Contaminated sediment as hot-spots of wide-scale marine pollution: a need to re-think sediment management and policy

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We have selected three SIN as pilot cases mainly because:

1. They are located in three different geological setting;
2. They are sites with an huge “historical” contamination of sediment recognised in marine environment;
3. For one of these was recognised impact to ecosystem and human health;
4. In one case is also detected dumping activities on the sea;
5. In all three there is a very articulated sub-marine canyons systems that acts as primary control of contaminants transport from coast to the deep sea.
Augusta Bay (SE Sicily), “closed” site

- **1950**: industrial development
- **1960s**: relevant dredging activities and breakwater building
- **1960s-1970s**: chlor-alkali plant (Montedison-Syndial) discharges without treatments about $260 \text{ kg } y^{-1}$ of mercury
- **1980**: waste treatments became operative
- **2003**: Augusta Bay was included in “The National Remediation Plan” by Italian Environmental Ministry (SIN)
- **2005**: chlor-alkali plant production stops
Augusta Bay

Contaminated Sediment
Volume = 30,000 m³

Hg background (Strait of Sicily) 0.04 mg Kg⁻¹
Hg Legal limit 0.3 mg Kg⁻¹

530 sediment cores + 39 superficial sediments

Salvagio Manta et al., 2016. Estuarine, Coastal and Shelf Science 181, 134-145
Bonsignore et al., 2015. Environmental Pollution 205, 178-185

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Augusta Bay

- Superficial contamination in spite of chlor-alkali plant production stop

- Scarce active erosion processes

- Relevant activities of dredging caused remobilization and diffusion of pollutants in the water column

Salvagio Manta et al., 2016. Estuarine, Coastal and Shelf Science 181, 134-143
Bonsignore et al., 2015. Environmental Pollution 205, 178-185
Augusta Bay - OFFSHORE

- Pollution transfer to the open sea

Salvagio Manta et al., 2016. Estuarine, Coastal and Shelf Science 181, 134-143
Bonsignore et al., 2015. Environmental Pollution 205, 178-185
Bellucci et al., 2012. Environmental Science and Technology 46, 2040-2046
Augusta Bay

Mass Balance: \( I + A + AD + R = O + D + V \)

- \( V = 1.7 \pm 0.02 \times 10^{-2} \text{ kmol y}^{-1} \) (Bagnato et al., 2013)
- \( AD = 0.42 \times 10^{-2} \text{ kmol y}^{-1} \) (Bagnato et al., 2013)
- \( I = 3.12 \pm 0.94 \times 10^{-2} \text{ kmol y}^{-1} \) (Kotnik et al. 2007)
- \( O = 0.54 \pm 0.08 \text{ kmol y}^{-1} \) (Salvagio Manta et al., 2016)
- \( R = 1.3 \pm 0.2 \text{ kmol y}^{-1} \) (Salvagio Manta et al., 2016)
- \( D = 0.84 \pm 0.22 \text{ kmol y}^{-1} \) (Salvagio Manta et al., 2016)
- \( A = 6.2 \times 10^{-2} \text{ kmol y}^{-1} \) (European Pollutant Emission Register)
- \( \sim 4\% \) of Hg anthropogenic input from coastal sources to the Mediterranean Sea (12.5 kmol y\(^{-1}\); Rajar et al., 2007; UNEPMAP, 2001)

**Superficial sediment**

**Deep sediment**

Salvagio Manta et al., 2016. *Estuarine, Coastal and Shelf Science* 181, 134-143
Bonsignore et al., 2015. *Environmental Pollution* 205, 178-185
Bagnato et al., 2013. *Chemosphere* 93, 2024-2032

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Bagnoli (S Italy), semi-closed site

Sprovieri et al., submitted
Bagnoli

- **1853**: industrial development
- **1908**: chemical plant (MONTECATINI)
- **1910**: steel production plant (ILVA)
- **1938**: cement-asbestos production plant (ETERNIT)
- **1954**: blast furnace slag for cement production (CEMENTIR)
- **1962**: tank filled
- **1985-1993**: Eternit and ILVA stop
- **2000**: Bagnoli was included in “The National Remediation Plan” by Italian Environmental Ministry (SIN, restricted in 2014)

Sprovieri et al., *submitted*
Bagnoli

- Geochemistry (organic compounds and heavy metals) testifies huge pollution
Bagnoli

• Multiphase succession of events of dumping detected in the superficial sediments

1999-2002

post-2005

Sprovieri et al., submitted
Bagnoli

- Three different polluted sector identified (A, B, C)
- Re-distribution from point source to a much larger region through three transit axis
- Physiographic barrier and potential accumulation zone

Sprovieri et al., submitted
Cagliari (SE Sardinia), open site

- 5 sediment cores (600-1100 m below sea level)

- **1960s**: industrial development of Macchiereddu-Grogastu conglomerate behind the Cagliari town (fluorine treatment, generation and distribution of propane, petrochemical plant)

- **1965**: refinery industrial development (Sarlux-Saras S.p.A.)

- **1980s**: building of Porto Canale (1.5 mln m³ of sediment)

- **1990s**: building of Flumini Mannu dam

- **1992**: termo electric plant development (Cagliari)

- **2003**: Cagliari was included in “The National Remediation Plan” by Italian Environmental Ministry (SIN)
**Cagliari**

- Natural $^{210}$Pb$_{xs}$ T1/2 = 22.23 yrs
- Artificial $^{137}$Cs T1/2 = 30.05 yrs

- $^{210}$Pb$_{xs}$ (continuously produced) and $^{137}$Cs (time dependent) radionuclides allowed to obtain reliable and accurate dating of the cores

- Geochemistry documents in great detail some important historically anthropogenic impact during the last 110 years

Tamburrino et al., 2019. Science of the Total Environment 647, 334-341
Cagliari

• $^{137}$Cs can be reliably considered as **tracer** of terrigenous fine sediment fraction in coastal areas thus we inferred a **potential relationship** between the distance of each sampling sites from Cagliari and $^{137}$Cs inventories

• Submarine **canyons act as preferential pathway** for transport of sediment from the shelf to adjacent basins producing a **focusing** action of contaminants in pristine areas
...summarising

★ Three different geological setting
★ Three different sources
★ Three different impacts

★ One common effect: pollution transfer from local to regional/global scale
A complete understanding of the real impact of contaminated sediments on the marine environment and the resulting potential effects on the ecosystem, demands more accurate modelling and reconstruction of the biogeochemical dynamics of contaminants at different time and spatial scale.

Specific and dense connections, in the coast to deep sea framework, challenge a static view on the potential impact of polluted sediments on the marine system. Thus, the traditional monitoring of marine sediments confined to analysis of space distribution of relatively polluted areas, reduces the real understanding of the effective impact on the environment.
Sediments, to be considered time and space modulated *active sources* of pollutants for the ecosystem and marine environment, must be considered in all their *highly dynamic biogeochemistry*

Events of specific “secondary” deposition of highly polluted sediments in historical contaminated marine areas calls for specific revision of *dumping regulation* in coastal marine areas

This approach needs for modern view on an holistic and suitable management of polluted marine sediments that must *take into account the biogeochemical dynamic of contaminants in variable environmental setting*
Thank you!

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