A new multidisciplinary approach to dredged sediment management: Venice Industrial Channels and other tests

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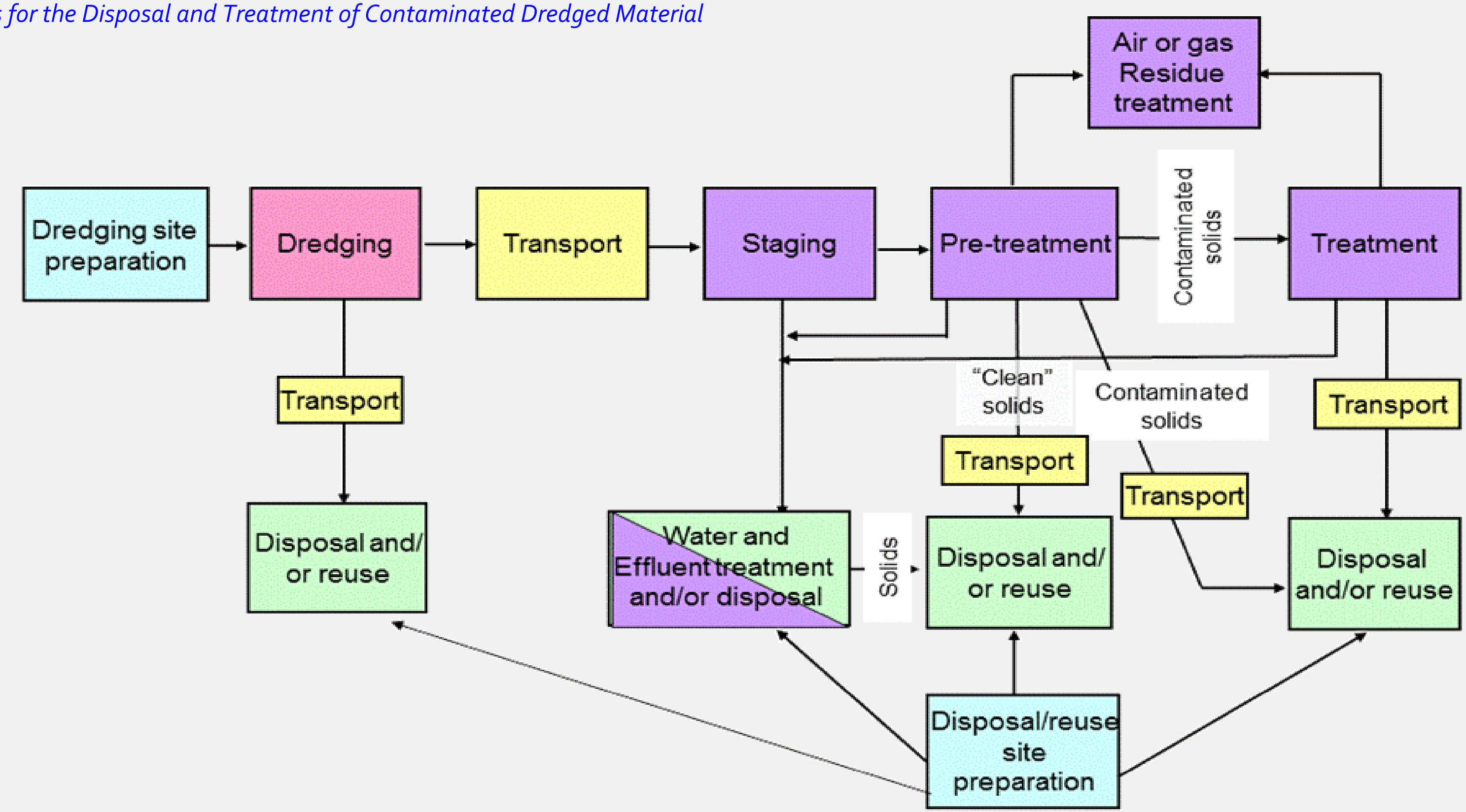
SedNet Conference 2013. Innovative Sediment Management: how to do more with less

Summary

1. **Generic Dredged Material Management Criteria**
2. Innovative *Ex Situ* Approach: focus on
   - "Enhanced" Soil Washing: Process Consolidation
   - "Enhanced" Soil Washing: Wet Oxidation
   - Pneumatic Flow Mixing
3. Pilot Testing:
   - Venice Lagoon
   - La Spezia and Livorno
4. Quick Conclusions – part 1
5. Quick Conclusions – part 2: are we really doing more with less?

Generic Dredged Material Management Criteria

From Vivian, Edwards, Apitz and Bardos (2011) Guidance for the Decision Framework for Assessing Options for the Disposal and Treatment of Contaminated Dredged Material



Sustainable management minimizes short-term exposures and resource use during all steps, and controls or eliminates long-term exposure risks. Where possible, uplift due to the waste hierarchy and beneficial re-use should be prioritized

Generic Dredged Material Management Criteria

Tables from Rapisardi, Slavik, Vanni, Preda, Apitz: the Sustainable Treatment, Reuse and Recycling of Contaminated Sediment in Porto Marghera, Venice – Wet Oxidation Demonstration Results – Battelle International Conference on Remediation of Contaminated Sediments – 2013 Dallas, Texas

Technical criteria

	Criteria (broad)	Sub-Criteria/ indicators
Feasibility	Technical feasibility	Is MA appropriate for contaminants?
		Is MA appropriate for sediments?
		Is MA appropriate for site?
		Is MA mature?
		Is MA available?
	Availability of si[illegible]	Disposal/use site avai[illegible]
		Conflict [illegible] other disposal/use site uses
		Staging/storage/treatm[illegible] site [illegible]
		[illegible] treatment site uses
	[illegible] regulations standards in the short and long terms	Do sediments meet [illegible] site [illegible]

	Criteria (broad)	Sub-Criteria/ indicators
Effectiveness at reducing ecological risk	Effectiveness at reducing risk over the long term	Number/severity/likelihood of long-term exposure pathways (ecological)
		Lifespan of risk reduction
		[illegible] of risk reduction
	Effectiveness at reducing risk over the [illegible]	Number/severity/likelihood of short-term exposure pathways (ecological)
		Time to reduction

Sediment Management

Cost criteria

	Criteria (broad)	Sub-Criteria/ Indicator
Costs	Monetary cost (i.e. would the measure be disproportionately costly to implement) including any long-term monitoring and maintenance requirements as well as potential remediation if required	Capital cost
		OM cost
		Monitoring cost
		Maintenance cost
		Liability measures
		Failure cost

Sustainability criteria

Environmental, Social, Economic elements

As the title of conference says, we face the need to do more with less

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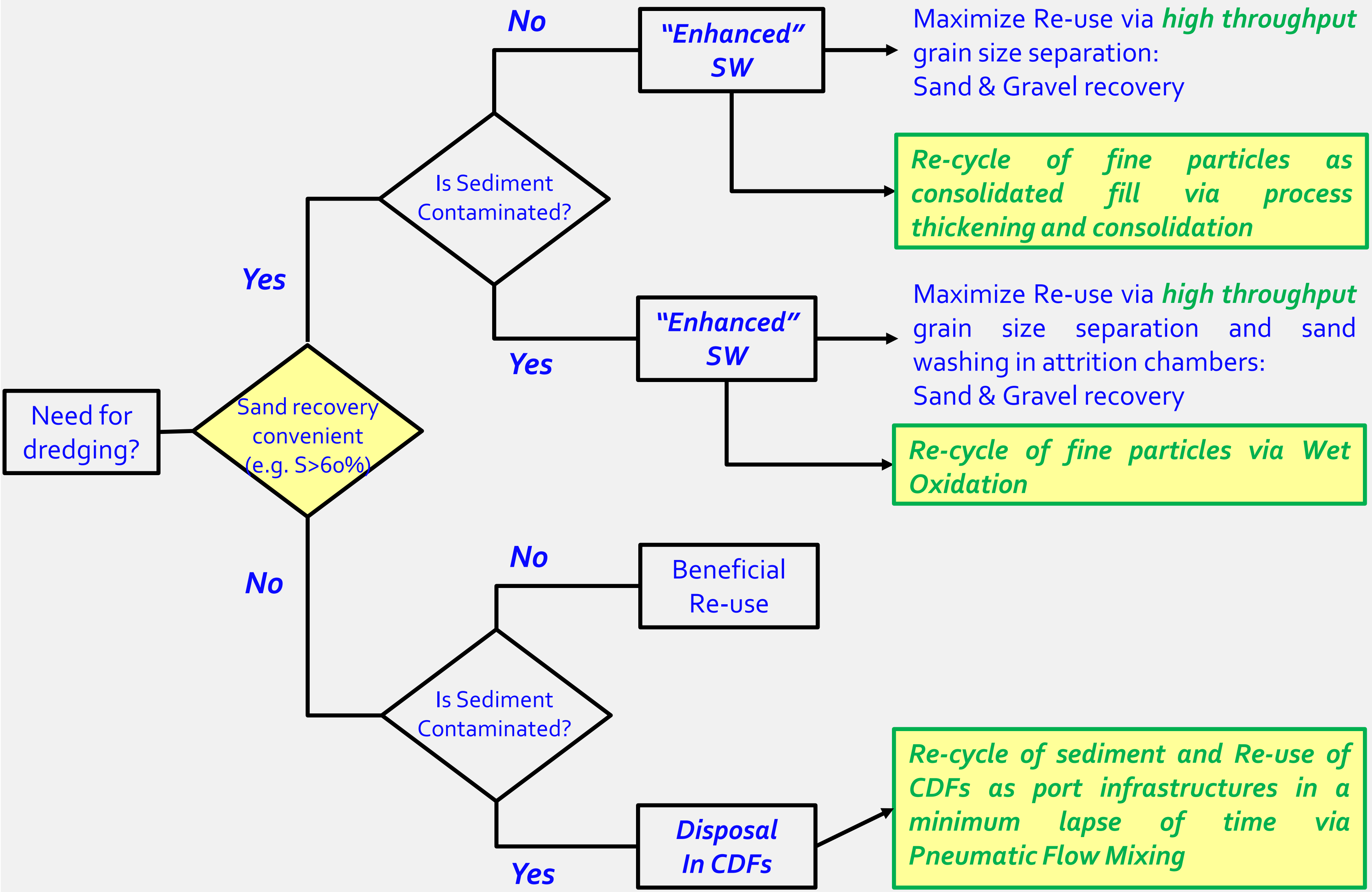
Innovative *Ex Situ* approach



“Enhanced” SW: focus on Process Consolidation

Dredged sediment, after fluidization, is pumped in an high throughput, small footprint size selection plant. To minimize water consumption, process water is used as thinner.

- **Physical forces wash contaminants and fines from coarse fraction**
- **It generates piles of coarse-grained material for re-use and a fluid stream containing silt and clay for further handling**
- **It handles large fluidized input (systems designed for 350-400 m3/h input) – high throughput**
- **It works automatically in small spaces – small footprint**

Trevi SpA – 3V Green Eagle SpA
Images from tests on Venice Industrial Channels sediments CCPV 2012

Automatic Process Thickening and Consolidation

After sand recovery a fluid stream is to handle. If it is classified as "not hazardous", it can be disposed in CDFs. In order to use these facilities as port infrastructures, sediments must have proper geomechanical characteristics.
These characteristics can be obtained by consolidating sediments by means of appropriate binders. The stabilization can be obtained during the disposal or later. The latter (currently more common) is more costly, logistically challenging and has longer delivery times.
Cement grout and the finest part of soil are been directly introduced into the centrifuge decanter's entrance, so that there is a careful mixing of the binder's particles with the solid matrix.

Trevi SpA – 3V Green Eagle SpA: Images from tests on Venice Industrial Channels sediments CCPV 2012

Automatic Process Thickening and Consolidation

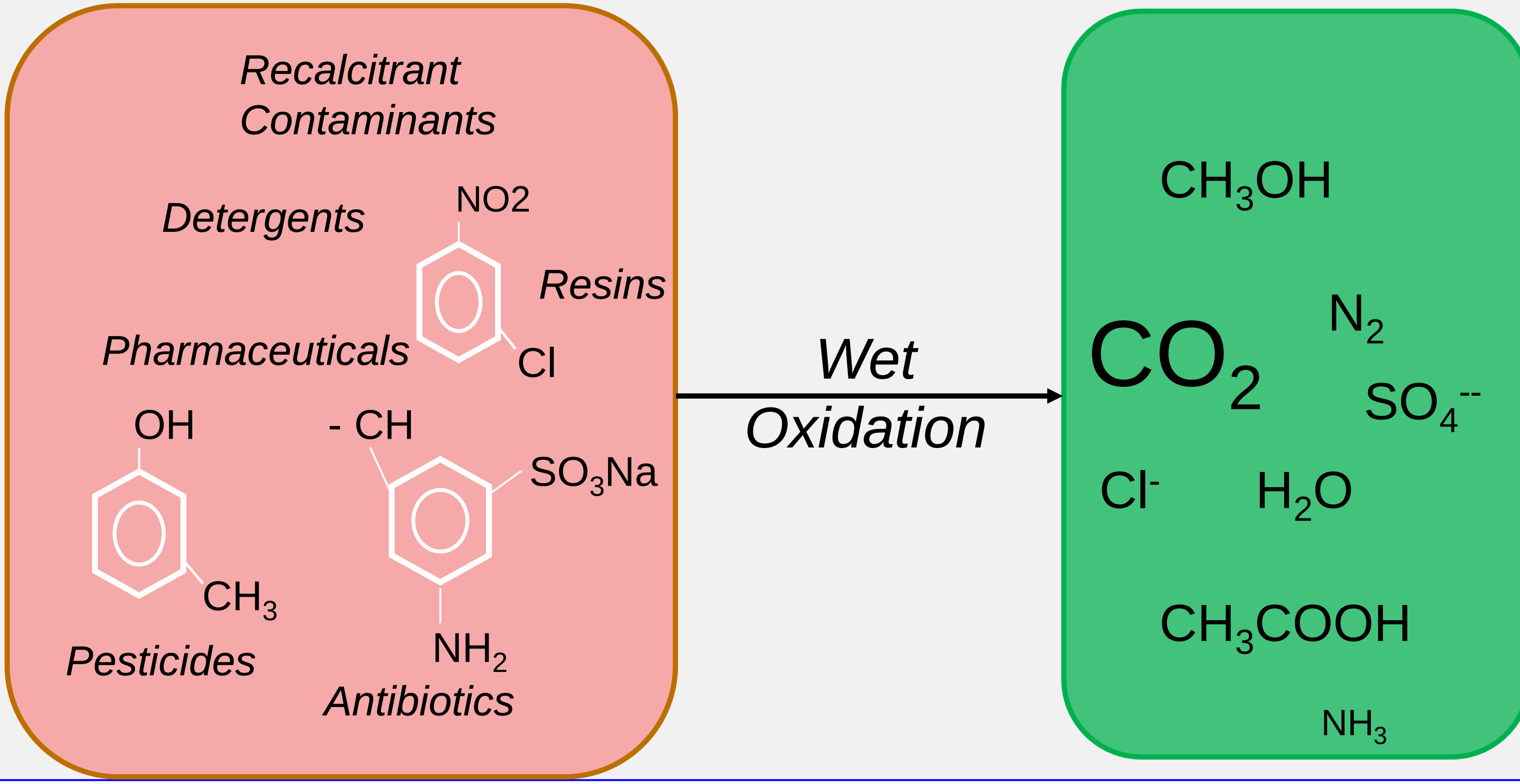
- A batch-specific cement grout is injected directly at the centrifuge input
- The quantity of binders added is automatically controlled based on sensors that measure inlet mud flow rate and density - adaptable
- This enhances the mixing of particles with binder; outputs start hardening immediately – rapid throughput for re-use
- Quantity of binders used is calculated based upon characteristics required for intended use – binders optimized
- Customization, homogeneity and quick hardening allow for immediate disposal, re-use or recycling practically without storage or drying

Trevi SpA – 3V Green Eagle SpA
Images from tests on Venice Industrial Channels sediments
CCPV 2012

“Enhanced” SW: focus on Wet Oxidation

What is “Wet Oxidation” ?

“Wet Oxidation” is the oxidation of dissolved or suspended components in water using oxygen as the oxidizer. The reaction is activated by injecting pure Oxygen in a high pressure reactor, and it allows to “burn in water - flameless” dissolved compounds, including recalcitrant compounds with very low biodegrability.

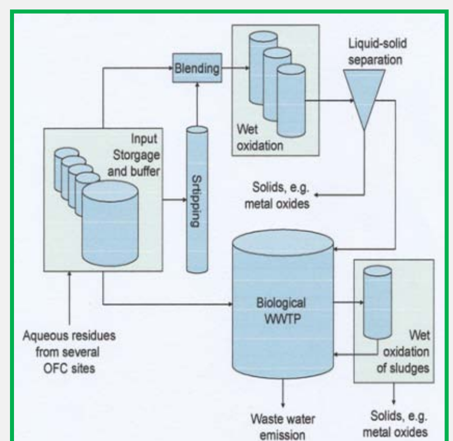


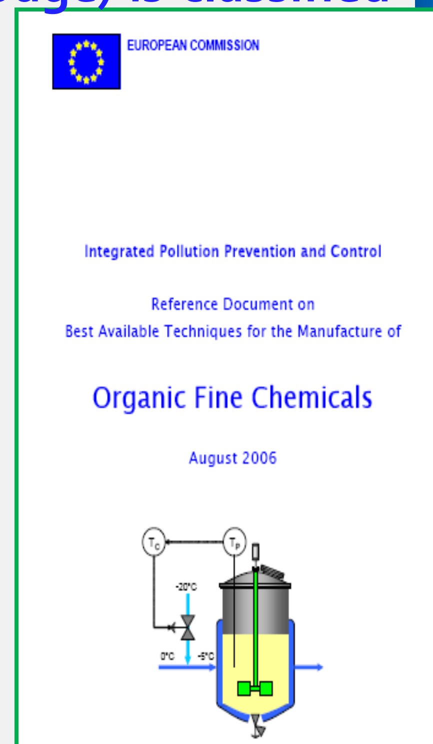
"Enhanced" SW: focus on Wet Oxidation

- Allows dissolved compounds to "burn in water - flameless" that, under dry conditions, would oxidize at much higher temperature and pressure;
- "Zero Discharge" process:
  - Allows for the removal of the organic content: the liquid effluent is a biodegradable wastewater fed to the subsequent WWTP;
  - Allows the almost complete removal of a wide variety of complex chemical compounds and recalcitrant contaminants;
  - Reaction occurs in water, therefore there very low gaseous emission, mainly CO_2 and O_2 in excess (the incondensable gases are burned in a heater);
  - The residue outflow is an inorganic material, recovered by conventional decantation and filtration, that can be converted into a primary-secondary material. This residue material has obtained the CE marking for bituminous coatings and similar, avoiding landfill disposal or can be used for the production of a lightening structuring material
  - Treated water restored to the environment (surface water) after biological treatment, respecting the most stringent regulatory limits
- Can treat both wastewater and sludge

"Enhanced" SW: focus on Wet Oxidation

- Can treat "single stream" effluent and "multi stream" effluent on industrial scale
- Overall process efficiency increases with highly contaminated streams
- Low operational costs. Investment costs compensated by medium to long term plant lifetime
- Ideal application with biological plant as post-treatment
- Process layout (Wet oxidation on both wastewater and sludge) is classified as "BAT" in the Organic Fine Chemicals BREF Document in 2004 and 2006




EUROPEAN COMMISSION

Integrated Pollution Prevention and Control

Reference Document on
Best Available Techniques for the Manufacture of

Organic Fine Chemicals

August 2006

Process Consolidation: Pneumatic Flow Mixing

If it is not convenient to separate the sandy fraction (due to the small quantity) from the sediment, stabilization can be made before the assignment or, as alternative, at the same time or after the reflux. For following interventions, punctual techniques can be employed such as the Deep Mixing, by treating the whole volume with punctual treatments performed with cutters having an horizontal or vertical axis. The main limits are:

- the overall cost of the treatment (70 – 100 €/m³)
- the logistic difficulties (working areas are not usually negotiable)
- the impossibility to stabilize the whole mass (e.g. If HDPE liner is present)
- the increased delivery times of the work (intervention after fill)

ALLU Shallow Mixing

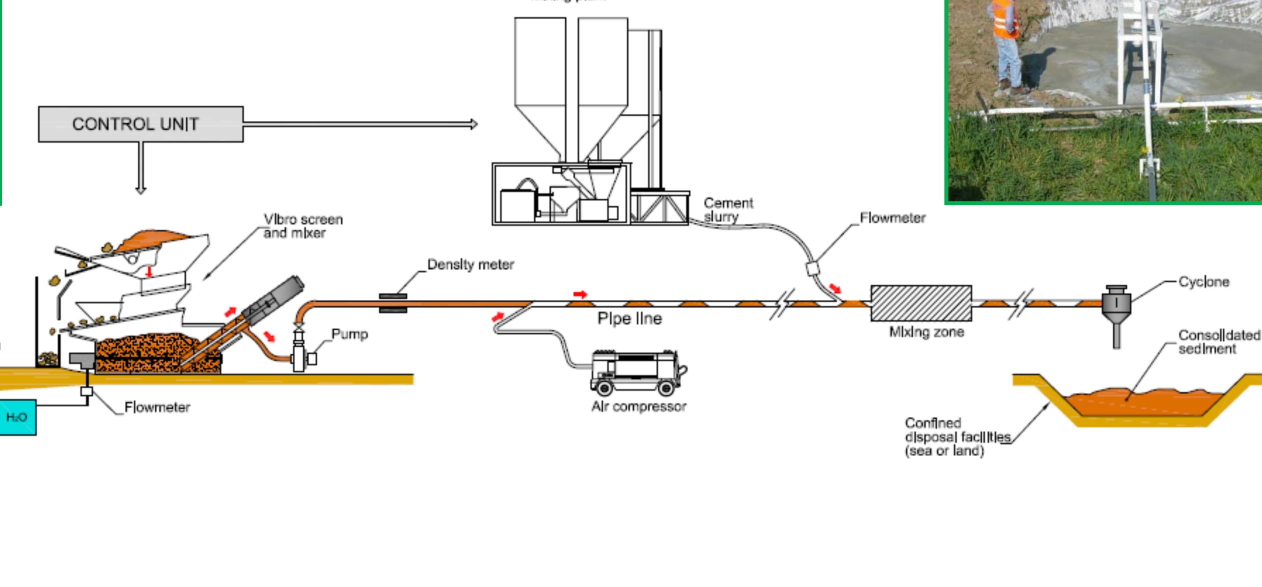
Trevi SpA – Turbomix , Livorno Harbour

Process Consolidation: Pneumatic Flow Mixing

PFM is an innovative consolidation process of dredged sediments, whose main peculiar features are:

– “Plug” Pneumatic transport of the dredged sediment: the dredged sediment is inserted inside a duct and driven by pressurized air;
– Process injection of the stabilizing additive: the stabilizer (usually, cement) is added to the dredged sediment before or during transport.


Trevi SpA - Pilot Plant




Trevi SpA - Pilot Plant

Process Consolidation: Pneumatic Flow Mixing

This consolidation technique enables:

- to cut costs thanks to the extreme simplification of the process (one single dredging /consolidation /disposal process)
- to displace huge amounts of sediments, thanks to the employment of suitably equipped barges, thus reducing working times.

The high turbulence generating as a result of friction on the pipe's walls and of compressed air's injection is capable of perfectly mixing binders with the dredged mud, thus obtaining a material (to be conveyed to the CDF) which hardens with no further interventions being carried out after said conveyance.

Trevi SpA – 3V Green Eagle SpA
Images from tests on sediments from La Spezia and Livorno – Sogesid 2013

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Venice Industrial Channels Test

n°3 batches of about 50 m³ each were dredged (pre-industrial scale test). Depending on contamination, 2 technological approaches have been developed:

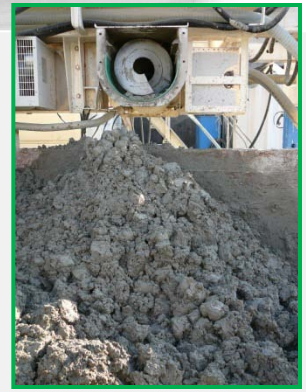
- For non/slightly-contaminated sediment:
  - Maximize Re-use via grain size separation: sand and gravel recovery (vibro-sieving);
  - Achieve silt geotechnical stabilization for Re-cycle: - Process thickening (centrifuge);
    - Process consolidation (adding binders);
- For contaminated sediment:
  - Maximize Re-use: sand and gravel recovery;
  - suspension of silt and process water to be sent to Wet Oxidation (Re-cycle after treatment)

Trevi SpA – 3V Green Eagle SpA
Images from tests on Venice Industrial Channels sediments CCPV 2012

VIC Test: Process Consolidation results

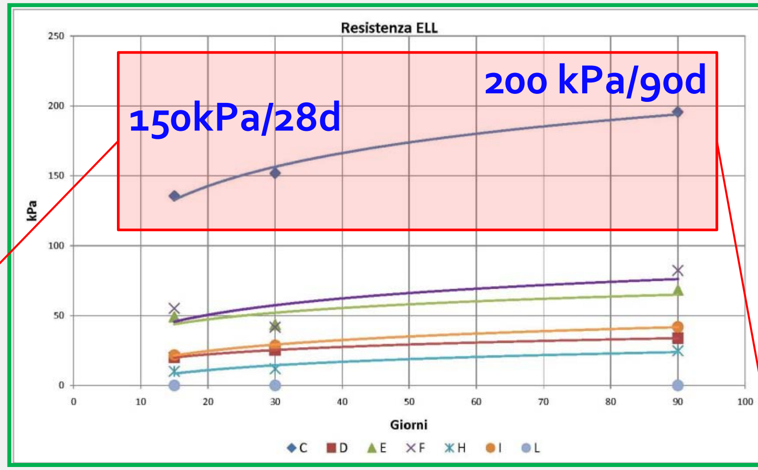
2 tests were carried out:

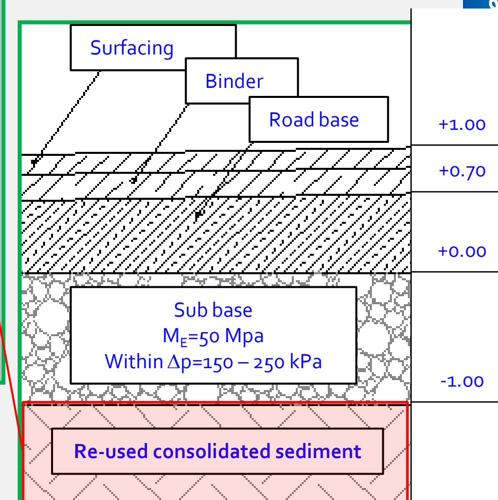
- maximum separation of solid-liquid: minimum volume when binders were added to it (Test 1).
- material added with binders having features such as to be sent to its disposal through pumps or pneumatic transport (Test 2).



Test	Sand %	Silt %	Clay %	Water Content w%	Unit Weight γ t/m^3	Specific Weight γ_s t/m^3
1	6,1	50,2	43,8	82,1	1,49	2,73
2				113,9	1,43	2,75

Test Type	Group of samples	Cement kg_{cem}/t_{DS}	Cement kg_{cem}/t	Cement kg_{cem}/m^3
1	C	115	110	66
1	D	45	45	26
1	E	65	65	37
1	F	85	85	51
2	H	75	35	50
2	I	100	47	66
2	L	45	22	31



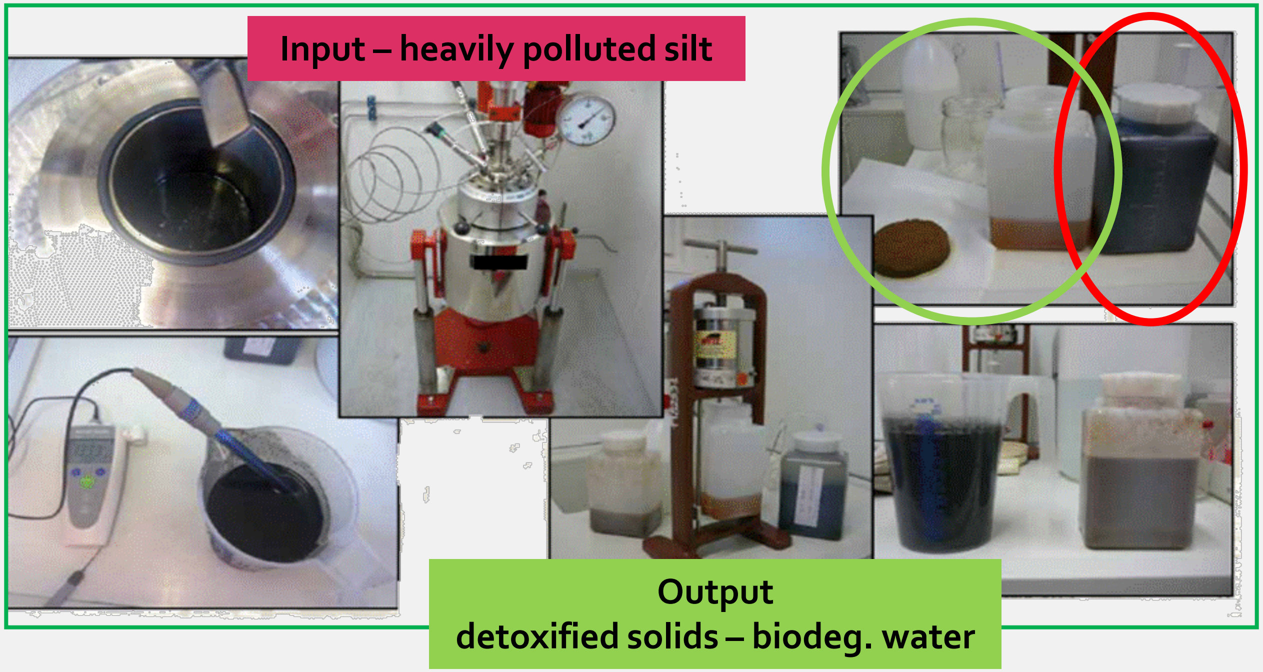


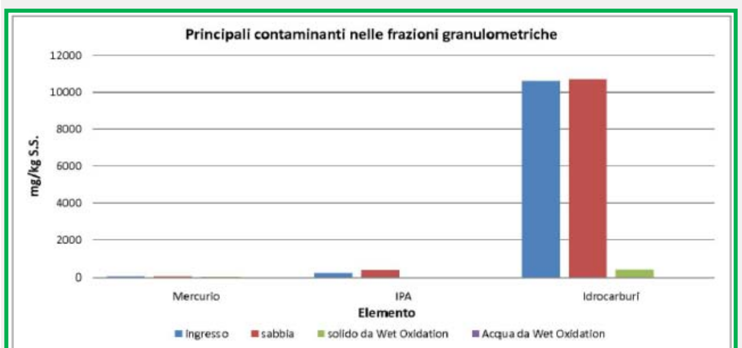
M_E [MPa]	Δp 50 – 150 kPa	Δp 150 – 250 kPa	Re-use in CDFs or for road embankements (Italian Design Limits)
Type 1 – C	42,88	30,93	1 meter below paving foundation

Tables from Vanni, Preda, Slavik: An innovative method for sediment management in reservoirs and hydraulic infrastructures -IECS 2013
9th ICOLD European Club Symposium – 2013 Venice, Italy

VIC Test: Wet Oxidation results

A critical aspect of the demonstration was the construction of a pilot plant for wet oxidation. A pilot autoclave was used to optimize operating conditions for heavily polluted silt.





73% mean reduction in COD

Reduction of HCs up to more than 95%

Reduction of PAHs up to more than 99%

SOGESID Test on *La Spezia* and *Livorno* sediment

In 2012 Trevi and 3V won a tender for tests on sediments from La Spezia and Livorno. n°5 batches of about 2 m^3 each were collected.

2 approaches were to verify:

- Line 1: maximize Re-use of sediment for environmental restoration;
- Line 2: achieve suitable geomechanical properties for Re-cycle in CDFs.

Tests were concluded on July 2013, analysis and lab test were concluded on September 2013.

CONFIDENTIAL

At the moment no permission to publish results

Livorno CDF

La Spezia Molo Garibaldi

LS and *LI* tests: what we did

2 different Pilot Plants were built:

- Soil&Sediment Washing Pilot Plant based at 3V Green Eagle facility in Grassobbio, Bergamo, Italy.
- Pneumatic Flow Mixing Pilot Plant based at Trevi facilities in Cesena, Italy.

Sediment suitable for tests was searched, performing samplings on Livorno CDF and vibrocorer samplings in front of Molo Garibaldi, La Spezia.

PPs are now available to customers, allowing to investigate the effectiveness of the chosen treatment technologies according to the sediment's site-specific characteristics.

LS and *LI* tests: what we did on LINE 1

n°3 batches of about 2 m³ each were grabbed.

Depending on contamination, 2 technological approaches have been developed:

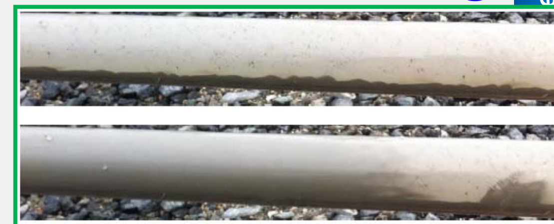
- For <u>non/slightly-contaminated sediment</u>:
  – Maximize Re-use via grain size separation: sand and gravel recovery (vibro-sieving);
  – Achieve silt geotechnical stabilization for Re-cycle:
    - Process thickening and consolidation (in centrifuge decanter, adding binders);
- For <u>highly contaminated sediment</u> (*not founded• doping with HCs*):
  – Maximize Re-use: sand and gravel recovery;
  – suspension of silt and process water to be sent to Wet Oxidation (Re-cycle after treatment)

LS and *LI* tests: what we did on LINE 2

n°4 batches of about 2 m³ each were treated.

The single "dredging"/consolidation/disposal process is tested, using Pneumatic Flow Mixing.

- Sediment is charged into the plant, well blended and fluidized;
- is pumped inside a duct and then driven by pressurized air;
- the stabilizer is added;
- The high turbulence perfectly mix binders with the dredged mud;
- Consolidated mud is discharged and checked.



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Quick Conclusions – part 1

Demonstration tests successfully met all project objectives

- Separation and batch-customized consolidation processes:
  - Handling large fluidized input (systems designed for 350-400 m3/h input) – high throughput;
  - Re-cycle of fine particles as consolidated fill;
  - Maximized opportunities for re-use and recycling of valuable sediment resources;
  - Minimized use of containment space.
- Wet Oxidation:
  - effectively decontaminated highly contaminated sediments,
  - with only clean or biotreatable, re-useable outputs (air, water and solids)
- Pneumatic Flow Mixing: re-cycle of sediment and re-use of CDFs as port infrastructures via a unique "dredging"/consolidation/disposal process - time and costs saving
- Technologies are mature, mobile and available
- Technologies are customized and adaptable to the site management strategies, maximizing the sustainability of Port and catching management plans

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Are we really doing more with less?

Proposal	What's more?	
"Enhanced" Soil Washing	Re-cycle of fine particles as consolidated fill	• Dehydrated sludges disposal to Landfill does not always provide a suitable solution • Thickened sludge management can be problematical due to the interaction between sludges and rainwater (slippery surface) 
	Re-cycle of fine particles via Wet Oxidation	• Chemical-Physical treatment transfers contaminants from ww to ww sludge; • Biological process is not adequately effective on high COD waters; • Incineration is not cost effective on liquid waste with moderate to high water content. It can also produce additional contaminants (dioxins and other micro-pollutants); • Sludge disposal to Landfill or Agriculture does not provide a sustainable long-term solution.

Are we really doing more with less?

Proposal	What's more?
Pneumatic Flow Mixing	Re-cycle of sediment and Re-use of CDFs as port infrastructures in a minimum lapse of time Cost and time saving

CDFs filled with fine sediment, hydraulically or mechanically dredged can be inaccessible for years. This problem is worldwide. Some examples:

From Pribaz, Lotti: "Management of Livorno Port sediment. New CDF design aspects" Remtech 2013, B.8: 104-111

(...) Thanks to tests evidences it's possible to assert that, 4 years after the complete 1st CDF filling, sediment don't achieve geomechanical properties, suitable for a logistic re-use of the CDF. Therefore, right now, every kind of use is precluded, except pure containment of sediment. (...)

Livorno CDF: tracks of Caterpillar during sediment sampling on December 2012

From Grubb, Chrysochoou, Smith, Malasavage: "Stabilized Dredged Material. I: Parametric Study" 2010, 136(8): 1011-1024

(...) The specific intent [of the study] was to collect high fines and water content DM that would represent some of the more challenging material in the CDF to be stabilized, if actively mined for large-scale construction. (...)

DM sampling event, USACE Craney Island, Hampton Roads, Va.

Thank you for your attention

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