Recovery and environmental recycling of sediments: CNR-IRET Pisa experience

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DREDGED SEDIMENTS

...in quantitative terms:

- the continuous stream of sediments, dredged from harbors and waterways for **maintaining shipping traffic efficiency** , produces **several million m³** of dredged material every year.

in Europe about 100-200 million m³ need to be disposed of in specific and expensive ways every year

... in qualitative terms:

- the sediments often have a **high level of contaminants** (heavy metals and hydrocarbons)

Lack of a dedicated community directive and normative fragmentation leads to doubts regarding interpretation and application

PEAT: NURSERY GROWTH SUBSTRATE

- Substrate most used for its physico-chemical properties
- Non-renewable resource
- Imported from North-East Europe
- High costs
- Need to identify alternative materials

Peat yearly used in Italy in nurseries 5•10⁶ m³

Are the dredged sediments waste?

Recovery and environmental recycling of sediments: CNR-IRET Pisa experience

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marine and brackish sediments

brackish sediments

Landfarming

Composting

Reused in

road construction

nursery and reconstituted soils

1.Phytoremediation

2.Landfarming

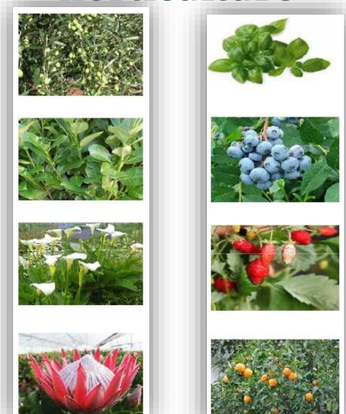
Reused in

nursery

brackish sediments

horticulture

nursery and horticulture



marine sediments

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2009-2012 AGRICULTURAL REUSE OF POLLUTED DREDGED SEDIMENTS NO. ECO/08/239065/S12.532262

brackish sediments: Navicelli Canal Pisa

soil-sediment 30%

Marine sediments: Livorno harbour

soil-sediment 30%

Selected plants

Nerium oleander

Paspalum vaginatum

Tamarix Gallica

Phragmites australis

Spartium Junceum

After about 2 years..............

Decontamination

- Decrease in **heavy metals (20%)** and total petroleum **hydrocarbons (50-60%)** concentration.

Agronomical recovery

- Improvement in chemical-nutritional properties (**25% increase in N and P**) of the treated sediments indicating the recovery of agronomical fertility.

Ecological-Functional Recovery

- Stimulation of the biological parameters contributed to creating a functional “soil ecosystem“ (**50% increase in number and activity of microorganisms**), called “**technosol**”

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2013-2016 INNOVATIVE INTEGRATED METHODOLOGY FOR THE USE OF DECONTAMINATED RIVER SEDIMENTS IN PLANT NURSING AND ROAD BUILDING (CLEANSED LIFE 12 ENV/IT/000652)

Phytoremediated brackish sediment (Agriport project)

Landfarming (3 months)

Periodically manual turning over of the sediments inside each container (12) by shovel

- homogenization of the substrate
- increase in biological activities (30%)
- further reduction in organic contamination(20%)
- increase in germination index (140% at the end)

Matrix suitable for reuse in nursery, in compliance with Italian regulation for agronomic substrate (D.lgs: 75/2010) with the exception of TOC: 3% instead of 4%

Treatments:

due to the low nutrient content and water holding capacity:
mix with agronomic soil (A) **50S:50(T50) – 33S:66 A (T33)– 0S:100 (CTL)**

Plants:

3 ornamental species:
Viburnum tinus L. (1)
Eleagnus macrophylla L. (2),
Photinia x fraseri var. Red Robin (3)

1

2

3

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Final biomass parameters

No difference in the three substrates for Photinia and Eleagnus

Viburnum tinus L.

	H Fin (cm)	ΔH (cm)	Ø fin (mm)	ΔØ (mm)	Leaf area (m^2)	DW Leaf (g)	DW wood (g)
CTL	64±14	39±15	23±5	11±5	1.24±0.6	152±65	152±78
T33	79±5	50±7	25±5	11±4	2.44±0.4	247±45	259±76
T50	89±5	62±5	28±6	16±8	2.2±0.5	237±51	269±67

Greater growth in T33 and T50 for viburnium

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Fresh brackish sediments

Landfarming (5 months)

periodical (once-twice per week) aeration by mechanically moving the sediment and turning it over

- Reduction in water to 40% → Not enough
- Reduction in organic matter (15%) → under 2% optimum for road construction
- Reduction in the organic contamination (60%) → under Italian regulations (D.lgs 152/2006)

Matrix suitable for road construction activity with addition of lime (15%)

100m road

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2015-2018 DEMONSTRATION OF THE SUITABILITY OF DREDGED REMEDIATED SEDIMENTS FOR SAFE AND SUSTAINABLE HORTICULTURE PRODUCTION (LIFE14 ENV/IT/000113)

Phytoremediated marine sediment (Agriport project)

Landfarming (3 months)

periodical (once per week) aeration by mechanically moving the sediments and turning them over

- **homogenization of the substrate**
- **increase in biological activities (double)**
- **further reduction in organic contamination(C>12 25%) but persistence of PAH and Dioxin like-PCBs**
- **reduction in toxicity (BioTox 50% lower)**

Parameters	Sediment at the end of landfarming	D. lgs. 75/2010
Bulk density (g/cm³)	1,08 ±0,07	0,95
pH	8,10 ±0,01	4,5-8,5
Electrical conductivity(dS/m)	0,33 ±0,04	<1
TOC %	1,57 ±0,02	>4
TN %	0,13±0,01	<2,5
TP (g/Kg)	0,58±0,03	
P_2O_5 %	0,11±0,02	<1,5
Cd (mg/kg)	0.96 ±0,06	1,5
Cu (mg/kg)	34,3 ± 4,3	230
Hg (mg/kg)	0,075± 0,001	1,5
Ni(mg/kg)	34,6 ± 5,33	100
Pb(mg/kg)	35,2 ± 3,7	140
Zn (mg/kg)	248 ± 11	500

Matrix suitable for reuse in horticulture in compliance with Italian regulation for agronomic substrate (D.lgs: 75/201f0) with the exception of TOC and bulk density

to reach the limits required by Italian regulations, mixing of sediments with a source of organic matter rich in Carbon and light, such as peat, is necessary

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Substrates

TS0
100% traditional substrates

TS50
50% decontaminated sediments
50% additional substrates

TS100
100% decontaminated sediments

STRAWBERRY PLANTS

Camarosa, Montere, Sant'Andrea

POMEGRANATE TREES

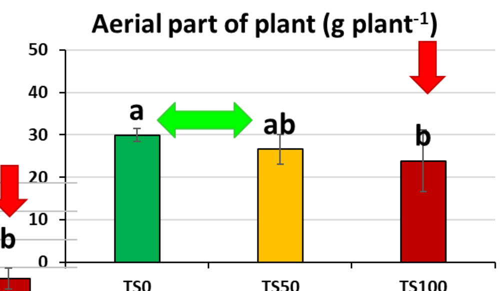
Purple Queen, Mollar

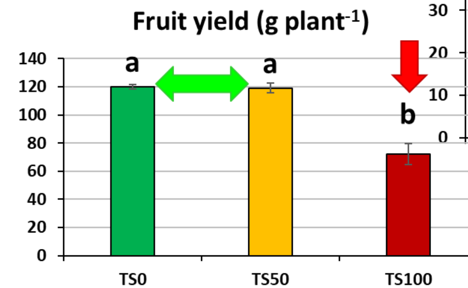
LETTUCE HEADS

Ballerina

Plant analysis

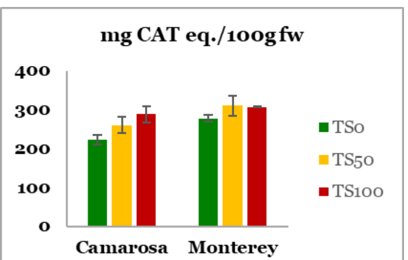
- **Plant Biomass**
- **Plant Production**
- **Nutraceutical qualities**
- **Food safety: Organic and inorganic contaminants**



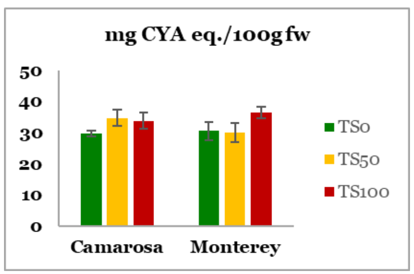


Nutraceutical properties

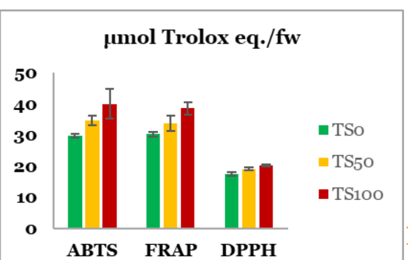
Total polyphenols



Total anthocyanins



Antioxidant capacity



in TS 50 and TS100 nutraceutical properties comparable or greater than the control

Agronomic and functional properties of all substrates, also TS100, were suitable for plant growth and development

Yield, number of fruits and average weight of fruits in TS50 and TS0 similar, while the worst production in TS100

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Treatment	Cu (mg kg^{-1} d.w)	Zn (mg kg^{-1} d.w)	Pb (mg kg^{-1} d.w)	Ni (mg kg^{-1} d.w)	Cd (mg kg^{-1} d.w)
TS0	3.8 a	15 a	<LOD	0.37 a	<LOD
TS50	3.2 a	11 a	<LOD	0.38 a	<LOD
TS100	2.3 b	13 a	<LOD	0.35 a	<LOD

No metal contamination was found in plants (roots, stem, leaves) nor fruits

CODEX ALIMENTARIUS

Hortised Life

Contaminants	Foods	mg/kg f.w. Maximum limits
mycotoxins	No fruits/vegetables	5
AS	mineral water	0.01
Cd	fruits and leafy vegetables	0.05
Pb	Fruits, small fruits and leafy vegetables	0.1
Hg	Water, fish	0.001
acrylonitrile	all	0.02
chloropropanols	hydrolyzed vegetable proteins	0.4
vinyl chloride	all	0.01

Organic contaminants in strawberry fruits

Congeners	C-TS0	C-TS50	C-TS100	M-TS0	M-TS50	M-TS100
PCB-77	0.23 (0.02) a	0.84 (0.07) bc	2.3 (0.9) b	0.4 (0.1) c	0.61 (0.07) bc	1.4 (0.6) bc
PCB-81	0.21 (0.02) a	0.20 (0.01) a	0.20 (0.01) a	0.20 (0.01) a	0.19 (0.01) a	0.20 (0.01) a
PCB-105	0.61 (0.06) a	2.9 (0.8) b	5.2 (0.8) c	0.7 (0.1) a	1.8 (0.6) b	10 (1) d
PCB-114	0.20 (0.01) a	0.30 (0.07) a	0.90 (0.07) b	0.20 (0.01) a	0.20 (0.01) a	1.3 (0.5) b
PCB-118	1.6 (0.5) a	6.1 (0.9) b	15.7 (0.9) c	2.0 (0.5) a	4.9 (0.8) b	27 (4) d
PCB-123	0.20 (0.02) a	0.30 (0.03) b	0.40 (0.07) bc	0.20 (0.01) a	0.20 (0.01) a	0.5 (0.1) c
PCB-126	0.21 (0.01) a	0.21 (0.01) a	0.21 (0.01) a	0.20 (0.01) a	0.21 (0.01) a	0.22 (0.01) a
PCB-156	0.21 (0.01) a	0.70 (0.06) b	0.99 (0.07) c	0.20 (0.01) a	0.43 (0.09) d	1.4 (0.8) abcd
PCB-157	0.20 (0.02) a	0.30 (0.05) b	0.20 (0.02) a	0.20 (0.01) a	0.21 (0.02) a	0.20 (0.01) a
PCB-167	0.24 (0.04) ac	0.30 (0.01) a	0.60 (0.11) b	0.20 (0.01) c	0.28 (0.04) a	0.61 (0.08) b
PCB-169	0.21 (0.01) a	0.20 (0.02) a	0.19 (0.01) a	0.22 (0.01) a	0.20 (0.01) a	0.20 (0.01) a
PCB-189	0.21 (0.01) a	0.21 (0.01) a	0.30 (0.05) b	0.20 (0.01) a	0.18 (0.01) a	0.21 (0.01) a
Σ DL-PCBs	4.3 (0.5) a	13 (2) b	27 (2) c	4.9 (0.5) a	9 (1) d	44 (4) e
Σ DL-PCBs (as TEQ)	0.028 (0.001) a	0.0270 (0.0007) a	0.0274 (0.0009) a	0.0266 (0.0007) a	0.0267 (0.0007) a	0.0275 (0.0004) a

Only dioxins were detected in the fruits. Similar results in all treatments and about four times lower than the maximum limits established by EU legislation 0.1 pg TEQ/g fw (EC, No 663/2014)

complete abatement

2018-2022 SUSTAINABLE SUBSTRATES FOR AGRICULTURE FROM DREDGED REMEDIATED MARINE SEDIMENTS: FROM PORTS TO POTS (LIFE SUBSED LIFE17 ENV/IT/000347)

Phytoremediated marine sediment (Agriport project)

Landfarming (3 months)

periodical (once per week) aeration by mechanically moving the sediments and turning them over

The other side of the basin

- Similar results of previous project
- Increase in microbial acivities
- Complete reduction of C>12 and persistence of PAH
- Increase in germination index (140% at the end)

Parameter	Sediments at the end of landfarming in the Subsed Project	D. lgs. 75/2010
Bulk density (g/cm³)	1,19 ±0,05	<0,95
pH	7,4±0,2	4,5-8,5
Electrical conductivity (dS/m)	0,13 ±0,01	<1
TOC %	1,38 ±0,08	>4
TN %	0,12 ±0,01	<2,5
P_2O_5 %	0,17 ±0,01	<1,5
Cd (mg/kg)	< LOD	1,5
Cu (mg/kg)	48,6 ±1,7	230
Hg (mg/kg)	0,070 ±0,001	1,5
Ni(mg/kg)	37,7 ±0,7	100
Pb(mg/kg)	37,2 ±6,4	100
Zn (mg/kg)	145 ±4	500

Suitable for reuse in horticulture in compliance with Italian regulation for agronomic substrate (D.lgs: 75/2010) with the exception of TOC and bulk density

to reach the limits required by Italian regulations, mixing of sediments with a source of organic matter rich in Carbon is necessary

Several mixtures and several plant species

other colleagues' presentations

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2018-2022 USE OF DREDGED SEDIMENTS FOR CREATING INNOVATIVE GROWING MEDIA AND TECHNOSOLS FOR PLANT NURSERY AND REHABILITATION (LIFE AGRISED LIFE17 ENV/IT/269)

brackish sediments

Navicelli channel (Pisa)

Agricultural canal (Kunice)

Similar properties: in particular
-high sand content (greater porosity, air and drainage)
-low content of heavy metals
-low salinity

Green waste

- grass
- corn cob
- wood chips
- wood
- leaves

provide carbon and nutrients that stimulate microbial activity and improve the physical structure

CO-Composting
(6/8 months)
Sediments and Green wastes
mixed in three ratios (w:w):
1:1; 3:1; 1:3

Reconstituted soil

nursery

Viburnum tinus

Photinia x fraseri

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co-composting monitoring

- temperature,
- humidity,
- bulk density
- organic matter
- humic substances
- pollutant contents
- microbial communities
- enzyme activities

stability and maturity of all co-composts

decrease and stabilization of organic matter content, electrical conductivity, microbial activity, organic contaminants and by the increase in humification rate and germination index

	Agrised Compost/substrate Czech Republic			Agrised Compost/substrate Italy			IT D. Lgs. 75/2010	CZ No.257/2009	European Legislation
	A 3S:1GW	B 1S:1GW	C 1S:3GW	A 3S:1GW	B 1S:1GW	C 1S:3GW	Mixed substrate	Sediment reuse in agriculture	Growth substrate
Bulk density(g/cm³)	1,00	0,81	0,75	0,88	0,69	0,58	<0,95		
pH	8,12	8,12	8,18	7,4	7,5	7,3	4,5-8,5		
E.C.(dS/m)	0,86	0,78	0,75	2,7	2,4	1,2	<1		
TOC %	3,02	3,04	5,04	1,66	3,54	9,39	>4		
TN %	0,26	0,31	0,48	0,15	0,31	0,58	<2,5		
P_2O_5 %	0,002	0,003	0,005	0,001	0,001	0,005	<1,5		
Salmonella	no	no	no	no	no	no		no	no
E.Coli (CFU/g)	<100	<100	<100	<100	<100	<100			<1000
Germination Index(%)	124	117	108	85	86	80		>30	
Cd (mg/kg)	0,2	0,02	0,2	0,38	0,30	0,23	<1,5	<1	<1,5
Cu (mg/kg)	34	27	32	33	29	21	<230	<100	<200
Hg (mg/kg)	<0,1	<0,1	<0,1	0,05	0,04	0,05	<1,5	<0,8	<1,5
Ni (mg/kg)	16	12	13	32	30	28	<100	<80	<50
Pb (mg/kg)	12	9,4	11	23	22	20	<140	<100	<120
Zn (mg/kg)	70	60	60	96	105	99	<500	<300	<500
Cr (mg/kg)	19	15	15	30	36	29	<100	<200	
As(mg/kg)	2,9	2,9	3,9					<30	
Be (mg/kg)	0,5	0,4	0,6					<5	
Co (mg/kg)	4,3	4,1	5,4					<30	
V (mg/kg)	20	19	24					<180	
IPA(mg/kg)	0,45	0,41	0,40					<6	
PCB (mg/kg)	<0,01	<0,01	<0,01					<0,2	
C10-C40 (mg/kg)	85,5	64,8	62,9					<300	

Compared with their own reference legislation:
-CZ: compost in compliance with the legislation for all parameters
-IT: Again lower TOC in A and B and higher Electrical Conductivity

proper substrate for plant nursery, in mixture with other substrate, and soil reconstitution for degraded soil rehabilitation

Subtrates

- Peatmoss – Pumice (1:1)
- Dredged sediments – green waste (1:3)
- Dredged sediments – green waste (1:1)
- Dredged sediments – green waste (3:1)
- Peatmoss – Pumice (1:1) 60% – dredged sediments – green waste (1:3) 40%
- Peatmoss – Pumice (1:1) 60% – dredged sediments – green waste (1:1) 40%
- Peatmoss – Pumice (1:1) 60% – dredged sediments – green waste (3:1) 40%

Greenhouse

DEGRADED SOIL
DREDGE SEDIMENT
DEGRADES SOIL / DREDGE SEDIMENT / SEWAGE SLUDGE
CO-COMPOST 1:1
CO-COMPOST 1:1 / DEGRADED SOIL
CO-COMPOST 1:1 / DEGRADED SOIL / SEWAGE SLUDGE
CO-COMPOST 1:3
CO-COMPOST 1:3 / DEGRADED SOIL
CO-COMPOST 1:3 / DEGRADED SOIL / SEWAGE SLUDGE
CO-COMPOST 3:1
CO-COMPOST 3:1 / DEGRADED SOIL
CO-COMPOST 3:1 / DEGRADED SOIL / SEWAGE SLUDGE

Good adaptation and growth in all substrates

outdoors

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The results obtained in these projects underline the great potential of environmental reuse of marine and brackish dredging sediments, both in terms of innovation and possibility of replication

These projects could make a significant contribution to sustainable sediment management

But

Resource

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Scientific articles on the recovery and reuse of decontaminated sediments

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2 more articles in writing

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Cristina Macci Grazia Masciandaro
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Manuele Scatena Francesca Vannucchi
Stefano Lucchetti Maria Castellani