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Environmental effects of using clay bricks produced with sewage sludge: Leachability and toxicity studies

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ABSTRACT

Use of sewage sludge from wastewater treatment plants as a raw material for making clay bricks has been analyzed to be an option to dumping sludges into landfills. This alternative has been shown feasible and interesting due to the high rate of use of ceramic materials in the building sector. However, it meets with some environmental issues and some prejudices on the part of users.

This work shows some leachability and toxicity tests (outgassing and offgassing) which demonstrate the environmental compatibility of these ceramic products to be used as building materials and even in deconstruction of the building once its useful life is ended.

1. Introduction

Disposal of sewage sludges from wastewater treatment plants (WWTP) is a serious global environmental issue. During the last 20 years, the most developed countries have been converting urban sludge into a resource such as: (a) fertilizer in agriculture, (b) industrial chemicals (i.e. cements), (c) energy, and/or (d) material for building. Depending on the composition and characteristics of the urban sludge, treatment is applied for a given resource use. Before the sludge can be converted into a resource, first it is important to solve the problem of its high moisture contents. There is no guarantee that the most efficient, most energy saving, and most economical sludge wastewater treatment technology will not develop a secondary environmental pollution. Transforming sludges as a raw material for making clay bricks may be one relevant solution to this problem if the final product achieves good environmental performances (Fig. 1).

Incorporating sewage sludges or incineration ashes to ceramic matrices has been proposed and researched since the eighties of the last century (Alleman and Berman, 1984; Ferreira et al., 1999; Lin and Weng, 2001; Weng et al., 2003; Liew et al., 2004; Montero et al., 2009). These authors have shown the feasibility of that industrial process. However, some sectors of public opinion are against to put in practice that process, because it claims that on one hand such a process is like a concealed incineration or pyrolysis that would emit hazardous air pollutants, and on the other hand the products from that process would not be innocuous for the health of users. Actually, the toxicity and health related issues are well documented and are relatively easy to find in the literature, for instance, REACH (2006) or WHO (2011).

In summary, there is a public concern about the sanitary safety of buildings built with these materials, since it is thought that it means to place toxic and hazardous wastes directly into houses. There is then necessary to achieve a deep and suitable environmental assessment of both industrial process and final products.

This paper aims to analyze the leachability and toxicity of ceramic products made with different types of municipal sewage sludges and paper industry sludges, in order to show the harmlessness of these materials during their life cycle. Emission of gases during their production has been already studied in other works (Cusidó et al., 2003).

Leachates are the eluates formed by reaction, draining or filtration of materials contained in the waste. They have some substances in solution or in suspension that can be infiltrated into ground giving rise to soil and/or underground water pollution issues, representing potential risks to environment. In our case, leachates from ceramic materials (clay bricks) made with sewage sludges are basically heavy metals that were present in the waste (or in the clay). Organic compounds from sludges are fully destroyed during firing at the ceramic production, and then do not appear in leachates (Weng et al., 2003).

From a general point of view, most important heavy metals which can damage human health are: arsenic (As, cancerigen),

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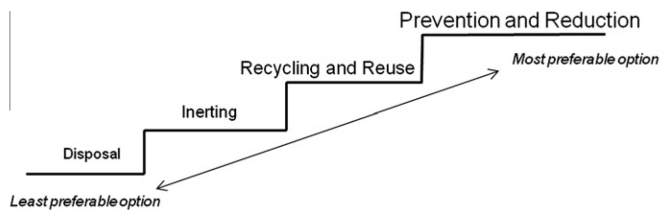

Fig. 1. Hierarchy of pollution prevention. The use of sewage sludge for making ceramic material is considered the second step: recycling and reuse.

cadmium (Cd, probably cancerigen, teratogenic and embryotoxic), chromium (Cr, cancerigen and probably mutagenic), lead (Pb, probably teratogenic), mercurium (Hg, teratogenic), and nickel (Ni, probably cancerigen and teratogenic). Apart from leachates, it is necessary to know the composition of unhealthy particles and gas emissions that could be released from ceramic products by means of rigorous degasification and toxicity studies. With these studies, we can assess the effective inertization of sewage sludges into ceramic matrix.

2. Experimental procedure

2.1. Products analyzed

Samples tested consisted of ceramic pieces made with different WWTP sewage sludges: physico-chemical, biological and from paper industry. These pieces were prepared by mixing variable percentages of clays, sludges, and eventually forest waste (sawdust), and then by extruding the mixture, according to the information presented in Table 4. Some of these pieces included coating ceramics made with spray-dried raw sludges from physico-chemical WWTP (dry route) (Fig. 2). Procedure for manufacturing is explained in Cusidó et al. (2003) and Devant et al. (2011).

Chemical composition of inorganic compounds in the sludges and clays tested is presented in Table 1. In our case, organic compounds were not a concern due to their total thermal destruction. General procedure for obtaining the ceramic pieces consists of the following stages: formation of the "green" (or wet) mixture, extrusion, drying, and thermal treatment up to 1050 °C, as usual in the industrial production of clay bricks and tiles (in this last case, the piece is formed by compressing dry dust from atomized sludge).

At this temperature, organic matter is totally destroyed and is responsible for the high porosity of the microstructure (Fig. 3). This porosity, although affects the mechanical resistance, gives the ceramic piece interesting properties such as low weight, and thermal and acoustic insulation. A description of the process for producing ceramic materials with sludges can be found in Alleman and Berman (1984), Almeida et al. (1997), Cusidó et al. (2003), and others.

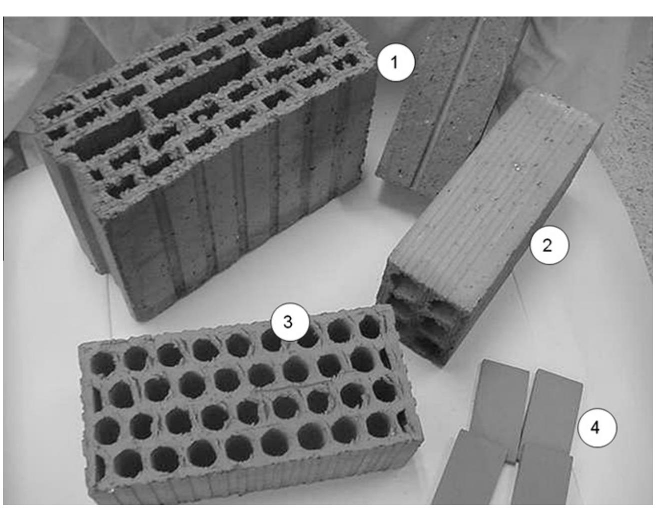

Fig. 2. Ceramic materials for building produced in industrial tests containing different percentages and types of sewage sludges that are under investigation: (1) ceramic block and clay brick made from biological treatment sludges and shredded forest residues (sawdust); (2) clay brick produced with physical–chemical treatment sludges; (3) structural ceramics made from paper industry sludge; (4) tiles obtained with atomized raw sludges from physical–chemical treatment.

2.2. Leaching/extraction test related to building materials

Development of leaching studies has issued a high scientific controversy about which should be the right methodology, especially as far as methods of chemical extraction of leachates are concerned. In this sense, there is a wide international literature and research (Wiebusch et al., 1998) and even some EU Directives have been dictated with the aim of harmonizing the methodologies related with building materials (Van der Sloot, 2005).

In the present study, we have followed the norm NEN 7345 from the Netherlands Tank Leaching Test (NEN 7345, 1993). This norm is expressly dedicated to building materials and largely applied in Netherlands and EU, in general.

To carry out the tests, three samples of 8 cm long were prepared to which volume, surface area and mass were measured, in each case. The samples were put into distilled water and the concentration of inorganic compounds was measured at several time intervals. Procedure was as follows.

2.2.1. Preparation of samples

Each piece was introduced into a polyethylene container and covered with distilled water at pH fitted to 4 by adding nitric acid which was used as extractant agent, according to NEN 7345. This norm is more severe than the more recent NEN 7375 (2004) in which the diffusion test is conducted with pH neutral instead of acidified water. In total, there were 12 sample recipients, three of them containing a blank (100% clay ceramic piece). Volume of extractant agent in each recipient should have to be 5 times the volume of the sample, and the sample had to be covered by a layer of not less than 5 cm high.

For each sample, eight extractions were done. The sample was left with a given number of days, such as indicated in Table 2, without agitation. The extractant agent was changed at every further sampling.

Leachate obtained from each extraction was filtered through a 0.45 mm filter, its pH was corrected with nitric acid, and chemical elements were analyzed following their appropriate technique:

- Heavy metals at pH = 2.
- Fluor at pH = 5–6.
- Cianures and ions: without pH correction.

2.2.2. Measurement and calculation

Elements measured and techniques used were those described in Table 3.

Eq. (1) was used to compute leachability of each pollutant at the *i*-th extraction:

$$E_i = \frac{(C_i - C_o)V}{1000A} \quad (1)$$

where E_i, leachability of a pollutant at the *i*-th extraction (mg m^{-2}); C_i, pollutant concentration at the *i*-th extraction (mg L^{-1}); C_o, pollutant concentration in the blank (mg L^{-1}); V, volume of extractant agent (L); A, surface area of the sample (m^2). After eight extractions,