjo stopnjo preperevanja geološkega ozadja. Vrednosti obogatitvenega faktorja (EF) potencialno toksičnih prvin prisotnih v sedimentu so definirale sediment Dojranskega jezera kot rahlo obogaten z Co, Cr, Cu, Pb in Zn, srednje obogaten z Au, Ni in Sb, srednje močno obogaten z Au, močno	

			obogaten z Sb in zelo močno obogaten z As. Navedena elementna obogatitev izvira iz različnih geogenih (geološko ozadje in polimetalna mineralizacija) in antropogenih (turizem, promet, obloge, neprečiščene odpadne vode in agrokemikalije) virov. Vertikalna razporeditev elementne sestave se z globino tudi zelo malo spreminja (0-5, 5-10, 10-15 cm). Primerjava vsebnosti potencialno toksičnih elementov z referenčnimi koncentracijami TEC in PEC so pokazale, da je jezerska biota lahko izpostavljena antropogenemu vplivu As, Cu in Ni. Glede na pridobljene rezultate, zaenkrat še ne moremo potrditi aplikacijo/uporabnost jezerskih sedimentov v balneoterapevtske namene.	
		ANG	In this study the mineralogical and geochemical characteristics of Lake Dojran surficial (0-5, 5-10, 10-15 cm) sediments were studied in order to determine their suitability for use as potential raw material in balneotherapeutic treatments. X-ray powder diffraction (XRD) and inductively coupled plasma mass spectrometry (ICP-MS) analyses were performed, and thereupon chemical index of alteration (CIA) and enrichment factor (EF) values were calculated. The XRD results revealed close association of sediment mineralogy with the prevailing metamorphic, volcanic and igneous rocks of the region surrounding Lake Dojran. CIA values of around 67 % suggest a moderate degree of weathering in the lake catchment area. According to the EF value results, surficial Lake Dojran sediments are little enriched with Co, Cr, Cu, Pb, and Zn, moderately enriched with Au, Ni and Sb, moderately severely enriched with Au, severely enriched with Sb and very severely enriched with As. This elemental enrichment likely originates from various different geogenic (geological background and polymetallic mineralization) and anthropogenic (tourism, traffic, coatings, untreated wastewater discharge and agrochemicals) sources. The abundances of the major elements, trace elements and rare earth elements (REEs) were almost constant, changing very little throughout the surficial (0-5, 5-10, 10-15 cm) sediments. Comparison of sediment trace element concentrations with consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC) values showed that lake biota may be under threat of contamination with As, Cu and Ni. Given the present results, we cannot recommend/confirm the application of Lake Dojran dark mud sediment in balneotherapeutic treatments.	
	Objavljeno v		Elsevier Scientific Publishing; Journal of geochemical exploration; 2015; Vol. 150; str. 73-83; Impact Factor: 2.432;Srednja vrednost revije / Medium Category Impact Factor: 2.211; WoS: GC; Avtorji / Authors: Rogan Šmuc Nastja, Serafimovski Todor, Dolenec Tadej, Dolenec Matej, Vrhovnik Petra, Vrabec Mirijam, Jaćimović Radojko, Logar Zorn Vesna, Komar Darja	
	Tipologija		1.01 Izvirni znanstveni članek	
2.	COBISS ID		17710614	Vir: COBISS.SI
	Naslov	*SLO*	Obseg vrtin za geotehnično raziskavo z uporabo mehkih in verjetnostnih vhodnih podatkov	
		ANG	Site soundings density for geotechnical investigation with combined fuzzy and probabilistic input information	
	Opis	*SLO*	Za načrtovanje terenske geotehnične preiskave je predlagan sistem mehke logike. Sistem upošteva parametre, kot so geologija in variabilnost tal, ki vplivajo na zahtevano število sondiranj za ustrezen opis lokacije gradnje. Omogoča tudi proučitev nejasnosti in pomanjkanje informacij. Sistem omogoča za projekte oceno števila sondirnih mest, na podlagi razoložljivih kvalitativnih in kvantitativnih podatkov. Monte Carlo simulacije vstopnih razponov, kjer ima vsaka točka enotno verjetnostno porazdelitev, omogoča izhodne podatke v obliki histogramov, opremljenih z verjetnostnimi	

			funkcijami. Predstavljeni primeri kažejo, da se sistem mehke logike lahko uporabi kot sistematična podpora pri odločanju inženirjev, ki se ukvarjajo s karakterizacijo lokacije gradnje.	
		ANG	A fuzzy sets decision support system is proposed for geotechnical site investigation. The system considers parameters such as geology and soil variability that affect the required number of soundings to adequately characterize a site. It permits also to consider vagueness and lack of information. On the basis of available qualitative and quantitative information, the system allows estimating, for common projects, the number of site soundings. Monte Carlo simulations of entry ranges, where each point has a uniform probability distribution, permit to arrange the output in form of histograms fitted with probability functions. The cases presented show that the fuzzy inference system can be used as a systematic decision support for engineers dealing with site characterization.	
	Objavljeno v		Chapman and Hall; Geotechnical and geological engineering; 2014; Vol. 32, iss. 2; str. 547-559; Avtorji / Authors: Boumezerane Djemalddine M., Belkacemi Smain, Žlender Bojan	
	Tipologija		1.01 Izvirni znanstveni članek	
3.	COBISS ID		27431207	Vir: COBISS.SI
	Naslov	SLO	Raziskave aktivnosti nanodelcev ničvalentnega železa pri odstranjevanju cinkovih kompleksov iz vodnih raztopin	
		ANG	Nanoscale zero-valent iron for the removal of Zn[sup](2+), Zn(II)-EDTA and Zn(II)-citrate from aqueous solutions	
	Opis	SLO	Določevali smo vplivne parametre pri odstranjevanju različnih oblik cinkovih kompleksov iz vodnih raztopin s pomočjo nanodelcev ničvalentnega železa. Pripravili smo različno modificirane nanodelce železa: površinsko obdelane in neobdelane delce, ter nanešene na delce SiO2. Ugotovili smo, da imajo različno pripravljeni nanodelci, njihova koncentracija v raztopini, pH raztopine in kontaktni čas odločilni vpliv na učinkovitost odstranitve Zn2+, Zn(II)–EDTA ali Zn(II)–citrata. Najbolj so bili učinkoviti površinsko neobdelani nanodelci.	
		ANG	The parameters which influence the removal of different zinc (Zn) species: Zn2+, Zn(II)–EDTA and Zn(II)–citrate from aqueous solutions by nanoparticles of zerovalent iron (nZVI) were investigated at environmental relevant pH values. Untreated, surface modified and silica-fume supported nZVI were applied at different iron loads and contact times to Zn solutions, which were buffered to pH 5.3, 6.0 and 7.0. The results revealed that pH, the type of nZVI, the iron load, the contact time, and the Zn species all had a significant influence on the efficiency of removal. Zn2+, Zn(II)–EDTA and Zn(II)–citrate were the most effectively removed from aqueous solutions by untreated nZVI. Zn2+ removalwas governed mainly by adsorption onto precipitated iron oxides. Complete removal of Zn2+ and Zn(II)–citrate was obtained at all pH values investigated. The removal of strong Zn(II)–EDTA complex was successful only at acidic pH,which favored degradation of Zn(II)–EDTA. Consequently, the released Zn2+ was completely removed from the solution by adsorption onto iron oxides.	
	Objavljeno v		Elsevier; Science of the total environment; 2014; Vol. 476-477; str. 20-28; Impact Factor: 3.163;Srednja vrednost revije / Medium Category Impact Factor: 2.143; A': 1; WoS: JA; Avtorji / Authors: Kržišnik Nina, Mladenovič Ana, Sever Škapin Andrijana, Škrlep Luka, Ščančar Janez, Milačič Radmila	
	Tipologija		1.01 Izvirni znanstveni članek	
4.	COBISS ID		6328417	Vir: COBISS.SI
	Naslov	SLO	Primerjava metod za karakterizacijo specifične površine glin	

		ANG	A comparison of methods used to characterize the soil specific surface area of clays	
	Opis	SLO	Članek obravnava uporabnost suhe strani retencijske krivulje za določitev specifične površine drobno zrnatih zemljin. Retencijska krivulja je temeljna zveza, ki opisuje zvezo med vlago zemljine in napetostojo porne vode (tenzijo) v času sušenja in močenja. V raziskavo je bilo vključenih 90 vzorcev realnih zemljin, za določitev specifične površine pa je bila uporabljena enačba po Tuller in Or (2005). Suha stran retencijske krivulje je bila določena z meritvami sukcije v potenciometru, ki deluje na principu merjenja temperature rosišča hlajenega ogledalca (proizvajalec Decagon, tip naprave WP4T). Vrednosti specifične površine, izračunane iz izmerjenih retencijskih krivulj so bile primerjene z vrednostmi, določenimi z uporabo klasičnih metod za določanje specifične površine, to je z uporabo metode BET (Brauner, Emmett in Teller) in metode metilen modro (MB). Primerjalna analiza rezultatov, v katero so bili vključeni tudi dostopni literaturni viri je pokazala, da je možno suho stran retencijske krivulje uporabiti za izračun specifični površine zrn zemljin s specifično površino nad 5 m2/g najmanj enako dobro in z enako zanesljivostjo kot preostali dve klasični metodi. Hamakerjeva konstanta z vrednostjo 6 x 1020 J se je v izračunih izkazala kot najboljša aproksimacija. Analiza je tudi pokazala, da imajo kraške gline, čeprav jih običajno opisujemo s klasičnimi kazalniki za identifikacijo lastnosti zrn (meja židkosti, indeks plastičnosti, aktivnost) specifično obnašanje, ki pa ni bilo podrobneje raziskano. Tuller in Or (2005) sta enačbo za določanje specifične površine zrn iz podatkov retencijske krivulje oblikovala na osnovi raziskav pripovršinskih zemljin in sta zato uporabnost metode tudi omejila na te zemljine. Opisana raziskava pa je dokazala široko uporabnost njune enačbe na področju širokega spektra inženirskih zemljin, tako normalno konsolidiranih in visoko prekonsolidiranih zemljin kot tudi mehkih kamnin, ki vsebujejo glino. Hkrati pa so raziskave na kraški glini pokazale, da bo potrebno v zemljinah z bolj kompleksno mineralno sestavo in strukturo izpeljati nove, poglobljene analize in tudi modificirati enačbo po Tuller in Or (2005).	
		ANG	In the study the dry end of the soil water characteristic curve (SWCC) was used to estimate the specific surface area (SSA) of 90 engineering soil samples, using the Tuller and Or (2005) model. The results of SSA obtained by measurements using a WP4T dew point potentiometer were compared with those obtained by means of traditional BET (Brunauer, Emmett, and Teller) surface area and the methylene blue (MB) techniques. An analysis of the results discussed in terms of the representative literature data showed that the SWCC method could provide a reliable estimation of the specific surface area in the case of fine grained inorganic soils with a total specific surface area greater than 5 m2/g. A Hamaker constant with a value of 6 × 10− 20 J was found to be a good approximation, in the case of SSA calculations. The study also shows that karstic clay — terra rossa exhibits specific behavior which was not investigated in detail in the study, but clearly shows that further research is needed in order to modify the Tuller and Or (2005) model to a wider range of engineering soils with more complex mineralogical composition and texture.	
	Objavljeno v		Elsevier; Applied clay science; 2013; Letn. 83-84; str. 144-152; Impact Factor: 2.703;Srednja vrednost revije / Medium Category Impact Factor: 2.554; A': 1; WoS: EI, PM, RE; Avtorji / Authors: Maček Matej, Mauko Alenka, Mladenovič Ana, Majes Bojan, Petkovšek Ana	
	Tipologija		1.01 Izvirni znanstveni članek	
5.	COBISS ID		1972071	Vir: COBISS.SI

	Naslov	SLO	Mulj iz Luke Koper -uporabnost v gradbeništvu	
		ANG	Dredged mud from the Port of Koper - civil engineering applications	
	Opis	SLO	Luka Koper, kot eno najpomembnejših pristanišč v severnem delu Jadranskega morja, se nenehno spopada s težavo akumulacije sedimentov na plovnih poteh, kar povzroča težave pri najbolj kritičnih delovnih zmogljivostih pristanišča. Po drugi strani ta material lahko obravnavamo kot potencialno surovino v gradbeništvu. V prispevku so podani preliminarni rezultati interdisciplinarnih raziskav, ki kažejo naslednje: prvič, koncentracija težkih kovin v izlužkih je nizka in drugič, v stanju, kot je, je sediment preveč vlažen, da bi ga bilo mogoče osuševati z naravnimi postopki in je zato potrebna dodatna tehnološka obdelava.	
		ANG	The Port of Koper, one of the biggest and the most important ports in the Northern Adriatic Sea, is constantly faced with the problems caused by the accumulation of marine sediments inside the port, disturbing some of the port's crucial operations. However, these sediments can be viewed as a potential raw material and, in order to define the best way of using them in the civil-engineering field, an extensive research project has been launched. The preliminary results of this project are presented and discussed in the paper. So far the project has given two main results: first, the concentrationof heavy metals in the aqueous leachates is low and, secondly, intheir present state, the sediments are too wet, so that there are only limited possibilities for drying them out naturally. For this reason additional technological treatment will be needed.	
	Objavljeno v		Inštitut za kovinske materiale in tehnologije; Materiali in tehnologije; 2013; Letn. 47, št. 3; str. 353-356; Impact Factor: 0.555;Srednja vrednost revije / Medium Category Impact Factor: 2.554; WoS: PM; Avtorji / Authors: Mladenovič Ana, Pogačnik Željko, Milačič Radmila, Petkovšek Ana, Cepak Franka	
	Tipologija		1.01 Izvirni znanstveni članek	

7.Najpomembnejši družbeno-ekonomski rezultati projektne skupine[6]

	Družbeno-ekonomski dosežek			
1.	COBISS ID		2100583	Vir: vpis v poročilo
	Naslov	SLO	Postopek izdelave za človeško okolje in zdravje sprejemljivega gradbenega materiala iz kontaminirane zemljine, vsebujoče vodotopne spojine težkih kovin.	
		ANG	Process for obtaining health - and environment acceptable construction materials from the soil containing water soluble compounds of heavy metals.	
	Opis	SLO	Izum spada na področje remediacije kontaminirane zemljine, s pomočjo katerih se zemljino z vsebnostjo nevarnih sestavin s pomočjo kemičnih reakcij pretvori v manj nevarno stanje. Pri tem je izum osnovan na problemu, kako iz zemljine s prekomerno vsebnostjo za okolje nesprejemljivih in/ali zdravju škodljivih vodotopnih spojin težkih kovin, še zlasti tistih na osnovi arzena As in/ali kadmija Cd in/ali svinca Pb in/ali cinka Zn, na ekonomičen način pridobiti za okolje in človeško zdravje sprejemljiv, kemijsko nevtralen in inerten gradbeni material, pri katerem vsebnost omenjenih kontaminantov ne bo presegala vnaprej določenih mejnih vrednosti.	
			The invention belongs to the field of remediation of contaminated soil. The contaminated soil is converted into a less dangerous form by means of chemical reactions. This invention is based on the problem of how to make	

		ANG	the soil with excessive level unacceptable to the environment and / or harmful water-soluble heavy metal compounds, particularly those based on arsenic As and / or cadmium Cd, and / or lead Pb, and / or zinc Zn at an economical way to obtain the inert and chemically neutral building material, in which the content of the contaminants does not exceed a predetermined threshold values and will be acceptable from environmental point of view and will not represent a threat for human health.	
	Šifra		F.32 Mednarodni patent	
	Objavljeno v		International application no. PCT/SI2015/000007. [S. l.]: Europen Patent Office (EPO) (ISA/EP), 2015. 15 f., 5 f. pril., tab. MLADENOVIČ, Ana, OPRČKAL, Primož, KRŽIŠNIK, Nina, MILAČIČ, Radmila, ŠČANČAR, Janez, SEVER ŠKAPIN, Andrijana.	
	Tipologija		2.23 Patentna prijava	
2.	COBISS ID		1914471	Vir: COBISS.SI
	Naslov	SLO	Odpadki kot vir v visokih in nizkih gradnjah - situacija v Sloveniji	
		ANG	Waste as a resource in building and civil engineering - the current situation in Slovenia	
	Opis	SLO	Trajnostni razvoj v gradbeništvu obsega tudi ponovno uporabo in recikliranje gradbenih in industrijskih odpadkov. Gradbene ruševine sestavljajo okoli 25-30 % odpadkov, ki letno nastanejo v Evropi, zato je nujno, da se ti materiali, skupaj z industrijskimi in drugimi odpadki, uporabijo v novih aplikacijah, ki imajo enake funkcionalne lastnosti kot konvencionalni materiali. Če so za to uporabljeni pravilni postopki, ni negativnega vpliva na okolje. V članku je predstavljena trenutna situacija v Sloveniji na področju uporabe odpadkov, kot tudi nekaj primerov dobre prakse in raziskav na področju ravnanja z odpadki, s poudarkom na žlindrah, reciklirani odpadni gumi in hladni reciklaži v cestogradnji.	
		ANG	Sustainable thinking in building and civil engineering assumes that recycling and demolition (R&D) waste, and industrial waste, is reused or recycled. SinceR&D waste represents approximately 25-30 % of the total waste generated every year in Europe, this waste, together with industrial waste, should be reused in new applications, i.e. for new products which will have the same functional characteristics as if conventional materials were used. If appropriate treatments are chosen, adverse effects on the environment become negligible. This paper discusses the current situation in Slovenia, and includes some examples of good practice and research in the field in sustainable waste management. These include the use of two types of steel slag, recycled rubber, and road pavement in-situ cold recycling.	
	Šifra		B.04 Vabljeno predavanje	
	Objavljeno v		Inženirska zbornica Slovenije; Sustainable construction for people; 2012; Str. 153-160; Avtorji / Authors: Mladenovič Ana, Kokot Darko, Mauko Alenka, Cotič Zvonko, Lenart Stanislav, Fifer Bizjak Karmen	
	Tipologija		1.08 Objavljeni znanstveni prispevek na konferenci	
3.	COBISS ID		1919335	Vir: COBISS.SI
	Naslov	SLO	Karakterizacija mulja iz Luke Koper in njegova potencialna uporabnost v gradbeništvu	
		ANG	Characterization of dredged sea mud from the port of Koper and its potential applications in civil engineering	
			Na mednarodni konferenci z naslovom "Dredging in the European Union: Regulations, problems and best practice" (Piombino, Italija, oktober 2012) je bil predstavljen problem, ki ga ima Luka Koper zaradi	

	Opis	SLO	sedimentacije mulja na plovnih poteh in rezultati raziskav, ki potekajo z namenom, najti optimalne rešitve za uporabo mulja kot gradbenega materiala v ekonomsko vzdržnih in trajnostih aplikacijah. Sodelovanje na tej konferenci je bilo pomembno, ker smo iz prve roke dobili informacijo o praksah v zvezi z ravnanjem s sedimenti v drugih evropskih pristaniščih.	
		ANG	The problem that the Port of Koper has to face due to the sedimentation of mud in its waterways, as well as the results of research that has been performed so far in order to find an optimal solution for the use of this mud as a building material, in economically viable and sustainable applications, was presented at the International conference entitled "Dredging and the European Union: Regulations, Problems and Best Practice" (Piombino, Italy, October 2012). Participation at this conference was important since it was necessary to obtain firsthand information about everyday practice relating to the management of sediments in other European ports.	
	Šifra		B.03 Referat na mednarodni znanstveni konferenci	
	Objavljeno v		2012; Avtorji / Authors: Mladenovič Ana, Pogačnik Željko, Milačič Radmila, Petkovšek Ana, Cepak Franka	
	Tipologija		3.15 Prispevek na konferenci brez natisa	
4.	COBISS ID		27997479	Vir: COBISS.SI
	Naslov	SLO	Okoljski vplivi gradbenih materialov, ki vsebujejo odpadke iz jeklarstva	
		ANG	Environmental impacts of building materials containing waste by-products from steel industry	
	Opis	SLO	Na Institutu za javno zdravje v Podgorici v Črni gori, so avtorji predstavili obsežno delo raziskovalne skupine na področju uporabe odpadnih materialov iz jeklarske industrije v gradbeništvu. Razgovori so tekli tudi v smer uporabe drugih odpadnih materialov, kot so mulji iz luk, elektrofiltrski pepeli iz termoelektrarn in rdeče blato, ki nastaja pri proizvodnji aluminija. Na osnovi skupnih interesov smo se dogovorili o potencialnem možnem sodelovanju na bodočih razpisih EU projektov. Na osnovi skupnih interesov smo pritegnili študentko Ano Drinčić, da je v okviru pridobljene štipendije Ad-futura prišla v Slovenijo opravljati doktorsko delo, ki bo povezano z uporabo odpadkov različnih odpadnih materialov v gradbeništvu.	
		ANG	In the Institute for Public Health the authors presented extensive investigations performed in the research group on environmental impacts of building materials containing waste by-products from steel industry. The discussion was carried also on the use of other secondary materials e.g. dredged sediments, fly ash from thermal electric power plants and red mud, generated during the production of aluminium. Based on common interests, successful collaboration started on potential EU projects applications. A Ph.D. student Ana Drinčić came to Slovenia, funded by Ad-futura fellowship for the doctoral studies. The topics of her Ph.D. is related to the re-use of different waste materials in civil engineering	
	Šifra		B.04 Vabljeno predavanje	
	Objavljeno v		Institute for Public Health; 2014; Avtorji / Authors: Ščančar Janez, Mladenovič Ana, Milačič Radmila	
	Tipologija		3.14 Predavanje na tuji univerzi	
5.	COBISS ID		1948263	Vir: COBISS.SI
	Naslov	SLO	Overview and current perspectives of applied petrography in Slovenia	
		ANG	Pregled in perspektive na področju aplikativne petrografije v Sloveniji	
			Vabljeno predavanje na Applied Petrography Group (Geological Society of London), 20.2.2013.	

	Opis	*SLO*	Delovanje Zavoda za gradbeništvo Slovenije na področju aplikativne in tehnične petrografije, s poudarkom na patologiji betona in na uporabi različnih industrijskih odpadkov in sedimentov iz vodnih okolij v gradbeništvu.
		ANG	Invited lecture at Applied Petrography Group (Geological Society of London), 02.20.2013. The activites within Slovenaian Nationa Building and cCIvil Engineering Institute in the field of applied and technical petrography, with an emphasis on pathology of concrete composites and the use of various industrial wastes and dredged sediments from aquatic environments in construction.
	Šifra		B.04 Vabljeno predavanje
	Objavljeno v		2013; Avtorji / Authors: Mladenovič Ana
	Tipologija		3.16 Vabljeno predavanje na konferenci brez natisa

8.Drugi pomembni rezultati projetne skupine[7]

V okviru preučevanja karakteristik sedimentov in možnosti njihove remediacije ter uporabe v gradbeništvu sta pripravljena še dva rokopisa člankov:
"Environmental characterisation of dredged sediments in relation to their potential use in civil engineering". Avtorji: Tea Zuliani, Ana Mladenovič, Janez Ščančar in Radmila Milačič. Članek smo poslali v objavo v revijo z Journal of Soils and Sediments, IF=2.285, Stratigraphy; 9/33; A' četrtina: 1. SNIP BAZA. Rokopis pripenjamo k temu poročilu.

"Environmental assessment study of Port of Koper surficial sediments (Northern Adriatic Sea)", avtorjev: Nastja Rogan Šmuc, Matej Dolenec, Sabina Kramar, Breda Mirtič, Tadej Dolenec, Franka Čepak in Ana Mladenovič, ki ga bomo poslali v objavo v revijo Environmental Science and Pollution Research, IF 2.757, JA – environmental sciences, 55/216, četrtina: 2.

9.Pomen raziskovalnih rezultatov projektne skupine[8]

9.1.Pomen za razvoj znanosti[9]

SLO

Odstranjevanje sedimentov iz vodnih teles se v Sloveniji izvaja sporadično, ko pa se, se odstranjeni sediment odloži kot odpadek. S tem na eni strani izgubljamo dragocene vire, na drugi strani pa imajo vodna telesa zaradi nakopičenih sedimentov zmanjšane ključne funkcije.
V projektu smo dokazali, da je možno z različnimi tehnološkimi postopki te materiale uporabiti v gradbeniških aplikacijah, v primeru, da so onesnaženi, pa z inovativnimi kombinacijami z drugimi materiali na osnovi odpadkov zagotoviti dolgoročno remediacijo strupenih snovi. Na področju remediacije onesnažene zemljine (kar vključuje tudi sedimente) je vložena prijava mednarodnega patenta, v katerem se s cenenim ter tehnično in zakonodajno izvedljivim postopkom kontaminirana zemljina reciklira v gradbeni proizvod za nasipe. Del raziskav je potekal tudi na področju remediacije onesnažene vode, pri čemer smo uporabili nanodelce ničvalentnega železa.
V okviru raziskav so bili proučeni mehanizmi remediacije in optimizirani sami postopki, kar je bistven prispevek k razvoju znanosti na področju uporabe in remediacije sedimentov ter remediacije vode, tako na nacionalnem kot tudi na mednarodnem nivoju.
Iz mednarodne povezave z University "Goce Delcev"-Stip, Faculty of Natural and Technical Sciences je bil objavljen en članek.
Projekt je prispeval tudi k izobraževanju enega mladega raziskovalca za dosego doktorata (ki sicer še poteka), v okviru katerega še naprej raziskuje remediacijo onesnaženih materialov in vode.

ANG

In Slovenia, the removal of sediments from water bodies is carried out only sporadically, and

when it is, the removed sediments are disposed of as waste. Thus, not only are precious resources wasted, but, due to the accumulated sediments, the key functions of these water bodies are reduced.
In this project, it has been shown that various technologies exist which could make these sediments suitable for use in civil engineering applications, and that, in the event that they are polluted, innovative combinations with other waste-based materials can used in order to ensure the long-term remediation of toxic substances. In the field of the remediation of contaminated soils (including sediments), an international patent has been applied for, in which, based on relatively low-priced technology, and procedures which are both technically and legislation-wise feasible, polluted soil could be used to produce a construction product for embankments. Part of the research was also performed in the field of the remediation of contaminated water, where the use of zero-valent iron nanoparticles was studied.
Within the scope of the research the mechanisms to be used for remediation, as well as the optimized procedures themselves, were studied, which represents an important contribution to the development of environmental science, including the remediation of sediments and water, both at the national as well as the international level.
Based on co-operation with the Faculty of Natural and Technical Sciences of the "Goce Delčev" University of Štip, Macedonia, one paper was published in a technical journal.
The project has also contributed to the education of a young researcher who is studying for his Ph.D. (still in progress), in which further research is being performed into the remediation of contaminated materials and water.

9.2. Pomen za razvoj Slovenije[10]

SLO

Raziskava je temelj, kako v slovenskem prostoru pristopiti k sanaciji vodnih objektov z veliko količino akumuliranih sedimentov in zlasti, kakšne remediacijske tehnologije uporabiti glede na tip sedimenta in vrsto morebitnega antropogenega onesnaženja.
Tematiko projekta so predlagali industrijski partnerji, med katerimi so takšni, ki jim predstavlja ravnanje s sedimenti ključno aktivnost ali pa to zaradi različnih razlogov identificirajo kot problem, in tudi takšni, ki se s temi materiali v praksi direktno ne ukvarjajo (pač pa z drugimi vrstami odpadkov), vendar so prepoznali, da z ekstrapolacijo in optimizacijo rešitve na tem področju lahko integrirajo v svojo prakso (npr. na področje blat iz komunalnih čistilnih naprav ali muljev iz galvanizacijskih postopkov). To zadnje potrjuje, da je tematika širšega nacionalnega pomena.
Rezultati raziskovalnega projekta bodo tako na razpolago in v pomoč v prvi vrsti sofinancerjem, preko Priročnika in nadaljnje diseminacije razultatov pa tudi širši strokovni javnosti (upravljavcem vodnih teles, imetnikom odpadkov – iz različnih področij dejavnosti – gradbenikom in projektantom).
Pričakovana sinergija na področju uporabe in remediacije sedimentov z industrijskimi odpadki in nove prakse na področju ravnanja z drugimi vrstami odpadkov (vse za končno rabo v gradbeništvu) bo prinesla pozitivne okoljske in ekonomske učinke. S tem se bo zmanjšalo obremenjevanje okolja, saj to pomeni manjšo porabo naravnih surovin, boljšo izkoriščenost lokalnih surovin, zaradi uporabe novih materialov in postopkov tudi manjšo porabo energije in izpustov toplogrednih plinov. Samo odstranjevanje sedimentov bo vplivalo tudi na večjo funkcionalnost vodnih objektov ter izboljšalo kakovost teh ekosistemov.
Z ohranjanjem in izboljševanjem okolja pa se bo nedvomno tudi povečala kvaliteta življenja prebivalcev Republike Slovenije.
Projekt je dal tudi produkt, ki je že validiran tudi na testnem polju, kar pomeni, da je praktično na stopnji trženja.

ANG

The performed research represents a foundation of how it would be possible, within the framework of Slovenian spatial planning procedures, to rehabilitate water facilities where there are large quantities of accumulated sediments, and in particular, and of what remediation technologies could be used depending on the type of sediment, and the type of anthropogenic pollution.
The idea of the project was proposed to several industrial partners, including those who have determined that dealing with sediments is a key activity, or who have, for various reasons, identified this as a problem, as well as some partners who are not directly involved with these

materials in practice (but with other types of waste), but who recognize that extrapolation and optimization solutions in this field could be integrated into their practice (e.g. in the field of sludge obtained from sewage treatment works, or from galvanizing processes). This proves the fact that this topic is of broader national interest.
The results of the research project will be made widely available, and will be particularly useful to co-financers, through guidelines to be published, as well as other forms of dissemination of the results to the wider public (managers of water bodies, holders of waste materials - from different fields of work, and designers and contractors in the construction industry).
In terms of the use and remediation of sediments by means of industrial waste, as well as new practice in the treatment of other kinds of waste (all of which should have their end-use in the construction industry) the expected synergies will bring positive environmental and economic impacts. This will reduce the burden on the environment since smaller quantities of natural resources will be used, locally-sourced raw materials will be better utilized, and the use of new materials and processes will also reduce energy consumption and greenhouse gas emissions.
Just the removal of sediments will also have a significant effect on the greater functionality of water facilities, and improve the quality of these ecosystems.
Through the maintenance and enhancement of the environment the quality of life of the inhabitants of the Republic of Slovenia will undoubtedly be improved.
The project will also result in a product whose use has already been validated on a test field, which means that it is practically at the marketing stage.

10.Samo za aplikativne projekte in podoktorske projekte iz gospodarstva! Označite, katerega od navedenih ciljev ste si zastavili pri projektu, katere konkretne rezultate ste dosegli in v kakšni meri so doseženi rezultati uporabljeni

Cilj		
F.01	**Pridobitev novih praktičnih znanj, informacij in veščin**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen
	Uporaba rezultatov	V celoti
F.02	**Pridobitev novih znanstvenih spoznanj**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen
	Uporaba rezultatov	V celoti
F.03	**Večja usposobljenost raziskovalno-razvojnega osebja**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen
	Uporaba rezultatov	Delno
F.04	**Dvig tehnološke ravni**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen
	Uporaba rezultatov	V celoti
F.05	**Sposobnost za začetek novega tehnološkega razvoja**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.06	**Razvoj novega izdelka**	

	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.07	**Izboljšanje obstoječega izdelka**	
	Zastavljen cilj	( ) DA (•) NE
	Rezultat	
	Uporaba rezultatov	
F.08	**Razvoj in izdelava prototipa**	
	Zastavljen cilj	( ) DA (•) NE
	Rezultat	
	Uporaba rezultatov	
F.09	**Razvoj novega tehnološkega procesa oz. tehnologije**	
	Zastavljen cilj	( ) DA (•) NE
	Rezultat	
	Uporaba rezultatov	
F.10	**Izboljšanje obstoječega tehnološkega procesa oz. tehnologije**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.11	**Razvoj nove storitve**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.12	**Izboljšanje obstoječe storitve**	
	Zastavljen cilj	(•) DA ( ) NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.13	**Razvoj novih proizvodnih metod in instrumentov oz. proizvodnih procesov**	
	Zastavljen cilj	( ) DA (•) NE
	Rezultat	
	Uporaba rezultatov	
F.14	**Izboljšanje obstoječih proizvodnih metod in instrumentov oz. proizvodnih procesov**	
	Zastavljen cilj	( ) DA (•) NE
	Rezultat	
	Uporaba rezultatov	
F.15	**Razvoj novega informacijskega sistema/podatkovnih baz**	
	Zastavljen cilj	( ) DA (•) NE

	Rezultat	
	Uporaba rezultatov	
F.16	**Izboljšanje obstoječega informacijskega sistema/podatkovnih baz**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.17	**Prenos obstoječih tehnologij, znanj, metod in postopkov v prakso**	
	Zastavljen cilj	◉ DA ○ NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.18	**Posredovanje novih znanj neposrednim uporabnikom (seminarji, forumi, konference)**	
	Zastavljen cilj	◉ DA ○ NE
	Rezultat	Dosežen
	Uporaba rezultatov	V celoti
F.19	**Znanje, ki vodi k ustanovitvi novega podjetja ("spin off")**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.20	**Ustanovitev novega podjetja ("spin off")**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.21	**Razvoj novih zdravstvenih/diagnostičnih metod/postopkov**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.22	**Izboljšanje obstoječih zdravstvenih/diagnostičnih metod/postopkov**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.23	**Razvoj novih sistemskih, normativnih, programskih in metodoloških rešitev**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.24	**Izboljšanje obstoječih sistemskih, normativnih, programskih in metodoloških rešitev**	
	Zastavljen cilj	◉ DA ○ NE
	Rezultat	Dosežen bo v naslednjih 3 letih

	Uporaba rezultatov	Delno
F.25	**Razvoj novih organizacijskih in upravljavskih rešitev**	
	Zastavljen cilj	◉ DA ○ NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.26	**Izboljšanje obstoječih organizacijskih in upravljavskih rešitev**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.27	**Prispevek k ohranjanju/varovanje naravne in kulturne dediščine**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.28	**Priprava/organizacija razstave**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.29	**Prispevek k razvoju nacionalne kulturne identitete**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.30	**Strokovna ocena stanja**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.31	**Razvoj standardov**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.32	**Mednarodni patent**	
	Zastavljen cilj	◉ DA ○ NE
	Rezultat	Dosežen bo v naslednjih 3 letih
	Uporaba rezultatov	Uporabljen bo v naslednjih 3 letih
F.33	**Patent v Sloveniji**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.34	**Svetovalna dejavnost**	

	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	
F.35	**Drugo**	
	Zastavljen cilj	○ DA ◉ NE
	Rezultat	
	Uporaba rezultatov	

Komentar

11.Samo za aplikativne projekte in podoktorske projekte iz gospodarstva!
Označite potencialne vplive oziroma učinke vaših rezultatov na navedena področja

	Vpliv	Ni vpliva	Majhen vpliv	Srednji vpliv	Velik vpliv	
G.01	**Razvoj visokošolskega izobraževanja**					
G.01.01.	Razvoj dodiplomskega izobraževanja	○	○	◉	○	
G.01.02.	Razvoj podiplomskega izobraževanja	○	○	○	◉	
G.01.03.	Drugo:	○	○	○	○	
G.02	**Gospodarski razvoj**					
G.02.01	Razširitev ponudbe novih izdelkov/storitev na trgu	○	○	○	◉	
G.02.02.	Širitev obstoječih trgov	○	○	○	◉	
G.02.03.	Znižanje stroškov proizvodnje	○	○	○	◉	
G.02.04.	Zmanjšanje porabe materialov in energije	○	○	○	◉	
G.02.05.	Razširitev področja dejavnosti	○	○	○	◉	
G.02.06.	Večja konkurenčna sposobnost	○	○	○	◉	
G.02.07.	Večji delež izvoza	◉	○	○	○	
G.02.08.	Povečanje dobička	○	○	◉	○	
G.02.09.	Nova delovna mesta	○	○	◉	○	
G.02.10.	Dvig izobrazbene strukture zaposlenih	○	○	◉	○	
G.02.11.	Nov investicijski zagon	○	○	◉	○	
G.02.12.	Drugo:	○	○	○	○	
G.03	**Tehnološki razvoj**					
G.03.01.	Tehnološka razširitev/posodobitev dejavnosti	○	○	◉	○	
G.03.02.	Tehnološko prestrukturiranje dejavnosti	○	○	◉	○	
G.03.03.	Uvajanje novih tehnologij	○	○	◉	○	
G.03.04.	Drugo:	○	○	○	○	
G.04	**Družbeni razvoj**					

G.04.01	Dvig kvalitete življenja	○	○	○	◉	
G.04.02.	Izboljšanje vodenja in upravljanja	○	○	◉	○	
G.04.03.	Izboljšanje delovanja administracije in javne uprave	○	◉	○	○	
G.04.04.	Razvoj socialnih dejavnosti	○	◉	○	○	
G.04.05.	Razvoj civilne družbe	○	○	◉	○	
G.04.06.	Drugo:	○	○	○	○	
G.05.	**Ohranjanje in razvoj nacionalne naravne in kulturne dediščine in identitete**	○	○	◉	○	
G.06.	**Varovanje okolja in trajnostni razvoj**	○	○	○	◉	
G.07	**Razvoj družbene infrastrukture**					
G.07.01.	Informacijsko-komunikacijska infrastruktura	◉	○	○	○	
G.07.02.	Prometna infrastruktura	◉	○	○	○	
G.07.03.	Energetska infrastruktura	◉	○	○	○	
G.07.04.	Drugo:	○	○	○	○	
G.08.	**Varovanje zdravja in razvoj zdravstvenega varstva**	◉	○	○	○	
G.09.	**Drugo:**	○	○	○	○	

Komentar

12.Pomen raziskovanja za sofinancerje[11]

	Sofinancer			
1.	Naziv	Ekosistemi d.o.o.		
	Naslov	Ulica XIV. divizije 14, 3000 Celje		
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:		10.797,14	EUR
	Odstotek od utemeljenih stroškov projekta:		3	%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.	Razvoj in raziskave na področju remediacije muljev iz vodnih teles, ki jih je možno aplicirati na področje stabilizacije/solidifikacije strupenih odpadkov.	F.01
		2.	Postopki nanoremediacije so aktualni za uporabo na področju imobilizacije težkih kovin v odpadkih in potencialno pretvorbo v gradbene proizvode.	F.05
		3.		
		4.		
		5.		
	Komentar		Kot sofinancer projekta "Sedimenti v vodnih okoljih: geokemična in mineraloška karakterizacija, remediacija ter njihova uporabnost kot sekundarna surovina", smo zainteresirani za rezultate remediacije sedimentov in njihovo uporabo v gradbeništvu, predvsem v smislu	

			možnega prenosa znanja, postopkov in tehnologij na področje ravnanja z drugimi odpadki, nenevarnimi in nevarnimi, kar je ena od dejavnosti našega podjetja.	
	Ocena		Ocenjujemo, da rezultati projekta kažejo na možnosti uporabe in prenosa raziskovalnih izsledkov v aktivnosti našega podjetja, predvsem v smislu zamenjave dosedanjih praks ravnanja z odpadki (deponiranje, prevoz do pooblaščenega predelovalca za visoke stroške, energetska) z bolj trajnostnimi in ekološko bolj sprejemljivimi rešitvami (materialna izraba).	
2.	Naziv		Ecologic d.o.o.	
	Naslov		Slovenčeva cesta 95, 1000 Ljubljana	
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:		10.797,14	EUR
	Odstotek od utemeljenih stroškov projekta:		3	%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.	Razvoj in raziskave na področju remediacije, ki so lahko izhodišče za modifikacijo postopkov pri ravnanju s komunalnimi odpadki.	F.01
		2.	Alternativne možnosti za ravnanje s komunalnimi odpadki s prenosom razvitih postopkov in tehnologij.	F.12
		3.		
		4.		
		5.		
	Komentar		Kot sofinancer projekta "Sedimenti v vodnih okoljih: geokemična in mineraloška karakterizacija, remediacija ter njihova uporabnost kot sekundarna surovina", smo zainteresirani za rezultate projekta, predvsem zaradi razvoja in validacije različnih alternativnih možnosti za ravnanje z odpadki in njihovo uporabo v gradbeništvu, ki se lahko smiselno uporabi tudi na področju ravnanja s komunalnimi odpadki, kar je sicer ena od dejavnosti našega podjetja.	
	Ocena		Ocenjujemo, da rezultati projekta kažejo na možnosti uporabe in prenosa raziskovalnih izsledkov v odpadkovno prakso našega podjetja, predvsem na področju, kjer je smiselna in upravičena materialna izraba odpadkov.	
3.	Naziv		Hidrotehnik Vodnogospodarsko podjetje d.d.	
	Naslov		Slovenčeva 97, 1000 Ljubljana	
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:		8.010	EUR
	Odstotek od utemeljenih stroškov projekta:		2	%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.	Izboljšanje obstoječega tehnološkega procesa oz. tehnologije	F.10
		2.	Prenos obstoječih tehnologij, znanj, metod in postopkov v prakso	F.17
		3.	Izboljšanje obstoječih organizacijskih in upravljavskih rešite	F.26
		4.		
		5.		
			Želja po zagotovitvi čim bolj optimalnega okolja za gospodarski in ekonomski razvoj, ki bi dolgoročno zagotavljal blaginjo prebivalstva je	

	Komentar	države Evrope privedel do potrebe po regulaciji in "podreditvi" narave in s tem tudi vodotokov (predvsem v smislu zmanjšanja ekstremov (poplave, suše) ter racionalnejše rabe naravnih virov. Upravljanje z vodami je v luči vse pogostejših ekstremnih dogodkov postalo ena izmed pomembnejših nalog Republike Slovenije. Spričo intenzivne rabe prostora in posledičnega nastanka vse večje gospodarske škode ob nastopu izjemnih hidrografskih dogodkov je problematika upravljanja s sedimenti vse pomembnejši aspekt upravljanja z vodami in zagotavljanja varnosti pred škodljivim delovanjem voda. Sedimenti vplivajo na okolje, kot življenjski prostor, tako na morfološke in hidrološke karakteristike, kot na kvaliteto vodnega in obvodnega prostora ter vseh dejavnosti vezanih na slednjega. Pri obravnavi problematike upravljanja s sedimenti se v luči urejanja vodotokov srečamo predvsem s tremi ključnimi aspekti pojava sedimentov – količino odloženega materiala, geomehanskimi lastnostmi (velikost osnovnih zrn, poroznost, odpornost na obrus ipd.) in kvaliteto sedimentov (predvsem kemično sestavo in obremenjenost). Vsi trije aspekti pogojujejo ponovno uporabo za namen omilitve posledic in zmanjšanje škode oziroma za vgradnjo materialov v druge varovalne objekte (npr. protipoplavne nasipe). Medtem, ko količina sedimentov vpliva na rečni režim v smislu zagotavljanja vodnega kontinuuma in stabilnih pogojev za razvoj poselitve ter različnih gospodarskih dejavnosti, pa predvsem kemijske lastnosti (prisotnost polutantov, težkih kovin), v manjši meri pa tudi količina odloženih sedimentov, narekujejo nujnost po odstranitvi ali ločitvi sedimentov od okolice, saj lahko pomenijo dodatno obremenitev okolja in posledično degradacijo vodnega prostora. Kot podjetje, katerega osnovna dejavnost je gradbeništvo in ki je v veliki meri povezano z urejanjem vodotokov in urbanega okolja ter varstvom okolja, stremimo k uporabi okolju čim bolj prijaznih tehnologij, ter ob enem trajnostni rabi prostora. Raziskave možnosti ponovne izrabe sedimentov iz različnih vodnih prostorov so tako pomemben delček v mozaiku pri implementaciji trajnostnega razvoja in nudijo nova znanja in vedenja o možnosti ponovne neškodljive uporabe sedimentov in materialov, ki so še v preteklosti veljali za neke vrste odpadni produkt, s tem pa tudi možnosti za razvoj okolju prijaznih tehnologij in načina gradnje, zmanjšanje obremenitev okolja in trajnostni izrabi naravnih surovin. Opravljene raziskave so tako prispevale nekatera izmed ključnih spoznanj o možnostih uporabe nekaterih sedimentov za namene izgradnje protipoplavnih ukrepov ter ob enem ponudile izhodišča za bolj inovativno izrabo naplavin, ki se v obliki sedimentov pojavljajo v vodotokih in vodnih telesih. Znanja nadalje sugerirajo nekonstruktivne oblike varovanja pred škodljivim delovanjem voda.
	Ocena	Upravljanje z vodami je ena izmed pomembnejših nalog Republike Slovenije, se zlasti v luči vse pogostejših ekstremnih dogodkov (predvsem poplav) ki smo jim priča v zadnjih letih. Projekt je bil ciljno usmerjen na problematiko upravljanja s sedimenti, ki je tesno povezana z eno izmed glavnih dejavnosti podjetja - torej urejanjem vodotokov in zagotavljanjem varnosti pred škodljivim delovanje voda. Rezultat in ugotovitve raziskovalnega projekta so prinesle potrditve nekaterih ugotovitev iz preteklosti, kot tudi nova spoznanja glede postopkov odvzema materialov ali tretiranja le-teh za ponovno vgradnjo, o možnosti ponovne uporabe in ne nazadnje smernice za ravnanje s sedimenti, ki se jim, spričo precejšnje erozijske ogroženosti Slovenskega ozemlja v veliki meri povezane prav z vodotoki, ne bo mogoče izogniti. Ugotovitve in znanja pridobljena v času izvedbe projekta so že v pomoč v praksi, saj bodisi potrjujejo ustreznost dosedanje organizacije dela

			(odvzem prodnatih materialov) in izvedbe del, bodisi nudijo nova spoznanja za izrabo sedimentov finejših frakcij ter s tem dajejo možnost za konkurenčnost za dokončno reorganizacijo podjetja ter prodor podjetja tudi na tista področja, kjer do sedaj le-to še ni nastopalo. Predvsem pa je projekt postregel z dragocenimi usmeritvami za trajnostno izrabo sedimentov, ki so nujno povezani s problematiko upravljanja in urejanja voda ter okolju bolj prijazne organizacije procesov. Ugotovitve pridobljene v sklopu projekta ob enem nudijo izhodišče za oceno možnosti in obsega uporabe sedimentov, saj so omogočile oceno se potrebnega vložka v logistično reorganizacijo dela podjetja za dejansko izrabo sedimentov in ponovno vgradnjo le-teh in nudijo podlago za sistemizacijo izrabe materialov, ki jih zakonodaja direktno ne obravnava in so v preteklosti veljali za gradbeni ali tehnološki odpadek.		
4.	Naziv		Luka Koper d.d.		
	Naslov		Vojkovo nabrežje 38, 6000 Koper		
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:			14.396,19	EUR
	Odstotek od utemeljenih stroškov projekta:			4	%
	Najpomembnejši rezultati raziskovanja za sofinancerja				Šifra
		1.	Na podlagi obsežnih in podrobnih laboratorijskih analiz je material celovito geomehansko, kemično in okoljsko karakteriziran.		A.04
		2.	Preverjene so bile različne možnosti stabilizacije, zgoščanja in vezanja v gradbene kompozite.		F.01
		3.			
		4.			
		5.			
	Komentar		Kot sofinancer projekta potrjujemo, da je delo na projektu potekalo skladno s programom. Zainteresirani smo za praktično uporabo rezultatov projekta. Dosedanji rezultati na odstranjenem sedimentu so zagotovile njegovo celovito karakterizacijo in definirale glavne probleme in ovire za aplikacijo kot surovina v gradbeništvu. Navedeno pomeni osnovo za izboljšanje tehnoloških postopkov pri manipulaciji s sedimentom in tudi za izbiro najbolj optimalnih rešitev glede na potrebe in možnosti podjetja, seveda ob upoštevanju tehničnih možnosti za aplikacijo v gradbeništvu.		
	Ocena		Velike količine sedimenta, ki ga je potrebno odstranjevati z morskega dna za zagotovitev funkcionalnosti plovnih poti, za podjetje trenutno in tudi dolgoročno predstavljajo velik problem. Zanje namreč ni ustreznega trajnega deponijskega prostora, poleg tega je ta material z geomehanskega stališča izjemno težaven, saj ga je težko osušiti in vgraditi. Rezultati, ki jih pričakujemo in se nakazujejo v okviru projekta, imajo zato za podjetje velik pomen, saj bodo (skupaj z morebitnimi smiselnimi tehnološkimi modifikacijami obstoječih postopkov ravnanja s sedimentom) predstavljali dolgoročno trajnostno rešitev za ta material.		
5.	Naziv		Vekton okoljski inženiring d.o.o.		
	Naslov		Kidričeva ulica 24a, 3000 Celje		
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:			10.797,14	EUR
	Odstotek od utemeljenih stroškov projekta:			3	%
	Najpomembnejši rezultati raziskovanja za sofinancerja				Šifra
			Rezultati raziskovalnega projekta do sedaj so naši		

		1.	družbi omogočili pridobitev novih dodatnih informacij in tehničnih ter praktičnih znanj, pomembnih za izvajanje dejavnosti družbe.	F.01
		2.	Dosedanji pridobljeni rezultati so pomembni tudi za načrtovanje razvoja novih izdelkov iz vodnih sedimentov za izvajanje predvsem zemeljskih del v gradbeništvu.	F.06
		3.		
		4.		
		5.		
	Komentar		Z raziskovalno organizacijo naše podjetje sodeluje predvsem na področju pridobitve realnih vzorcev sedimentov iz vodnih teles in proučevanja prostorske možnosti morebitne njihove ponovne uporabe v gradbeništvu.	
	Ocena		Pomen pridobljenih rezultatov projekta je za našo organizacijo zelo velik. Ker se naše podjetje profesionalno ukvarja s področjem predelave in ponovne koristne uporabe predelanih odpadkov (kar sedimenti iz vodnih okolij tudi so), bomo z novo pridobljenimi znanji lahko z razvojem novih izdelkov iz obdelanih vodnih sedimentov nudili zainteresiranim povzročiteljem oz. imetnikom tovrstnih odpadkov ustrezne rešitve. Hkrati bomo z novo pridobljenimi znanji lahko tudi bolj kvalitetno spodbujali čim večji obseg uporabe predelanih odpadkov (konkretno sedimentov iz vodnih teles), kar pa je ena od pomembnejših usmeritev tako Slovenije kot Evropske unije.	
6.	Naziv		PKG Šprinzer Mirko s.p.	
	Naslov		Ruška cesta 7, 2000 Maribor	
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:		7.198,10	EUR
	Odstotek od utemeljenih stroškov projekta:		2	%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.	Rezultati raziskovalnega projekta so za našo družbo pridobitev določenih novih tehničnih znanj ter informacij in veščin s področja možnosti uporabe sedimentov iz vodnih okolij kot sekundarne surovine.	F.01
		2.	Pridobljeni rezultati bodo zelo pomembni za načrtovanje nudenja novih storitev naše družbe na področju ravnanj z vodnimi sedimenti in po predelavi njihove uporabe predvsem v gradbeništvu.	F.11
		3.		
		4.		
		5.		
	Komentar		Z realizacijo projekta smo zadovoljni in z raziskovalno organizacijo aktivno sodelujemo. Naše aktivnosti so usmerjene predvsem v analiziranje izvedbe določenih posegov v prostor (v fazi odvzema sedimentov iz vodnih teles) s prostorskega in okoljskega področja (morebitno potrebno pridobivanje določenih dovoljenj in soglasij) ter organizacijske možnosti uporabe produktov predelava v gradbeništvu).	
			Pomen pridobljenih rezultatov projekta po njegovem zaključku je za našo organizacijo zelo velik. Ker se naše podjetje profesionalno ukvarja s	

	Ocena	področjem nudenja storitev predelave in ponovne koristne uporabe predelanih odpadkov (kar sedimenti iz vodnih okolij tudi so), bomo z novo pridobljenimi znanji iz zaključenega projekta lahko z razvojem nudenja novih storitev uporabe materialov iz obdelanih vodnih sedimentov nudili zainteresiranim povzročiteljem oz. imetnikom tovrstnih odpadkov še celovitejše ustrezne rešitve. Izvajanje omenjenih storitev ni več samo nivo poslovnega interesa morebitnih naročnikov, temveč tudi njihova obveznost po veljavni tako slovenski kot evropski regulativi. Povzeto, z rezultati projekta smo zadovoljni in upamo na še bodoča podobna sodelovanja.		
7.	Naziv	Salonit Anhovo		
	Naslov	Anhovo 1, 5210 Deskle		
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:		35.990,48	EUR
	Odstotek od utemeljenih stroškov projekta:		10	%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.	Določena oksidna sestava amorfne mineralne faze sedimenta Luke Koper in s tem posredno pucolanska lastnost ter možnost uporabe v sistemih s hidravličnimi vezivi.	F.02
		2.	Na glinenem sedimentu Luke Koper je bila preverjena možnost obdelavnosti in solidifikacije.	F.09
		3.	Izbira oziroma razvoj optimalnega veziva za solidifikacijo sedimenta Luke Koper po postopku hladne vezave z izkoriščanjem hidratacijskih in pucolanskih mehanizmov.	F.11
		4.		
		5.		
	Komentar	Podjetje Saloni Anhovo Gradbeni materiali d.d. je kot proizvajalec veziv v okviru dosedanjih rezultatov dobilo informacijo o sedimentu iz Luke Koper in njegove karakteristike ter s tem tudi podlago za modifikacijo in razvoj primernih veziv za izdelavo vezanih kompozitov, ki so aktualni zlasti v primerih, ko so sedimenti onesnaženi, predvsem za aplikacije, kjer so zahtevani materiali z nizko trdnostjo. To so zlasti različni zasipi in dinamično neobremenjeni nasipi v cestogradnji. Pričakovati je tudi, da bodo aplikacije in postopki, ki se razvijajo v projektu za sedimente iz vodnih teles, lahko uporabljeni tudi za podobne materiale, pridobljene iz industrijskih/rudarskih odpadkov.		
	Ocena	Ocenjujemo, da dosedanji rezultati kažejo na možnosti uporabe in prenosa raziskovalnih izsledkov v tehnološko prakso našega podjetja, predvsem v smislu izdelave mešanic hidravličnih veziv, ki bi bila primerna za stabilizacijo/solidifikacijo onesnaženih sedimentov in posredno tudi drugih nenevarnih in nevarnih sipkih industrijskih/rudarskih odpadkov.		

13.Izjemni dosežek v letu 2014[12]

13.1. Izjemni znanstveni dosežek

13.2. Izjemni družbeno-ekonomski dosežek

Prijava mednarodnega patenta.

Postopek izdelave za človeško okolje in zdravje sprejemljivega gradbenega materiala iz kontaminirane zemljine, vsebujoče vodotopne spojine težkih kovin.

Izum spada na področje remediacije kontaminirane zemljine, s pomočjo katerih se zemljino z vsebnostjo nevarnih sestavin s pomočjo kemičnih reakcij pretvori v manj nevarno stanje. Pri tem je izum osnovan na problemu, kako iz zemljine s prekomerno vsebnostjo za okolje nesprejemljivih in/ali zdravju škodljivih vodotopnih spojin težkih kovin, še zlasti tistih na osnovi arzena As in/ali kadmija Cd in/ali svinca Pb in/ali cinka Zn, na ekonomičen način pridobiti za okolje in človeško zdravje sprejemljiv, kemijsko nevtralen in inerten gradbeni material, pri katerem vsebnost omenjenih kontaminantov ne bo presegala vnaprej določenih mejnih vrednosti.

C. IZJAVE

Podpisani izjavljam/o, da:

- so vsi podatki, ki jih navajamo v poročilu, resnični in točni
- se strinjamo z obdelavo podatkov v skladu z zakonodajo o varstvu osebnih podatkov za potrebe ocenjevanja ter obdelavo teh podatkov za evidence ARRS
- so vsi podatki v obrazcu v elektronski obliki identični podatkom v obrazcu v pisni obliki
- so z vsebino zaključnega poročila seznanjeni in se strinjajo vsi soizvajalci projekta

Podpisi:

zastopnik oz. pooblaščena oseba raziskovalne organizacije:	in	*vodja raziskovalnega projekta:*
Zavod za gradbeništvo Slovenije		Ana Mladenovič

ŽIG

Kraj in datum:	Ljubljana	16.3.2015

Oznaka poročila: ARRS-RPROJ-ZP-2015/185

[1] Napišite povzetek raziskovalnega projekta (največ 3.000 znakov v slovenskem in angleškem jeziku) Nazaj

[2] Napišite kratko vsebinsko poročilo, kjer boste predstavili raziskovalno hipotezo in opis raziskovanja. Navedite ključne ugotovitve, znanstvena spoznanja, rezultate in učinke raziskovalnega projekta in njihovo uporabo ter sodelovanje s tujimi partnerji. Največ 12.000 znakov vključno s presledki (približno dve strani, velikost pisave 11). Nazaj

[3] Realizacija raziskovalne hipoteze. Največ 3.000 znakov vključno s presledki (približno pol strani, velikost pisave 11) Nazaj

[4] V primeru bistvenih odstopanj in sprememb od predvidenega programa raziskovalnega projekta, kot je bil zapisan v predlogu raziskovalnega projekta oziroma v primeru sprememb, povečanja ali zmanjšanja sestave projektne skupine v zadnjem letu izvajanja projekta, napišite obrazložitev. V primeru, da sprememb ni bilo, to navedite. Največ 6.000 znakov vključno s presledki (približno ena stran, velikost pisave 11). Nazaj

[5] Navedite znanstvene dosežke, ki so nastali v okviru tega projekta. Raziskovalni dosežek iz obdobja izvajanja projekta (do oddaje zaključnega poročila) vpišete tako, da izpolnite COBISS kodo dosežka – sistem nato sam izpolni naslov objave, naziv, IF in srednjo vrednost revije, naziv FOS področja ter podatek, ali je dosežek uvrščen v A'' ali A'. Nazaj

[6] Navedite družbeno-ekonomske dosežke, ki so nastali v okviru tega projekta. Družbeno-ekonomski rezultat iz obdobja izvajanja projekta (do oddaje zaključnega poročila) vpišete tako, da izpolnite COBISS kodo dosežka – sistem nato sam izpolni naslov objave, naziv, IF in srednjo vrednost revije, naziv FOS področja ter podatek, ali je dosežek uvrščen v A'' ali A'.

Družbeno-ekonomski dosežek je po svoji strukturi drugačen kot znanstveni dosežek. Povzetek znanstvenega dosežka je praviloma povzetek bibliografske enote (članka, knjige), v kateri je dosežek objavljen.

Povzetek družbeno-ekonomskega dosežka praviloma ni povzetek bibliografske enote, ki ta dosežek dokumentira, ker je dosežek sklop več rezultatov raziskovanja, ki je lahko dokumentiran v različnih bibliografskih enotah. COBISS ID zato ni enoznačen, izjemoma pa ga lahko tudi ni (npr. prehod mlajših sodelavcev v gospodarstvo na pomembnih raziskovalnih nalogah, ali ustanovitev podjetja kot rezultat projekta … - v obeh primerih ni COBISS ID). Nazaj

[7] Navedite rezultate raziskovalnega projekta iz obdobja izvajanja projekta (do oddaje zaključnega poročila) v primeru, da katerega od rezultatov ni mogoče navesti v točkah 6 in 7 (npr. ni voden v sistemu COBISS). Največ 2.000 znakov, vključno s presledki. Nazaj

[8] Pomen raziskovalnih rezultatov za razvoj znanosti in za razvoj Slovenije bo objavljen na spletni strani: http://sicris.izum.si/ za posamezen projekt, ki je predmet poročanja Nazaj

[9] Največ 4.000 znakov, vključno s presledki Nazaj

[10] Največ 4.000 znakov, vključno s presledki Nazaj

[11] Rubrike izpolnite / prepišite skladno z obrazcem "izjava sofinancerja" http://www.arrs.gov.si/sl/progproj/rproj/gradivo/, ki ga mora izpolniti sofinancer. Podpisan obrazec "Izjava sofinancerja" pridobi in hrani nosilna raziskovalna organizacija – izvajalka projekta. Nazaj

[12] Navedite en izjemni znanstveni dosežek in/ali en izjemni družbeno-ekonomski dosežek raziskovalnega projekta v letu 2014 (največ 1000 znakov, vključno s presledki). Za dosežek pripravite diapozitiv, ki vsebuje sliko ali drugo slikovno gradivo v zvezi z izjemnim dosežkom (velikost pisave najmanj 16, približno pol strani) in opis izjemnega dosežka (velikost pisave 12, približno pol strani). Diapozitiv/-a priložite kot priponko/-i k temu poročilu. Vzorec diapozitiva je objavljen na spletni strani ARRS http://www.arrs.gov.si/sl/gradivo/, predstavitve dosežkov za pretekla leta pa so objavljena na spletni strani http://www.arrs.gov.si/sl/analize/dosez/. Nazaj

Obrazec: ARRS-RPROJ-ZP/2015 v1.00a
35-1A-0E-86-33-1C-F2-16-CF-BE-12-30-63-D8-9A-74-DA-7D-2E-CB

Priloga 1

Journal of Soils and Sediments

Environmental characterisation of dredged sediments in relation to their potential use in civil engineering

--Manuscript Draft--

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Corresponding Author:	Tea Zuliani, Ph.D. SLOVENIA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	
Corresponding Author's Secondary Institution:	
First Author:	Tea Zuliani, Ph.D.
First Author Secondary Information:	
Order of Authors:	Tea Zuliani, Ph.D.
	Ana Mladenovič, Ph.D.
	Janez Ščančar, Ph.D.
	Radmila Milačič, Ph.D.
Order of Authors Secondary Information:	
Abstract:	Purpose: During capital and/or maintenance dredging operations large amounts of material are produced. Instead of their discard, dredged sediments may be a valuable natural resource if not contaminated. One of the possible areas of application is civil engineering. In the present work the environmental status of seaport dredged sediment was evaluated in order to investigate its potential applicability as a secondary raw material. Materials and methods: Element concentrations in digested samples, aqueous extracts and fractions from sequential extraction were determined by inductively coupled plasma mass spectrometry (ICP-MS). The partitioning of elements in the sediments was studied by the use of sequential extraction procedures, and their elemental impact also evaluated by calculation of enrichment factors. Results and discussion: The total element concentrations determined showed moderate contamination of the dredged sediments with As, Ba, Ni, Zn, Mo, Se, Pb, Sb, Ag, Co, Fe and Mn as a result of industrial and port activities, as indicated by their high enrichment factors. Elemental concentrations in the aqueous extract were very low, and therefore do not represent any hazard for the environment. The water soluble element concentrations were also under the threshold levels set by the EU Directive on the landfill of waste on the basis of which the applicability of dredged sediments in civil engineering is evaluated. Conclusions: The investigated sediments can be recycled and used as embankments in engineering applications only within the port area because of their high water soluble content of chloride and sulphate. Their application outside the port area would be possible if additional treatment to immobilise anions were to be applied.
Suggested Reviewers:	Philippe Baveye, Ph.D. Rensselaer Polytechnic Institte

	baveyp@rpi.edu Prof. Baveye is a renowned professor from the field of soil sciences. He is investigating the fate of pollutants in the terrestrial environment and ecosystem modelling. He is adequate reviewer of the present manuscript.
	Ondřej Drábek, Ph.D. Czech University of Agriculture in Prague drabek@af.czu.cz Dr. Drábek is a senior researcher from the field of soil sciences. He investigates the fate of pollutants in the terrestrial/aquatic environments by the use of component analysis as a tool to indicate the origin of potentially toxic elements in soils and sediments. He is adequate reviewer of the present manuscript.
Opposed Reviewers:	

SEDIMENTS, SEC 1 • SEDIMENT QUALITY AND IMPACT ASSESSMENT • RESEARCH ARTICLE

Environmental characterisation of dredged sediments in relation to their potential use in civil engineering

Tea Zuliani*[a], Ana Mladenovič[c], Janez Ščančar[a,b] and Radmila Milačič[a,b]

[a] Department of Environmental Sciences, Jožef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

[b] Jožef Stefan International Postgraduate School, Jamova 39, 1000 Ljubljana, Slovenia

[c] Slovenian National Building and Civil Engineering Institute, Dimičeva 12,1000 Ljubljana, Slovenia

***Corresponding author:**
Tea Zuliani
Tel: + 386 1 477 3542
Fax: + 386 1 477 3235
e-mail: tea.zuliani@ijs.si

Abstract

Purpose: During capital and/or maintenance dredging operations large amounts of material are produced. Instead of their discard, dredged sediments may be a valuable natural resource if not contaminated. One of the possible areas of application is civil engineering. In the present work the environmental status of seaport dredged sediment was evaluated in order to investigate its potential applicability as a secondary raw material.

Materials and methods: Element concentrations in digested samples, aqueous extracts and fractions from sequential extraction were determined by inductively coupled plasma mass spectrometry (ICP-MS). The partitioning of elements in the sediments was studied by the use of sequential extraction procedures, and their elemental impact also evaluated by calculation of enrichment factors.

Results and discussion: The total element concentrations determined showed moderate contamination of the dredged sediments with As, Ba, Ni, Zn, Mo, Se, Pb, Sb, Ag, Co, Fe and Mn as a result of industrial and port activities, as indicated by their high enrichment factors. Elemental concentrations in the aqueous extract were very low, and therefore do not represent any hazard for the environment. The water soluble element concentrations were also under the threshold levels set by the EU Directive on the landfill of waste on the basis of which the applicability of dredged sediments in civil engineering is evaluated.

Conclusions: The investigated sediments can be recycled and used as embankments in engineering applications only within the port area because of their high water soluble content of chloride and sulphate. Their application outside the port area would be possible if additional treatment to immobilise anions were to be applied.

Keywords Dredged marine sediment • Environmental assessment • Leaching test • Pollutants • Sequential extraction

1 Introduction

With increasing size, ships need improved navigation channels to enter and leave ports and harbours safely. Periodic maintenance dredging of sediments, as well as occasional enlarging and deepening of navigation channels, is therefore essential to keep maritime traffic operating efficiently. Depending on the quantity and quality (sediment composition, degree of contamination) of the dredged material different options are available for its subsequent handling and management, such as beneficial reuse (beach replenishment, land reclamation, construction), disposal on land in licensed landfill sites or disposal at sea.

Dredging and management of contaminated sediments are covered by a certain number of international conventions which set up a specific framework used as a basis for European Union (EU) and national strategies. The most important international conventions that define the regulatory framework for dredging are the London Convention (1972), the Protocol to the London Convention (IMO 1996, 2007, 2009), the Convention for the protection of the Mediterranean Sea against Pollution - Barcelona Convention (UNEP-MAP 1995a), the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR 1992) and the Convention on the Protection of the Marine Environment of the Baltic Sea Area - Helsinki Convention (HELCOM 1992). European legislation does not deal specifically with dredged materials. In the former Waste Framework Directive (WFD) (Council Directive 75/442/EC) dredged material was classified as waste, but this was changed in the new WFD (Council Directive 2008/98/EC). In the latter WFD non-hazardous dredged material is excluded from the Directive's scope. However, in the WFD the parameters for the hazardousness of dredged material are not defined. To our knowledge, there are no specific EU documents that define the handling of dredged material. In Slovenia, as in some other EU countries, the parameter on which the applicability of dredged material in civil engineering is evaluated is the content of As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Zn, chlorides, fluorides and sulphates in the water extract obtained after 24 h of shaking the solid material with water (SIST EN 1744-3). The chemical parameters must be under the threshold levels for inert waste as defined by the Slovenian Decree on landfill of waste (OJRS 61/2011) that is derived from the EU Directive on the landfill of waste (Council Directive 1999/31/EC).

Dumping dredged marine sediment at sea was the most common practice for its removal (DelValls et al. 2004). Recently, several treatment methods such as thermal treatment, bio-remediation, stabilisation by hydraulic binders, washing (Agostini et al. 2007), and beneficial reuse (e.g. manufacture of aggregates for construction, reuse as fine aggregates for road construction) of dredged marine sediments were investigated (Dang et al. 2013; Kamali et al. 2008; Limeira et al. 2010). The use of dredged marine sediments is possible when such material possesses technical characteristics appropriate for its specific utilization and is environmentally acceptable. The main obstacles to the use of dredged marine sediments as secondary raw material are their potential contamination and salinity.

Inorganic contaminants such as As, Zn, Cd, Pb and Ni are generally associated with the sulphide mineral phase (Lions et al. 2010). When dredged sediments are exposed to air progressive oxidation of this phase and subsequent solubilisation of the associated contaminants takes place. The elements released may either precipitate as a secondary phase, remain in solution or be retained by hydroxides, clay and organic matter (Du Laing et al. 2009). The redistributed contaminants are potentially more mobile than the original reduced sulphide forms (Hartley and Dickinson, 2010). Chlorides as contaminants are highly water soluble and tend to rapid and progressive leaching (Achard et al. 2013). Moreover, changes in salinity also play a major role in metal distribution, especially when washing is applied as a remediation technique or when dredged sediments are disposed to landfill. Generally, trace metals tend to be more mobile at lower salinity. An exception is Cd, since its mobility increases with salinity (Guevara-Riba et al. 2005). Besides metals, organotin compounds

(OTCs), especially tributyltin (TBT), may be present in the marine environment as a consequence of their leaching from antifouling paints that were applied to ships' hulls. TBT is by far the most toxic of the OTCs to aquatic organisms. It may causes imposex and shell malformations (Hoch, 2001). Because of its high toxicity, TBT was included on the list of priority pollutants in the field of water policy in the EU Water Framework Directive-integrated river basin management for Europe (Council Directive 2008/105/EC).

Sediment quality guidelines (SQGs) were developed for assessment of the degree of sediment contamination. There have been numerous SQGs set during the past 30 years to assist regulators in dealing with contaminated dredged sediments (Allen Burton 2002). The Canadian SQG Interim Sediment Quality Guideline (ISQG) (Environment Canada 2002) corresponds to the threshold levels below which adverse biological effects are not expected and Probable Effects Levels (PEL) that characterize concentrations of pollutants that may affect aquatic life are established. The Australian SQG (McCready et al. 2006) sets ISQG-low and ISQG-high that correspond to the lower 10th percentile and 50th percentile, respectively, of the chemical concentrations associated with adverse biological effects. The two guidelines classify concentrations of sediment-associated contaminants into three ranges, where adverse effects are expected rarely (<ISQG-low), occasionally (≥ISQG-low and <ISQG-high), and frequently (≥ISQG-high) (McCready et al. 2006). Most European countries that are contracting parties to the OSPAR Convention use action level (AL), threshold concentrations of contaminants that define different classes of dredged material. The criteria for establishing the ALs are not common to the OSPAR contracting parties. Each country establishes its own criteria. Most countries use a lower AL (AL1) and an upper AL (AL2) in order to define three categories of dredged sediments. Contaminant concentrations under the AL1 represent those of little concern. Those between AL1 and AL2 may trigger further investigation of the material proposed for dumping. Dredged sediments with concentrations of contaminants

above AL2 are generally not allowed to be dumped into the sea (OSPAR 2004). Recently, The European Council (EC) has provided technical guidance for the derivation of SQGs as part of a common implementation strategy for the Water Framework Directive (WFD) (EC Technical Report 055, 2011).

The Port of Koper (Slovenia, SW Europe) (Fig. 1) is one of the biggest and the most important ports in the Northern Adriatic Sea and it is primarily transit-oriented. It is a multi-purpose port with two piers and 26 berths and 12 specialized terminals. One of its main problems is related to the constant accumulation of marine sediments inside different parts of the port, which result in disturbances in some of the Port's crucial operational properties. A total of 80.000 m^3 of sediment have to be removed annually. This sediment is a mixture of clay and silt and represents a waste for which there is insufficient disposal space along the limited Slovenian coast. Therefore, new solutions for this material that are in accordance with national environmental and technical legislation must be found. The aim of the present paper was to focus on the chemical characterization of dredged sediments from the three basins in the Port of Koper. The level of sediment contamination was evaluated on the basis of the total concentrations of the elements listed in the Decree on the landfill of waste (OJRS 61/2011) and tributyltin (TBT). Since the data on total element concentrations is not an adequate indicator of element toxicity and bioavailability, the partitioning of elements in the sediment was studied by the use of sequential extraction procedures. The environmental impact was additionally evaluated by calculation of the enrichment factors and by comparison of the element concentration data with the relevant sediment quality guidelines. On the basis of the outcome of the present study, the use of dredged sediments in civil engineering will be further considered from the environmental point of view. To help distinguish between the natural and the anthropogenic origin of an element in the sediment, it is recommended to normalize the total metal concentrations obtained to the regional background values.

2 Materials and methods

2.1 Instrumentation

A CEM Corporation (Matthews, NC, USA) CEM MARS 5 Microwave Acceleration Reaction System was used for digestion of the sediments. Element concentrations in digested samples, aqueous extracts and fractions from sequential extraction were determined by inductively coupled plasma mass spectrometry (ICP-MS) on an Agilent (Tokyo, Japan) 7700x ICP-MS at optimal measurement conditions (Table 1).

OTCs determination was carried out on an Agilent 6890 gas chromatograph (Agilent Technologies, Santa Clara, CA, USA) equipped with an Agilent 6890 Series Autosampler Injector. A GC was coupled to an Agilent 7700x ICP-MS via a heated transfer line and fitted with a 15 m x 0.25 mm DB-5MS capillary column (film thickness 0.25 µm) coated with 5 % phenylmethylpolysiloxane (Agilent J&W Scientific, Palo Alto, CA, USA). Control and operation of the coupled system was performed using Agilent MassHunter software.

For the separation of OTCs the following GC temperature programme was applied: for the first 0.5 minutes the column temperature was held at 80 °C, then raised to 200 °C at a heating rate of 25 °C min^{-1} and held there for 0.5 min, then raised to 220 °C at a heating rate of 40 °C min^{-1} and, in a final step, raised to 280 °C at a heating rate of 40 °C min^{-1} and held at this temperature for 3 minutes. The operating parameters of the GC and ICP-MS are presented in Table 1.

Anions were determined using a Hach DR/2010 spectrophotometer (Hach Company, Loveland CO, USA). A Mettler AE 163 (Zürich, Switzerland) analytical balance was used for all weighing. Samples were centrifuged in a Hettich Universal 320 Centrifuge (Hettich GmbH & Co. KG, Tuttlingen, Germany).

2.2 Reagents and materials

Ultrapure 18.2 MΩ cm water obtained from a Direct-Q 5 Ultrapure water system (Millipore Watertown, MA, USA) was used. Suprapur nitric acid, hydrofluoric acid, hydrochloric acid and sodium chloride were purchased from Merck (Darmstadt, Germany). A Stock ICP Multi Element Standard Solution IV CertiPUR containing 1000 mg L^{-1} ± 10 mg L^{-1} in 1 mol L^{-1} HNO_3 of different elements was obtained from Merck. The standards for quantification, of monobutyltintrichloride ($MBTCl_3$, 95%) and tributyltinchloride (TBTCl, 96%) were purchased from Aldrich (Milwaukee, WI, USA). Dibutyltindichloride ($DBTCl_2$, 98%) and tripropyltin chloride (TPrTCl, 98%) were obtained from Merck. OTCs standard stock solutions containing 1000 mg L^{-1} (expressed as Sn) were prepared in methanol and stored in the dark at 4 °C. Working OTCs standard solutions were prepared daily.

Acetic acid, nitric acid, isooctane, methanol and sodium acetate were obtained from Merck (Darmstadt, Germany). Sodium tetraethyl borate ($NaBEt_4$, 98%) was obtained from Strem Chemicals (Newburyport, MA, USA). The aqueous solution of $NaBEt_4$ (2% (w/v)) was prepared just before derivatization.

For checking accuracy SPS-SW1 Quality Control Material for Surface Water Analysis from SPS Spectrapure Standards AS (Oslo, Norway), the certified reference material CRM 320R Trace Elements in River Sediment from the Community Bureau of Reference (Geel, Belgium) and the Marine Sediment certified reference material PACS-2 for butyltins from the National Research Council Canada (Ontario, Canada) were used.

Sartorius (Goetingen, Germany) 0.45 μm cellulose nitrate membrane filters of 25 mm diameter were used in the filtration procedure.

2.3 Sampling and sample preparation

After hydraulic dredging by sucking a mixture of mud and water from the sea bottom, the material was transferred to three temporary lagoons, designated as lagoons B1, B2, and B3, which are located inside the port area, and where a sedimentation process starts. Due to the low permeability of the sediment and the fact that the desiccation and consolidation processes inside the lagoons are very slow, this dredged mud retains its plastic consistency for several months. Sampling of mud was carried out in each lagoon separately. Ten sub-samples were taken from the mud in each lagoon with the help of a corer, and then blended together and homogenised into batch samples typically of approximately 30 kg each. After transfer to the laboratory, the samples were dried at 40 °C to constant mass, and then further subdivided for chemical analysis. Additionally, a sediment sample was taken in an unaffected area (reference point) of the Slovenian part of the NE Adriatic Sea. This sampling point was in the area of the marine nature reserve in the Bay of Strunjan.

2.4 Determination of total element concentrations

Approximately 0.25 g of dry sediment sample was weighed into a Teflon tube and subjected to microwave-assisted digestion using a mixture of nitric, hydrofluoric and hydrochloric acid, as described by Ščančar et al. (2007). Elements in digested samples were determined by ICP-MS under optimal measurement conditions.

2.5 Sequential extraction procedure

A modified sequential extraction procedure originally developed by Tessier et al. (1979) was applied. To Tessier's original partitioning scheme a pre-step of extraction with water was added in order to assess the extent of leaching of elements into the most mobile sediment fraction. A detailed description of the sequential extraction procedure applied was given by Milačič et al. (2012). Briefly, the procedure consisted of six steps. In step I (F1) 2 g of sample was shaken with 20 mL of water. The information obtained in step I also enabled comparison of the data on leaching of elements and anions with the legislative requirements set by the Decree on the landfill of waste (OJRS 61/2011). In step II (F2) the extraction reagent was $MgCl_2$. The element contents extracted in these two extraction steps represent the exchangeable forms present in the sediment. In step III (F3) $NaCH_3COO$ was used as extractant in order to release elements that are bound to carbonates. In step IV (F4) the extraction of elements bound to iron and manganese oxides was performed by extraction with NH_2OH x HCl and CH_3COOH. In step V (F5) elements bound to organic matter were extracted by a mixture of HNO_3 and H_2O_2. In step VI (F6) the elements present in the residue were determined after microwave-assisted acid digestion.

2.6 Determination of organotin compounds

0.5 g of air-dried sediment sample was extracted with 20 mL of glacial acetic acid by mechanical stirring for 16 h. The suspension was centrifuged for 15 min. The supernatant was then added to 20 mL of 1 M sodium acetate-acetic acid buffer (pH 5) and ethylated with 1 mL of 2 % (w/w) $NaBEt_4$ solution. The ethylated OTCs were extracted into 1 mL of isooctane and their concentrations determined by GC-ICP-MS.

3 Results and discussion

3.1 Quality control of analytical data

To check the accuracy of the total element concentration determination by ICP-MS in extracts from the sequential extraction procedure, SPS-SW1 (Quality Control Material for Surface Water Analysis) was analysed. The accuracy of total element determination in sediments was checked by the analysis of the certified reference material CRM 320R (Trace Elements in River Sediment), while for MBT, DBT and TBT determination the certified reference material PACS 2 (Marine Sediments) was analysed. The results presented in Tables 2 and 3 indicate good agreement between the determined and certified values, confirming the accuracy of the applied analytical procedures.

3.2 Total concentrations and partitioning of elements in dredged sediments

Knowledge of the total elemental concentrations present in a sediment is not sufficient for the estimation of its potential hazard to the environment. In addition to the total concentrations, the most significant information is how the elements are distributed between the different compartments of the sediment matrix, since only a fraction of the total amount of elements present may be regarded as bioavailable, labile, mobile and therefore potentially toxic. The partitioning of the elements in the sediment samples from the three basins was investigated by applying a modified Tessier's sequential extraction procedure (Tessier et al. 1979).

Total element concentrations in the sediments B1, B2 and B3 from the Port of Koper, together with those of the reference point (Bay of Strunjan, BS), are presented in Table 4. Fig. 2 displays the results of the partitioning study of As, Cd, Cr, Cu, Mo, Ni, Pb, Sb, Se, and Zn in the sediments B1, B2 and B3.

To check the accuracy of the sequential extraction, the concentrations of an element in each extraction step were summed and compared with the total element concentration (Table 4). Since the mass balance agreed within ± 5%, these data confirmed the precision of the analytical work.

Total concentrations of As found in the dredged sediments from the Port of Koper, B1, B2 and B3, were found to be 14.6, 32.5 and 37.6 mg kg^{-1}, respectively. Except for the As content of the sediment from B1, the As concentrations are higher than that in BS (17.5 mg kg^{-1}) and in the Gulf of Trieste (from 6.4 to 18.2 mg kg^{-1}) (Aquavita et al. 2010). Lower As concentrations were found in superficial sediments of the Central Adriatic, which ranged from 2 to 8 mg kg^{-1} (Žvab Rožič et al. 2012). The higher As concentrations are probably linked to the influence of industrial/port activities. From the results of the partitioning study for As (Fig. 2) is evident that its concentration in the water-soluble fraction was very low (between 0.025 and 0.042 mg kg^{-1}) and that most As was associated with the insoluble residual fraction.

Total Ba concentrations determined in the sediments B1, B2 and B3 ranged from 339 to 398 mg kg^{-1}, while its concentrations in sediments from the NE Adriatic Sea were found to range between 116 to 190 mg kg^{-1} as determined by Dolenec et al. (Dolenec et al. 1998). In the Central Adriatic Sea an average of 30 mg kg^{-1} was found (Žvab Rožič et al. 2012). These high Ba concentrations in the dredged sediments are most probably related to industrial and port activities.

Total Cd concentrations in dredged sediments B1, B2 and B3 were found to be around 0.35 mg kg^{-1}, while its concentrations in BS, in the Bay of Koper and in the Central and NE Adriatic Sea were between 0.1 and 0.2 mg kg^{-1} (Faganeli et al. 1991; Ščančar et al. 2007; Žvab Rožič et al. 2012). The partitioning study on Cd (Fig. 2) showed that most of it was present in the insoluble residual fraction (60 %). The partitioning of Cd between carbonates and iron and manganese oxides was similar (around 15 %). About 3 % of Cd was determined to be exchangeable and bound to organic matter, while the water soluble fraction contained only 0.1 %.

Total Cr concentrations in B1, B2 and B3 were higher (208 – 354 mg kg^{-1}) than the values found in sediments from BS (135 mg kg^{-1}). Lower Cr concentrations were also found in other coastal areas of the Slovenian part of the NE Adriatic Sea (120 – 150 mg kg^{-1}) (Ščančar et. al, 2007) and in the Gulf of Trieste (35 – 170 mg kg^{-1}) (Acquavita et al. 2012). Although in the coastal area some marinas and a dockyard are situated, the Cr present in the sediments probably originates mostly from the heavy mineral fraction that in turn is derived from the presence of chromite and chromium bearing spinels in flysch (Lenaz et al. 1996). From the partitioning study (Fig. 2) it was found that almost all Cr is present in the insoluble residual fraction.

The total Cu concentrations in the dredged sediments B1, B2 and B3 were around 40 mg kg^{-1} which is slightly higher than those usually found in the sediments of the NE Adriatic Sea (25 – 35 mg kg^{-1}) (Faganeli et al. 1991; Ščančar et al. 2007), except for sediment from the Portorož Marina (87 mg kg^{-1}) (Ščančar et al. 2007). The results of the partitioning study (Fig. 2) showed that Cu is bound to carbonates (1 – 4.5 %), iron and manganese oxides (2 – 5 %) and organic matter (8 – 16 %). But the highest fraction of Cu was found in the insoluble residual fraction (76 – 84 %).

In B1, B2 and B3 dredged sediments from the Port of Koper, the total Hg concentration ranged from 0.27 to 0.36 mg kg^{-1}. The estimated natural background levels of Hg range between 0.04 mg kg^{-1} (Ogorelec et al. 1981) and 0.10 mg kg^{-1} (Faganeli et al. 1991) for the southern part and 0.17 mg kg^{-1} for the western part (Covalli et al. 2006) of the Gulf of Trieste. The highest concentrations were found at the mouth of the River Soča (Isonzo) due to mining activities upstream in Idrija, Slovenia (Covelli et al. 2006). With distance from the source, the concentration of Hg decreases. In the vicinity of the Port of Trieste the concentration of Hg was 2.86 mg kg^{-1}, presumably due to a source in the port (Aquavita et al. 2010). Similarly, the slightly higher Hg concentrations in B1, B2 and B3 than in BS (0.10 mg kg^{-1}) may be caused by activities in the Port of Koper. In the water soluble fraction the Hg concentrations were below the limit of detection.

Total concentrations of Ni and Zn in the dredged sediments B1, B2 and B3 were in a similar range (120 – 190 mg kg^{-1}), while in BS total Ni and Zn concentrations were 70 and 90 mg kg^{-1}, respectively. Levels of Zn in the Bay of Koper ranged from 53 to about 100 mg kg^{-1}, while in the Gulf of Trieste the Zn content was similar to the dredged sediments (90 to 150 mg kg^{-1}) (Faganeli et al. 1991). The lowest Zn concentrations were found in the Bays of Mesečev Zaliv and of Sečovlje, 56 and 35 mg kg^{-1}, respectively (Faganeli et al. 1991; Ščančar et al. 2007). For Ni few data exist. The lowest concentration found in the NE Adriatic Sea was in the Bay of Mesečev Zaliv (37 mg kg^{-1}) (Ščančar et al. 2007), while in the Bay of Koper it was around 70 mg kg^{-1} (unpublished data). The elevated concentrations may be related to the presence of anthropogenic sources such as city runoff and port activities. Zn and Ni also exhibited a similar pattern of partitioning (Fig. 2). They were bound to the same extent to carbonates and organic matter (about 3 %) and to iron and manganese oxides (9 % Zn and 5 % Ni). The majority of Zn and Ni were found in the residual insoluble fraction (> 80 %).

Total Mo concentrations found in the dredged sediments B1, B2 and B3 were in the range from 2.2 to 4.2 mg kg^{-1}, while Se concentrations ranged from 12.7 to 16.5 mg kg^{-1}. The Mo value at the reference point BS was 0.86, while in other Slovenian coastal areas it ranged between 0.68 and 0.87 mg kg^{-1} (unpublished data), whereas Se was found to be rather constantly around 2 mg kg^{-1}. Higher Mo and Se levels in the basin sediments are most probably related to port activities. The results of the partitioning study (Fig. 2) showed that Mo is distributed between almost all the fractions. The lowest amount (3 %) was found to be bound to iron and manganese oxides, followed by the water soluble fraction (between 5 – 15 %). Similar fractions of Mo were found in the exchangeable part and bound to organic matter. The remaining (65 – 72 %) Mo was found in the insoluble residual fraction. Se was mostly present in the insoluble residual fraction (90 %), the rest being equally distributed between carbonates and iron and manganese oxides.

The total Pb concentrations in B1, B2 and B3 ranged from 25 to 36 mg kg^{-1}, while in BS it was 25 mg kg^{-1}. In the Bay of Koper its concentration was about 25 mg kg^{-1}, while in the remote areas of the Bay of Mesečev Zaliv and Piran, the concentrations of Pb were not higher than 9 mg kg^{-1} (Ščančar et al. 2007). Similar concentrations were reported for the SE part of the Gulf of Trieste (10 mg kg^{-1}) (Faganeli et al. 1991), while in the inner part of the Gulf the total Pb (Aquavita et al. 2010) concentrations were similar to those of B1, B2 and B3, whereas in the Gulf of Muggia the concentrations were 10 times higher (between 160 and 490 mg kg^{-1}) (Solis-Weiss et al. 2004). Results from the sequential partitioning experiments (Fig. 2) showed that most of the Pb was present in the insoluble residual fraction (65 %). About 10 % of Pb was associated with carbonates and 20 % with iron and manganese oxides.

The concentration of Sb in the basins sediments was three times higher (average 1.75 ± 0.25 mg kg^{-1}) than the concentration at the reference point BS (0.6 mg kg^{-1}), showing an anthropogenic source in the port area. Most of the Sb in the sediments was present in the insoluble residual fraction (Fig. 2), while in the water soluble fraction only approximately 1 % of Sb was found.

Ag, Co, Fe and Mn concentrations were all significantly higher in the dredged sediments B1, B2 and B3 than in the sediment from BS and in sediments from the Slovenian coastal area (average concentrations of Ag, Co, Fe and Mn of 0.20 ± 0.06, 9 ± 3, 1000 ± 200 and 350 ± 90 mg kg^{-1}, respectively). The higher concentrations are the consequence of the city runoff and port activities. Ag and Co were present mostly (90 – 98 %) in the insoluble residual fraction (data not shown). Mn was distributed between carbonates (25 %) and manganese oxides (23 – 32 %), and the rest was present in the residual fraction. Co was distributed between carbonates (5 – 10 %), iron and manganese oxides (15 %), organic matter (5 %) and residual (70 %).

The water soluble concentrations of the studied trace elements (Table 5) in the dredged sediments from Port of Koper were generally lower than the threshold limits for inert waste in the Decree on landfill of waste (OJRS 61/2011). Considering anions none of the three basins can be categorized as inert waste, since the concentrations of sulphate and chloride anions in the aqueous leachates are higher than the threshold limits (Table 5). They can be considered as non-hazardous waste and as such they cannot be directly used as secondary raw material but must be treated/remediated.

3.3 Organotin compounds

Besides metals and metalloids OTCs in the marine environment may also represent a serious environmental burden. Although their use has been banned in 2008 (AFS Convention 2003), they can still be found in marine sediments. Considering previous TBT analyses of sediments from the Bay of Koper (half a mile in front of the entry to the port), the concentrations show a decreasing trend since the year 2005 (765 μg Sn kg^{-1}) (Milivojevič Nemanič et al. 2009) to 2.85 μg Sn kg^{-1} in 2011 (unpublished data). In the dredged sediments B1, B2 and B3 the highest TBT concentration was found in B1 (15.2 ± 0.8 μg kg^{-1}), while lower concentrations were present in B3 (5.18 ± 0.26 μg kg^{-1}) and B2 (3.78 ± 0.19 μg kg^{-1}).

3.4 Estimation of the origin of trace elements and evaluation of their environmental impact

To distinguish between the natural and anthropogenic origins of an element in sediment, it is recommended to normalize the obtained total elemental concentrations to the regional background values (Covelli and Fontolan 1997). The most appropriate background value can be obtained from the analysis of mineralogically and texturally comparable, uncontaminated sediment from a nearby area or the deepest level of cores from the area of interest (Covelli and Fontolan 1997). The choice of normalizing element is not universal but depends on the study area and the anthropogenic loads that are involved. The most commonly used elements for normalisation are Al, which is one of the most important constituents of the aluminosilicate mineral fraction, and Li for normalization of data from sediments derived mainly from the glacial erosion of crystalline rocks (Loring 1990). Other elements that can be applied for normalisation are Fe, Cs Eu, Rb, Sc, Sm and Th. They can be used when their anthropological inputs are lower or equal to the natural levels (Covelli and Fontolan 1997).

In the present study background levels for the studied elements were determined in sediments from an unaffected area of the Slovenian part of the NE Adriatic Sea, (the Bay of Strunjan) (Table 4). Additionally, Al, Sc and Rb were determined in sediments B1, B2, B3 and BS as potential elements for use in normalization (Table 6). Al, Fe and Rb concentrations in the sediment from the reference point were lower than their concentrations in the dredged sediments, indicating an anthropogenic input from Port activities. Therefore, none of them was applied for normalisation purposes. Sc was the element of choice, since its concentration was constant in all sediments analysed.

For estimation of anthropogenic inputs a non-dimensional enrichment factor (EF) was calculated by the equation (Eq. 1) (Covelli and Fontolan, 1997):

$$EF = (El/Sc)_{sample} / (El/Sc)_{background} \qquad \text{(Eq. 1)}$$

where $(El/Sc)_{sample}$ is the element to Sc ratio in the sample and $(El/Sc)_{background}$ is the natural background value of the element to Sc ratio. If EF > 1, enrichment due to anthropogenic input with respect to the natural background could be hypothesized (Aquavita et al. 2010).

As can be seen from Fig. 3 EF is in general higher than 1 for all the trace elements analysed. The highest EFs were determined for Fe (43.6, 56.4 and 63.2), followed by Se (6.3, 6.5 and 7.8), Mo (2.5, 3.9 and 4.6), Hg (3.5, 2.3 and 3.5), Cd (3.5, 3.0 and 3.7) and Sb (3.4, 2.5 and

2.8), which indicates a high degree of contamination. EFs of other trace elements ranged between 1 and 2. Only the EFs for Pb and As in B1 were lower than 1. The EF data confirmed our previous presumptions that most of the elements analysed in the dredged sediments were of anthropogenic origin, mostly from port activities.

Estimation of potential adverse toxic effects of the dredged sediments on the benthic community was assessed by the use of SQG, since there is a lack of local toxicological data. In order to verify the environmental hazard the total elemental and TBT concentrations were compared with values set by the SQGs of Canada, Australia and the Atlantic-EU countries. From comparison of the data given in Tables 7 (SQG) and 4 (total element concentrations in dredged sediments), it can be seen that As concentrations in dredged sediments from the three basins are under the Canadian PEL value and in the range of lower AL (AL1). According to the Australian SQG the As concentrations are in the range where adverse effects may be expected occasionally. The Cd concentrations determined in sediments B1, B2 and B3 were lower than the Canadian, Australian and EU threshold levels. Total Cr concentrations from B1, B2 and B3 were higher than the Canadian PEL but lower than the Australian ISQG-high, and in the middle range of the European AL2. Cu concentrations in all three basins exceeded the Canadian ISQG, but were lower than the PEL and Australian ISQG-high, and fell in the middle of the European AL2 range. The Hg sediment concentrations exceeded the Canadian ISQG and Australian ISQG-low, but were lower than PEL and ISQG-high, and in the range of AL1. Zn concentration in B1 did not exceed the Canadian ISQG, while B2 and B3 were above that value, but still under the PEL value. Also the Australian and EU SQGs were not exceeded. On the contrary, Ni concentrations were above both the Australian IQSGs by about a factor of 3 to 6, but were in the AL2 range. Sb present in the dredged sediments did not exceed the Australian ISQGs.

TBT concentrations, except for basin 2, were higher than 5 µg kg^{-1}, which was set as the low ISQG by the Australian SQG (Table 1). Moreover, the TBT concentration in B1 was also slightly higher than 10 µg kg^{-1}, the level which was found to cause no imposex effects in the marine snail *H. reticulate,* which is used as a bioindicator species of harbour pollution [Oehlmann et al. 2000].

3.5 Applicability of the seaport dredged sediments

Taking into account the above results, it is indicated that from the environmental point of view dredged sediments from the Port of Koper exhibit slight to moderate contamination in regard to elemental and TBT concentrations. Since these dredged sediments are of seaport origin, their levels of chlorides (naturally present from the sea) and sulphates (possible contamination due to dry cargo loading, mostly coal) exceed currently valid regulations, so that their use as embankments in engineering applications (which, in terms of the amount of dredged sediments, and its possible utilization, makes the most sense) is possible only within the area of the Port of Koper. The environment in the port area is brackish, therefore any leachates will not have adverse consequences. Moreover, due to the mineralogical composition, the fine grain size of the dredged mud and its high degree of compaction (> 92%), transport of water through such an embankment is expected to be relatively low, thus presenting an additional safety measure against pollution. Embankments and other engineering applications outside the area of the Port would be possible only if additional technologies are implemented to ensure the immobilization of hazardous anions and complete impermeability of the structure.

Due to the large amounts of sediment available, civil engineering applications such as the construction of embankments and backfilling are the most beneficial, rational, and economical recycling solution. Other applications, too, have been considered (e.g. brick making), but they have two drawbacks: firstly, their production is, at present, not economically feasible, and secondly the market is still in depression. An increased release of heavy metals from such products has also been observed.

4 Conclusions

Due to the potential leaching of pollutants from dredged sediments, their inappropriate handling or disposal may cause hazardous effects to terrestrial and aquatic ecosystems. In the present paper, the chemical characterisation of dredged sediments from three basins in the Port of Koper was performed. The main objective of the characterisation was to evaluate the environmental status of the dredged sediments in order to determine whether they can be used as secondary materials in different areas of civil engineering.

Based on total elemental concentrations and the EF data it was demonstrated that the sediments from the three basins investigated are affected by port activities. Nevertheless, from the analysis of water soluble element concentrations it can be concluded that the dredged sediments can be used as a secondary raw material, since the element concentrations were lower than the threshold limits for inert waste of the Decree on the landfill of waste. The sequential extraction procedures revealed that the elements were distributed mostly in the residual, sparingly soluble sediment fraction, while in the most mobile water soluble fraction only negligible concentrations were found. TBT concentrations were close to, or slightly higher than the level which was found to cause no imposex effects on the marine snail *H. reticulate*. The biggest problem for the reuse of dredged marine sediments is represented by the high concentrations of sulphate and chloride anions, which in the aqueous leachates substantially exceeded the threshold limit for inert waste of the Decree on the landfill of waste.

Due to the large amounts of sediment available, civil engineering applications are the most beneficial, rational, and economic recycling solution; however they must be kept inside the port area, where the environment is brackish, so that any leachates will not have adverse consequences for the environment.

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Table 1: Instrumental operating conditions for element and OTC determination.

	Element determination
Nebulizer	Miramist
Spray chamber	Scott double-pass
RF Power	1550 W
Plasma gas flow	15 L min^{-1}
Carrier gas	0.75 L min^{-1}
Dilution gas	0.45 L min^{-1}
Sampling depth	7.5 mm
Sample uptake rate	0.3 mL min^{-1}
Sampling and skimer cones	Nickel
Cell gas (flow rate) / Elements	No gas Mode : Sb, Ba, Cd, Pb, Hg Ag He Mode (4.3 mL He min^{-1}): Al, Zn, Cu, Co, Mn, Mo, Ni, Sc, Rb HECM (10 mL He min^{-1}): As, Se, Cr, Fe
	GC-ICP-MS
ICP-MS	
RF power	1500 W
Sample depth	7.5 mm
Optional gas (20 % $^{v}/_{v}$ O_2 in Ar)	10 %
Optional gas flow rate	0.25 L min^{-1}
Integration time per isotope	0.1 s
Isotopes measured	^{118}Sn, ^{120}Sn
Tune gas	100 ppm Xe in Ar
Total acquisition time	730 s
GC	
Injection volume	2 µL
Mode	Splitless
Gas	He
Column flow	1 mL min^{-1}
Inlet temperature	280°C
Transfer line temperature	280°C

Table 2: Determination of elements in Quality Control Material for Surface Water analysis SPS-SW1 (μg L^{-1}) and in Certified Reference Material 320R (Trace Elements in River Sediment) (mg kg^{-1}) by ICP-MS. The result represents the mean ± standard deviation of three independent analyses.

QCM/CRM	Element	Certified value	Determined value
SPS-SW1	As	10.0 ± 0.1	9.4 ± 0.9
	Cd	0.5 ± 0.01	0.49 ± 0.01
	Co	2.0 ± 0.02	1.95 ± 0.04
	Cr	2.0 ± 0.02	1.97 ± 0.02
	Cu	20 ± 1	19.5 ± 0.8
	Fe	20 ± 1	20.3 ± 0.6
	Mn	10.0 ± 0.1	9.8 ± 0.2
	Mo	10.0 ± 0.1	10.0 ± 0.1
	Ni	10.0 ± 0.1	9.7 ± 0.2
	Pb	5.0 ± 0.1	5.1 ± 0.1
	Se	2.0 ± 0.02	2.04 ± 0.06
	Tl	0.5 ± 0.01	0.51 ± 0.01
	Zn	20 ± 1	19.5 ± 0.7
CRM 320R	As	76.7 ± 3.4	75.9 ± 0.6
	Cd	0.533 ± 0.026	0.51 ± 0.02
	Cr	138 ± 7	1.97 ± 0.02
	Cu	44.1 ± 1	43.1 ± 1.4
	Ni	75.2 ± 1.4	74.6 ± 1.3
	Pb	42.3 ± 1.6	42.3 ± 0.3
	Zn	142 ± 3	139 ± 5

Table 3: Values for MBT, DBT and TBT in Certified Reference Material PACS 2 (Marine sediment) determined by GC-ICP-MS. The result represents the mean ± standard deviation of three independent analyses.

OKS	Certified (ng Sn g^{-1})	Determined (ng Sn g^{-1})
MBT	600#	688 ± 85
DBT	1047 ± 64	1100 ± 70
TBT	890 ± 105	753 ± 67

Indicative value

Table 4: Total element concentrations in sediments from basins B1, B2 and B3 from the Port of Koper (basins B1, B2, B3) and the reference point in the Bay of Strunjan (BS). All concentrations are expressed as mg kg^{-1} dry mass.

Element	B1	B2	B3	BS
As	14.6 ± 1.2	32.5 ± 1.6	37.6 ± 1.0	17.5 ± 0.5
Cd	0.352 ± 0.035	0.311 ± 0.037	0.391 ± 0.045	0.100 ± 0.002
Co	19.9 ± 0.8	20.9 ± 0.5	24.7 ± 0.7	9.0 ± 2.0
Cr	208 ± 9	241 ± 3	354 ± 10	135 ± 3
Cu	36.9 ± 1.8	37.0 ± 1.6	44.2 ± 1.6	35.0 ± 1.3
Hg	0.358 ± 0.02	0.266 ± 0.01	0.364 ± 0.02	0.100 ± 0.005
Mo	2.22 ± 0.09	3.46 ± 0.17	4.20 ± 0.15	0.86 ± 0.02
Ni	136 ± 9	146 ± 3	175 ± 6	70 ± 1
Pb	25.0 ± 0.5	29.7 ± 0.4	36.2 ± 0.5	25.0 ± 0.8
Zn	120 ± 2	152 ± 2	191 ± 11	90 ± 2
Sb	2.07 ± 0.08	1.50 ± 0.33	1.69 ± 0.09	0.60 ± 0.01
Ba	378 ± 27	339 ± 12	398 ± 2	162 ± 3
Se	12.7 ± 0.5	13.2 ± 2	16.5 ± 1.4	2.0 ± 0.1
Ag	0.326 ± 0.020	0.418 ± 0.048	0.519 ± 0.040	0.200 ± 0.004
Mn	781 ± 30	731±13	809 ± 22	350 ± 7

Table 5: Elemental, chloride, fluoride and sulphate concentrations in the water soluble fraction (mass per volume 1:10) from basins B1, B2 and B3, and the threshold concentrations of the elements in water leachate set by the Decree on the landfill of waste (OJRS, 61/2011) for inert (IW) and non-hazardous wastes (NHW). All concentrations are expressed as mg kg^{-1} dry mass.

Element	B1	B2	B3	IW	NHW
As	0.042 ± 0.001	0.029 ± 0.001	0.025 ± 0.001	0.5	2
Ba	0.159 ± 0.008	0.045 ± 0.002	0.064 ± 0.003	20	100
Cd	0.00036 ± 0.00001	0.00041 ± 0.00001	0.00034 ± 0.00001	0.04	1
Cr	0.0023 ± 0.001	0.0023 ± 0.001	0.0028 ± 0.0002	0.5	10
Cu	0.013 ± 0.001	0.019 ± 0.001	0.013 ± 0.001	2	50
Hg	< 0.0002	< 0.0002	< 0.0002	0.01	0.2
Mo	0.334 ± 0.002	0.332 ± 0.007	0.234 ± 0.006	0.5	10
Ni	0.043 ± 0.001	0.030 ± 0.001	0.0090 ± 0.0005	0.4	10
Pb	0.0014 ± 0.0001	0.0083 ± 0.0001	0.017 ± 0.001	0.5	10
Sb	0.034 ± 0.001	0.017 ± 0.001	0.074 ± 0.001	0.06	0.7
Se	0.012 ± 0.001	0.012 ± 0.001	0.05 ± 0.003	0.1	0.5
Zn	0.015 ± 0.001	0.020 ± 0.001	0.017 ± 0.001	4	50
Ag	0.00029 ± 0.00001	0.00031 ± 0.00001	0.00022 ± 0.00001	/	/
Co	0.0045 ± 0.0001	0.0017 ± 0.0001	0.00060 ± 0.00001	/	/
Fe	0.030 ± 0.001	0.40 ± 0.01	0.020 ± 0.001	/	/
Mn	0.0063 ± 0.0002	0.0143 ± 0.0005	0.0258 ± 0.0009	/	/
Tl	0.00034 ± 0.00001	0.00030 ± 0.00001	0.00028 ± 0.00001	/	/
Chloride	115 ± 10	8700 ± 400	12000 ± 600	800	15000
Fluoride	7.8 ± 0.4	9.5 ± 0.5	6.9 ± 0.3	10	250
Sulphate	1600 ± 100	5000 ± 300	4800 ± 250	1000	20000

Table 6: Total element concentrations of Fe, Al, Sc and Rb in sediments from the Port of Koper and the reference point in the Bay of Strunjan (BS). All concentrations are expressed as mg kg^{-1} of dry mass.

Element	B1	B2	B3	BS
Fe	44200 ± 400	57500 ± 500	66500 ± 700	1000 ± 50
Al	58700 ± 600	63200 ± 500	55700 ± 500	39100 ± 400
Sc	15.6 ± 0.2	15.5 ± 0.2	16.1 ± 0.2	15.3 ± 0.3
Rb	130 ± 1	171 ± 2	172 ± 2	103 ± 2

Table 7: Canadian, Australian and North European Countries' (Belgium, Finland, France, Germany, The Netherlands and Spain) SQG's for marine sediments.

Contaminant	Canada (Canadian Environmental QG, 2002)		Australia (McCready et al. 2005)		EU – Atlantic Sea (OSPAR 2004)	
	ISQG	PEL	ISQG-low	ISQG-high	Range AL1	Range AL2
As (mg kg^{-1})	7.24	41.6	20	70	9-80	30-200
Cd (mg kg^{-1})	0.7	4.2	1.5	10	0.5-2.5	2.4-12.5
Cr (mg kg^{-1})	52.3	160	80	370	50-200	180-1000
Cu (mg kg^{-1})	18.7	108	65	270	20-100	90-400
Pb (mg kg^{-1})	30.2	112	50	220	40-120	200-600
Hg (mg kg^{-1})	0.13	0.70	0.15	1	0.1-1.0	0.7-5.0
Zn (mg kg^{-1})	124	271	200	410	130-500	400-3000
Sb (mg kg^{-1})	/	/	2	25	/	/
Ni (mg kg^{-1})	/	/	21	52	20-100	50-400
Ag (mg kg^{-1})	/	/	1	3.70	/	/
TBT (µg kg^{-1})	/	/	5	/	/	/

/ not defined

Figure Captions

Fig. 1 Map of the sampling site

Fig. 2 Partitioning of selected elements in dredged sediments from the three basins of the Port of Koper (B1, B2, B3). F1 – water soluble fraction; F2 – exchangeable ; F3 – bound to carbonates; F4 – bound to iron and manganese oxides; F5 – bound to organic matter, F6 – residual.

Fig. 3 Calculated EF for the trace elements analysed.

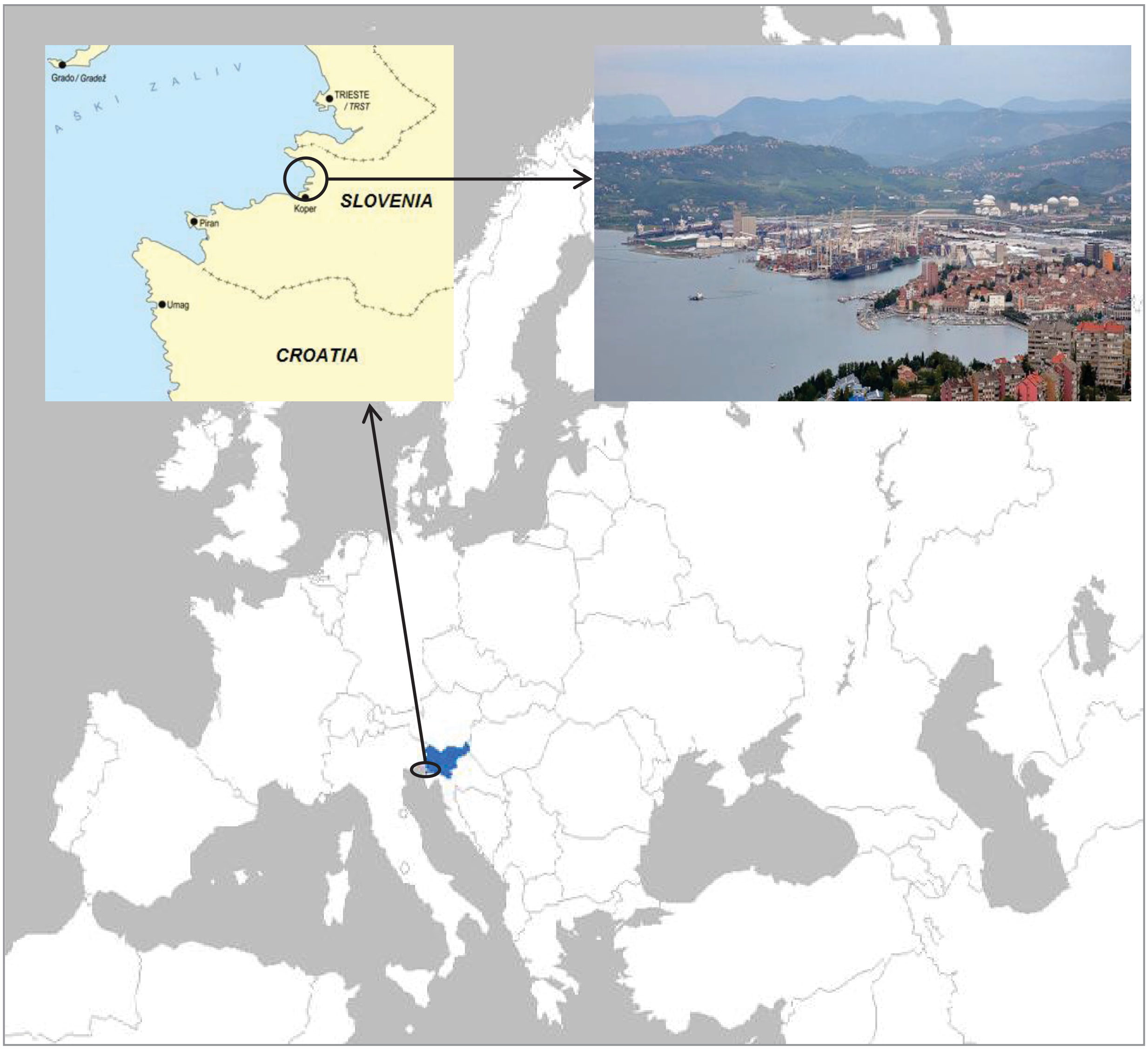

Grado / Gradež
TRIESTE / TRST
SLOVENIA
Koper
Piran
Umag
CROATIA

Fig.1

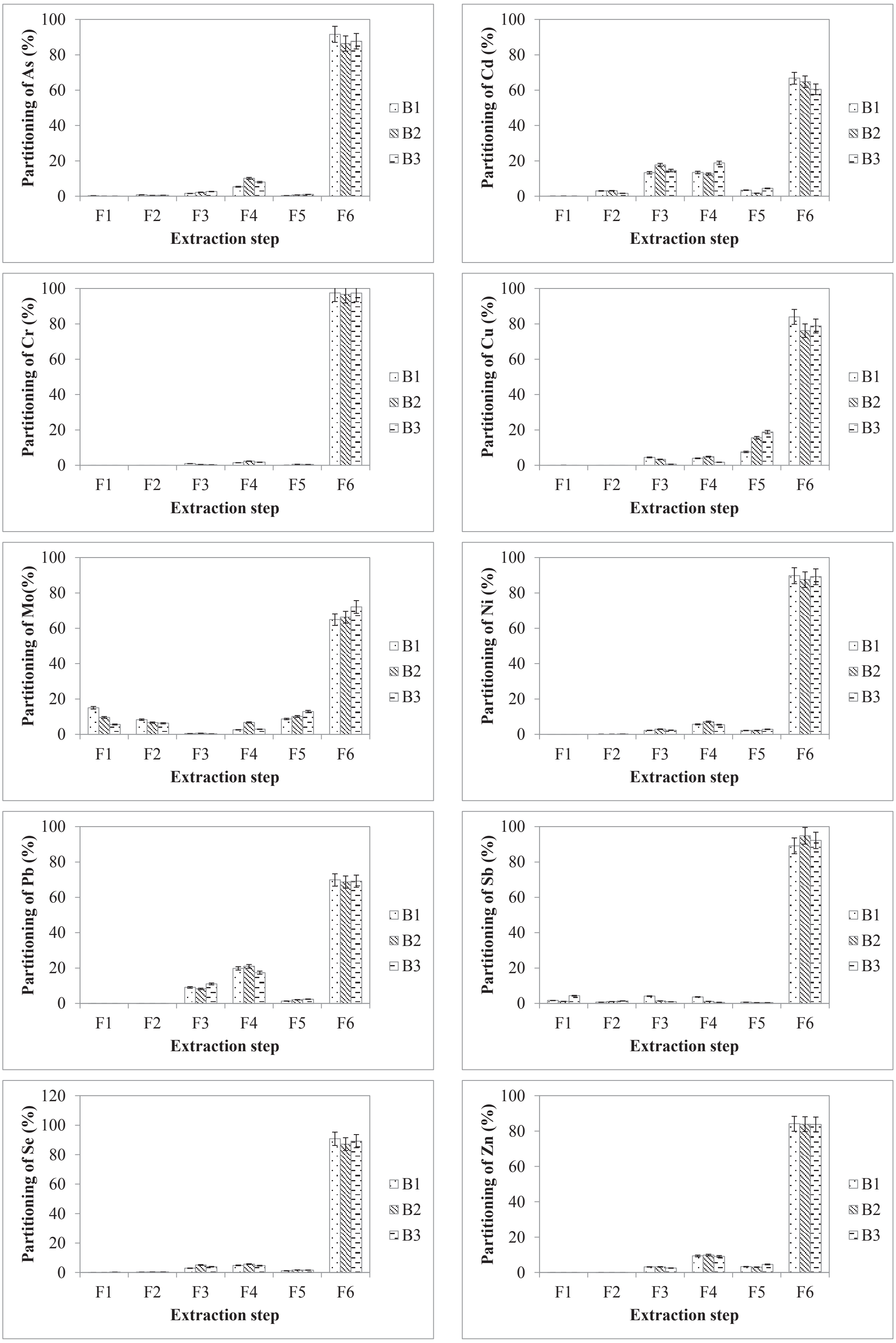

Partitioning of As (%)
Partitioning of Cd (%)
Partitioning of Cr (%)
Partitioning of Cu (%)
Partitioning of Mo(%)
Partitioning of Ni (%)
Partitioning of Pb (%)
Partitioning of Sb (%)
Partitioning of Se (%)
Partitioning of Zn (%)
F1
F2
F3
F4
F5
F6
Extraction step
B1
B2
B3

Fig. 2

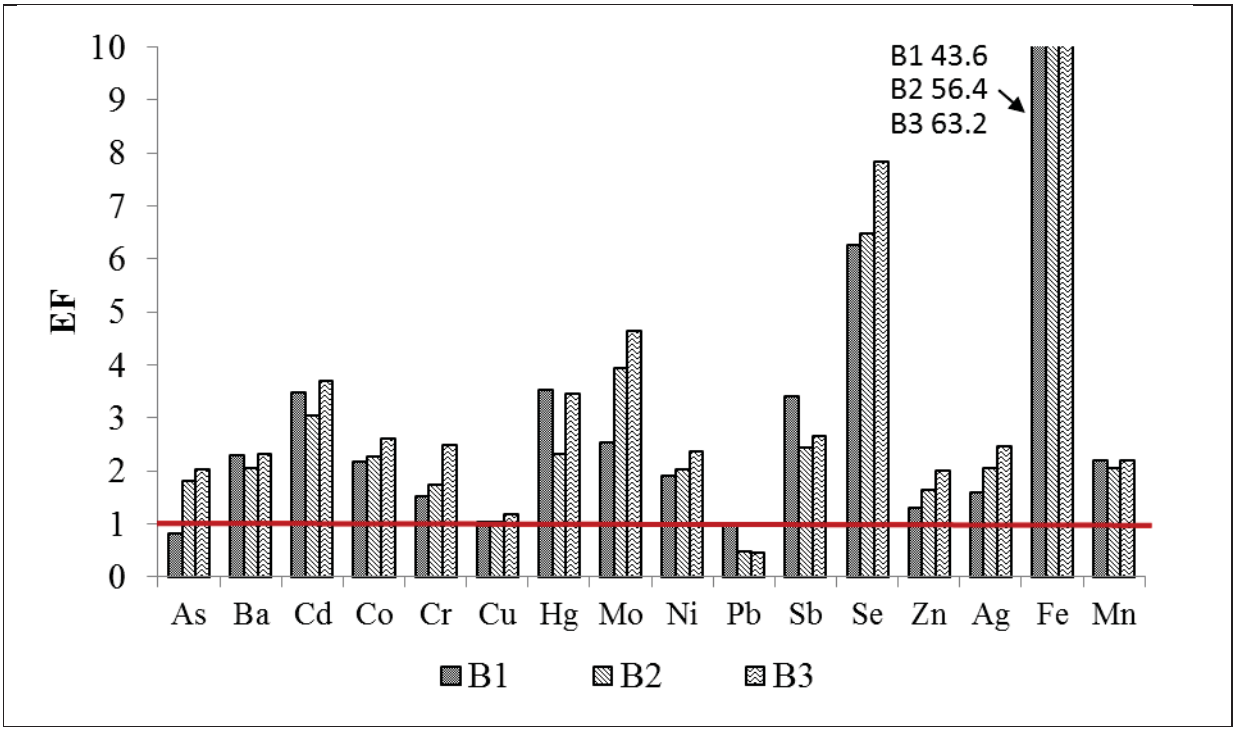

B1 43.6
B2 56.4
B3 63.2
EF
10
9
8
7
6
5
4
3
2
1
0
As
Ba
Cd
Co
Cr
Cu
Hg
Mo
Ni
Pb
Sb
Se
Zn
Ag
Fe
Mn
B1
B2
B3

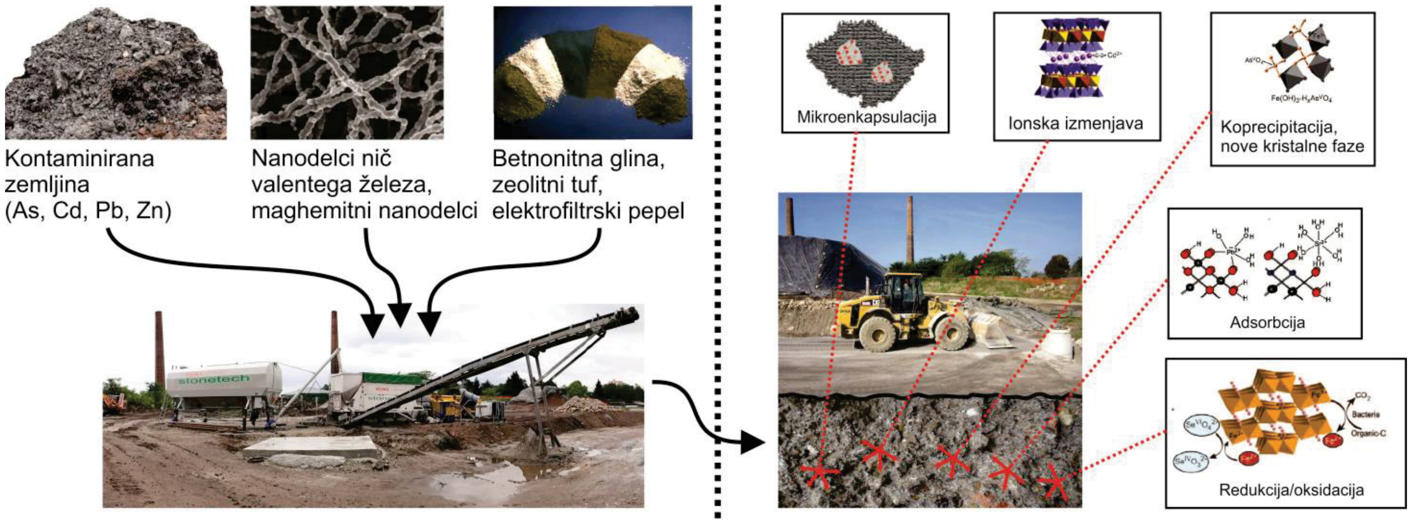
Fig. 3

Priloga 2

VEDA: naravoslovje
Področje: 1.06 geologija
Dosežek 1

Vir: A. Mladenović, P. Oprčkal, N. Kržišnik, R. Milačič, J. Ščančar, A. Sever Škapin. ***Postopek izdelave za okolje in človeško zdravje sprejemljivega gradbenega materiala iz kontaminirane zemljine, vsebujoče vodotopne spojine težkih kovin***. Patentna prijava – International application no: PCT/SI2015/000007 z dne 11.2.2015

Napredna metoda za remediacijo zemljin, onesnaženih s težkimi kovinami



Razvili smo napredno metodo remediacije zemljin *in-situ*, po pristopu imobilizacije težkih kovin **As**, **Cd**, **Zn** in **Pb**. Cilj postopka je iz kontaminirane zemljine pridobiti reciklirani gradbeni material. V postopku so zemljini primešani aditivi: **železovi nanodelci**, **bentonitne gline** ali **zeoliti**, **kalcijski elektrofiltrski pepel**. Kompozit se **s primernimi geotehničnimi postopki vgrajuje z zgoščanjem v plasti**, da dosežemo minimalno vodoprepustnost, maksimalno zgoščenost. **Nanodelci nič valentnega železa** s procesi redukcijsko inducirane koprecipitacije ter površinskimi adsorpcijskih procesi imobilizirajo težke kovine. S procesi adsorpcije težke kovine imobilizirajo **maghemitni železovi nanodelci**, **bentonitne gline** ali **zeoliti**. **Kalcijski elektrofiltrski pepel** dvigne pH na stopnjo, kjer je slabo mobilnih večina težkih kovin. Zaradi vsebnosti prostega CaO pride do pucolanskih reakcij in hidratacije, ki omogočajo fizikalno imobilizacijo znotraj cementirane matrice ter kemično imobilizacijo s tvorbo stabilnih slabo topnih mineralnih faz z vključenimi ioni težkih kovin.

Postopek remediacije s težkimi kovinami onesnaženih zemljin, omogoča sanacijo okolja na mestu. Pri tem so zemljini železovi nanodelci in naravni materiali (bentonitne gline, zeoliti) ter kalcijski elektrofiltrski pepel. Učinek imobilizacije je zagotovljen z uporabo geotehničnih postopkov kompaktiranja recikliranega materiala v plasti.