



Sediment's vitrification from industrial sites and their reuse as secondary raw materials for mineral wool production

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Abstract:

The results of a vitrification test carried out on potentially contaminated sediment samples collected in different Italian coastal areas (Lazio, Sardinia, and Tuscany Regions) are presented. One sample has physical and chemical properties compatible with reuse for production of industrial hollow glass. Other three samples were selected and mixed in a batch simulating a composition close to that of mineral wool products. The results of the present investigation indicate that the inertization of these hazardous material is possible and their reuse as secondary raw material for the production of mineral wool is achievable and likely sustainable.

Keywords: Sediment management, Contamination, Vitrification, Raw materials.

1. Introduction

The potentially contaminated sites were surveyed by the Italian Regional Authorities according to DM 185/99 and from the sites requiring remediation established by Ministerial Decree 471/99. To date, the sites to be reclaimed are about 5,000, or 38% of the 13,000 sites potentially contaminated, of which 12,943, in many cases of limited extension, are under competence of the Region Authorities (SIR). There are also 57 sites of national interest (SIN) that covers more than 3% of the country's area, including a total of 821,000 ha of land areas and nearly 340,000 ha of sea areas (Fig. 1). About 50% of contaminated sites falls along coastal areas and Northern Italy. The main source of contamination (69%) is related to industrial and production activities in the chemical-petrochemical-metallurgical-mechanical-shipbuilding-energy sectors, followed by uncontrolled abandonment of wastes (29%). Remediation of contaminated sediments is a theme, increasingly addressed by the scientific community (CAPPUCCI *et al.*, 2011), especially in harbour areas where the quantitative assessment of potentially contaminated sediment is becoming a challenging scientific issue (AUSILI *et al.*, 2012).

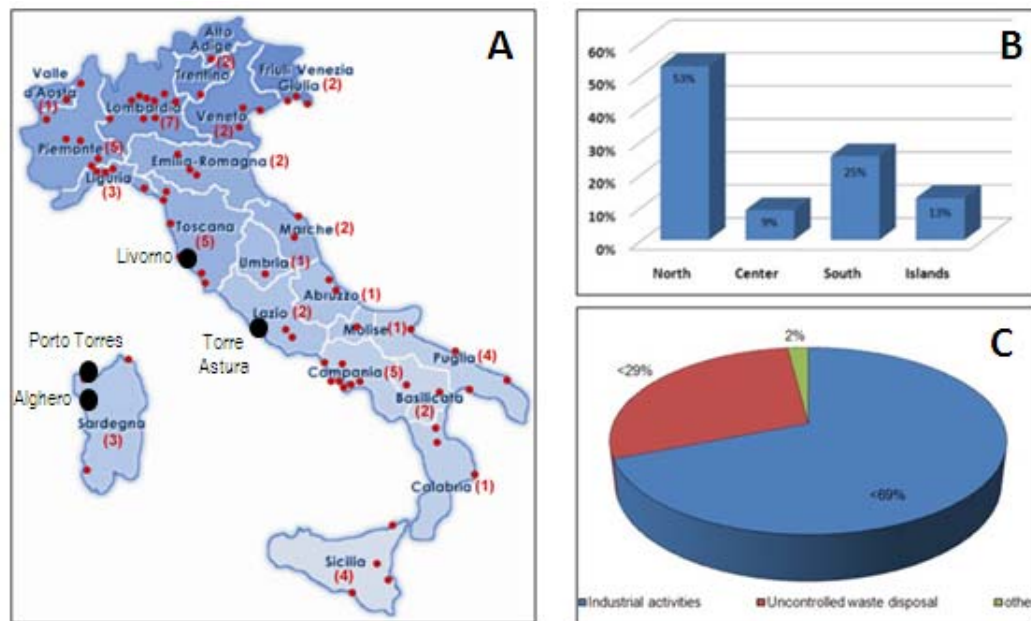


Figure. 1. Distribution of the 57 contaminated sites of national interest (A), their geographic distribution (B) and the main source of contamination (C).

2. Materials and Methods

A detailed description of the methodology used in the present research is reported in the work of FABRIZIO (2014) and is synthetically described as follow.

2.1 Delimitation of sedimentary provinces

The first phase of the work consisted in identification of the sampling sites. All information regarding the geological, sedimentological, morphological and historical information related to coastal characteristics have been consulted from the "Italian Atlas of Beaches".

2.2 The studied sites

Once the location and extent of each sedimentary province was determined along the Italian coast, the selection of sampling sites were chosen following these criteria: (a) presence of sediments with a quartz or silica content greater than 40%; (b) presence of a contaminated site of national interest and; (c) possible or imminent dredging of an harbor and/or possible contamination of the sediment by human activities.

Two sampling sites were chosen in coastal marine areas adjacent or included in the Reclamation Sites of National Interest (SIN; Porto Torres in Sardinia and Livorno in Tuscany). Other two sites were selected where local land use planning involves the construction of new port facilities (Astura, Latium) or the expansion of existing ones (Alghero, Sardinia).

2.3 Physical, mineralogical and chemical analysis

Sediments were wet and dry sieved and grain size distributions were determined both gravimetrically and by using the Coulter® Laser counter. The chemical and mineralogical compositions were assessed by WDXRF, XRD and SEM/EDX analysis. Inorganic contaminants were detected by means of both ICP-AES and ACP-MS analysis and SEM/EDX investigation.

2.4. Preparation of an ingot

Three samples (from Livorno, Torre Astura and Alghero), out of four, were selected and mixed in a batch simulating a composition close to that of mineral wool products. About 1 kg of the batch was melted in an electric furnace at a maximum temperature 1400 °C for 4 hours, casted in a steel plate and annealed at 550 °C. A homogeneous dark glass was produced. A leaching test was performed according to the UNI EN 1245-2 and it was classified as inert material.

3. Results

Many results were obtained but only part of them will be presented in Table 1, 2 and 3. One sandy sample (from Porto Torres) has physical and chemical properties that suggest its possible reuse as silica sand raw material for production of industrial hollow glass. Three samples, out of four, can be considered representative of hazardous/toxic waste in case of removal of the sediment from the seafloor, requiring expensive disposal in hazardous waste landfill by using standard management solution. They were selected and mixed in a batch simulating a composition close to that of mineral wool products. The chemical composition of the produced dark glass (Fig. 2) was compared with the calculated theoretical one (Table). A leaching test was performed according to the UNI EN 1245-2 norm and the obtained "glass" was classified as inert material.

Table 1. Grain size distribution of sediment samples and classification.

Sieve	Sample Name				Sediment
	Porto Torres	Alghero	Torre Astura	Livorno	
<i>(mm)</i>	<i>(g)</i>	<i>(g)</i>	<i>(g)</i>	<i>(g)</i>	
4,000	5,110	0,000	0,000	0,000	Gravel
2,000	34,520	0,240	0,070	5,559	
1,000	329,970	0,980	0,060	1,690	
0,500	170,850	15,510	78,150	2,141	Sand
0,250	1,030	311,180	255,880	2,467	
0,125	0,290	91,320	58,150	2,331	
0,075	0,100	0,440	0,410	1,711	
				0,000	Silt
				13,405	
				18,995	
				21,028	Clay
				10,101	

Table 2. Bulk chemical composition of sediment samples. Concentrations are reported both in weight % and ppm (according to prescription of Italian environmental national law for contaminated sites).*

	Porto Torres	Alghero	Torre Astura	Livorno
Oxides	Wt. %	Wt. %	Wt. %	Wt. %
SiO₂	90.5	59.4	43.0	55.6
TiO₂	0.04	0.11	2.35	0.76
Al₂O₃	3.40	5.90	7.10	17.2
Fe₂O₃tot	0.26	0.26	15.6	6.75
MnO	<0.02	<0.02	0.32	0.09
MgO	0.16	1.23	9.75	3.50
CaO	3.10	30.1	20.6	10.1
Na₂O	0.80	1.97	0.50	2.73
K₂O	1.64	0.57	0.20	2.77
P₂O₅	<0.03	0.04	0.16	0.22
Cr₂O₃	<0.02	<0.02	0.12	0.03
SO₃tot	<0.05	0.24	< 0.05	0.11
ZrO₂	< 0.01	0.01	0.15	0.02
L.o.i Wt. (100 °C - 1000 °C)	2.6	20.4	1.30	14.9
Metals	mg/kg ss	mg/kg ss	mg/kg ss	mg/kg ss
As*	7,32	3,35	3,63	15,8
Cd*	0,011	0,069	0,032	0,258
Cr tot*	2,09	5,04	41,1	78,7
Cu*	4,37	4,61	19,9	53,4
Hg*	0,006	< 0,01	< 0,01	0,21
Ni*	1,36	8,45	38,9	73,00
Pb*	1,67	4,22	19,6	29,50
Zn*	14,2	14,9	420	129
V*	9,17	7,62	852	48,51
Al	0,05	0,14	0,86	1,39
Fe	0,12%	0,07	1,20	2,67

Table 3. Mineralogical compositions.

Sample	Phase
Alghero	Quartz
	Calcite
	Aragonite
	Plagioclase (anortite)
Torre Astura	Pyroxenes (augites)
	Quartz
Livorno	Quartz
	Calcite
	Illite/Muscovite

Table 4. Theoretical (TC) and analysed (AC) composition of produced glass compared to typical composition ranges of mineral wool (ERCOLE, 2012).

<i>Wt. %</i>	<i>TC</i>	<i>AC</i>	<i>Typical mineral wool composition ranges</i>
<i>SiO₂</i>	50.7	49.0	38 - 57
<i>Al₂O₃</i>	10.4	10.5	0 - 23
<i>Na₂O</i>	1.57	1.13	0.5 - 5
<i>K₂O</i>	1.17	1.10	
<i>MgO</i>	5.86	6.00	18 - 40
<i>CaO</i>	18.8	18.3	
<i>TiO₂</i>	1.35	1.54	0.5 - 4
<i>Fe₂O₃tot</i>	9.43	11.7	0.5 - 12
<i>P₂O₅</i>	0.16	0.20	0 - 3



Fig. 2. Picture of black glass due to the dark sand and the presence of Fe₂O₃ and MgO.

4. Conclusions

In all countries sediment management is becoming a relevant issue, particularly when the dredging of contaminated materials is needed for port maintenance. Supply of raw materials are also essential for national, European and world economy. Scarcity of raw materials coexists with a considerable increase of waste's production, the disposal of which, along with the over-exploitation of the land, is leading further environmental degradation. On the other hand, a widespread concern is related to the possibility of replacing a certain raw material with another one. Taking into account these two aspects, the present paper contributes to technological developments that allow a sustainable exploitation of known contaminated sedimentary bodies, providing a solution to both the long lasting dredging authorisation's procedure and the remediation within harbours.

The results of this preliminary investigation indicate that the inertization of hazardous sediment and the reuse as secondary raw material for the production of mineral wool is achievable. In particular, the recovery of contaminated sediments as a raw material for the production of glass for mineral wool industry has been proved by production of an

ingot of matter that would allow to produce samples of batches on a pilot plant. This product is facing an increasing interest of many countries (FABRIZIO *et al.*, 2014). Nonetheless, further investigation and industrial scale tests are required in order to confirm the feasibility of the industrial implementation.

For this reason, in July 2014, the Italian Ministry of Economic Development (Directorate General for Industrial Policy, competitiveness and SME), has requested to ENEA a research proposal dedicated to the remediation of contaminated sites as part of a larger program agreement, but such activities have not yet been funded.

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