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Mineralogical and chemical characterization of Joule heated soil contaminated by ceramics industry sludge with high Pb contents

Francesco Dellisanti, Piermaria L. Rossi, Giovanni Valdrè *

Dipartimento di Scienze della Terra e Geo-Ambientali, Università di Bologna, Piazza di Porta, S. Donato, 1 I-40126, Bologna, Italy

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Abstract

This research deals with the first attempt to vitrify by a Joule heating process soils contaminated by Pb (2.85 wt.%) from ceramic industry sludges.

Physical, mineralogical, and chemical characterization of the glasses were obtained by using several imaging and analytical techniques, namely Scanning Electron Microscopy (SEM) with coupled Energy Dispersive Spectroscopy (EDS), X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and by a specifically built-in sensor for "in-situ" temperature measurements of the melt. The chemical stability of the glass produced by the process was determined by leaching tests.

The progressive heating and successive melting of the soil led to decomposition of organic compounds and removal of volatile metals. The cooling of the melt formed a monolithic glass with the aim of immobilizing the heavy metals and inorganic contaminants.

All the glasses were found, on a macroscopic scale, mineralogically, chemically and morphologically homogeneous independent of the starting composition. However, on a microscopic scale an inhomogeneous glass matrix was observed. SEM-EDS and XRD revealed the presence of micro-sized Pb particles and Zr_2SiO_4 (zircon) crystals. In agreement with the microscopical observations, leaching tests indicated high leaching behaviour for Pb.

These results should be considered as a general study of the technological effectiveness of vitrification by Joule heating technology with a view to scaling up the process on a field scale and to the treatment of large amount of inorganic industrial wastes containing high amounts of Pb.

Keywords: Joule heating vitrification; Remediation treatment; Glassy materials; Thermal process; Lead

1. Introduction

Abundant literature deals with treatments based on physical and thermal properties of soils by vitrification process to remediate inorganic contaminants (Jacob, 1991; Johnson and Cosmos, 1989; Jouan et al., 1986; Komatsu et al., 1990; Orfeuil, 1987). In particular, many efforts have been devoted to develop in-field remediation treatments, in order to prevent or at least reduce the risks related to the removal of contaminated materials.

Significant research findings on in-situ vitrification technology (ISV) can be found for instance in reports of the United States-Environmental Protection Agency (Richardson et al., 1995), and of the Pacific Northwest Laboratory (Buelt and Bonner, 1989; Buelt et al., 1987; Farnsworth et al., 1990; Kuhn, 1992; Thompson et al., 1992; Timmerman and Peterson, 1990).

* Corresponding author. Tel.: +39 51 2094943.
E-mail address: giovanni.valdre@unibo.it (G. Valdrè).

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Table 1
Chemical data obtained by X-ray fluorescence (XRF) of the starting materials: R-1, uncontaminated soil; SCI, sludge ceramic industry. LOI value (Loss On Ignition) takes into account the volatile components (H_2O, CO_2, organic matter etc.) evaluated by calcination at 950 °C

% Weight	R-1	SCI
SiO_2	39.35	46.23
TiO_2	0.56	0.52
Al_2O_3	12.58	9.42
Fe_2O_3	5.19	3.32
MnO	0.10	0.15
MgO	3.48	1.82
CaO	15.28	10.44
Na_2O	0.49	2.3
K_2O	2.13	1.61
P_2O_5	0.13	0.15
PbO	<d.l.	3.07
ZrO_2	<d.l.	4.03
LOI	20.70	16.02

Instrumental detection limit is ~0.01%.

ISV treatment is a thermal process based on the Joule effect (Aneko et al., 1992; Buelt and Bonner, 1989; Farnsworth et al., 1990; Spalding et al., 1992; USEPA, 1992), which consists in heating the polluted soil by high power currents up to the melting temperature. The progressive heating destroys organic contaminants and removes volatile and semi-volatile metal compounds (Alexiades et al., 1994; Kuhn, 1992; Spalding et al., 1992). After cooling the melt forms a glassy product that immobilizes the inorganic contaminants.

ISV process, initially developed by Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE) (Buelt and Bonner, 1989; Spalding et al., 1992; Thompson et al., 1992), should be capable of reclaiming polluted soils contaminated by a wide variety of inorganic industrial wastes including heavy metals, mine tailings, radioactive metals, sludge, fly ash, asbestos, etc. (Farnsworth et al., 1990; Paxton, 1985; Roberts, 1989; Thompson et al., 1992). The main advantages of this innovative technique are both the capability to treat simultaneously different pollutants and to avoid the problems and risks associated with the recovery and transportation of contaminated soils.

Table 2
Semi-quantitative mineralogical composition (accuracy of ±1%) obtained by normative recalculation of the chemical and XRD data of the starting materials: R-1, uncontaminated soil; SCI, sludge ceramic industry

% Weight	R-1	SCI
Quartz	30	31
Calcite	24	18
Dolomite	12	<1
Plagioclase	4	20
K-feldspar	4	<1
Chlorite	10	<1
Micas	14	16
Kaolinite	<1	5
Alamosite	<1	4
Zircon	<1	6

The present paper originates from the development of in-situ vitrification technology promoted by a research project of the University of Bologna and of a national company (AREA-HERA S.p.A., Italy) with the aim to develop large scale remediation processes of contaminated soils.

In order to verify the technological effectiveness of the ISV treatment, the research was initially conducted on a pre-pilot scale before the scaling up to the field

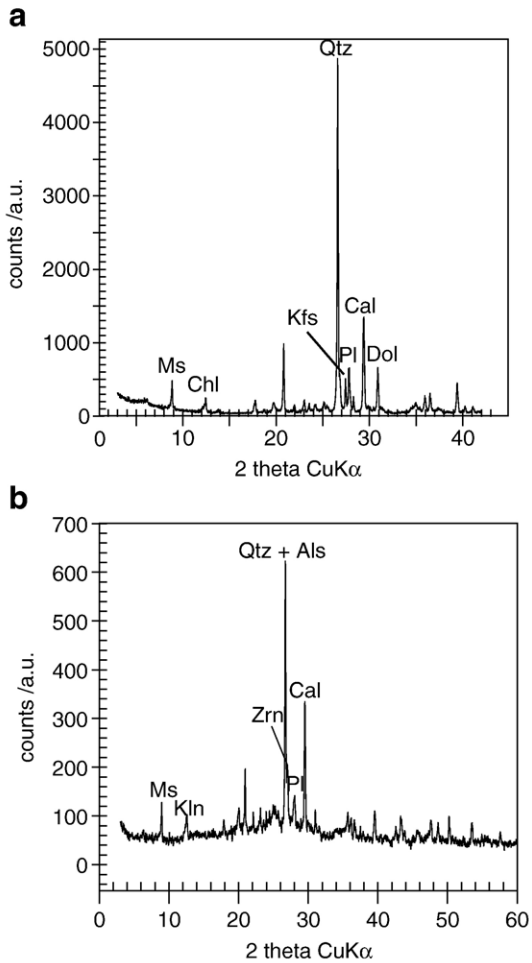

Fig. 1. XRD patterns of starting materials treated by the vitrification process, a) uncontaminated soil R-1; b) sludge ceramic industry (SCI); Qtz: quartz; Cal: calcite; Dol: dolomite; Pl: plagioclase; Kfs: k-feldspar; Ms: micas; Chl: chlorite; Kln: kaolinite; Zrn: zircon; Als: alamosite.