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Application of sewage sludge in the manufacturing of ceramic tile bodies

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Abstract

The substitution of clayey raw materials urban sewage sludge in the production of traditional ceramics could give place to a cost saving due to the utilisation of wastes as secondary raw material. At the same time, it can help to solve the environmental problems associated to such wastes. This research shows the results of the substitution of clay for sewage sludge in different proportions in a ceramic body. The sludge characterisation has been carried out by an analytical protocol. After that, the most suitable products were selected regarding to the chemical composition and the technological characterisation of the resulting ceramic material.

Keywords: Sewage sludge; Ceramic clays; Ceramic tiles; Recycling; Technological characterisation

1. Introduction

Due to determining environmental factors, the use of water treatment and purification process have been generalised worldwide, specially in those countries with an increasing scarcity of water resources. There are several water purification processes, but from every case and type of treatment, a waste denominated as "sewage sludge" is generated. If an integral treatment of the whole generated sewage were to be developed in Spain, and considering a population of 40 million habitants, a total production of about 3 million tons of sludge per year would be reached. After being composted and estimating between 60% and 70% of sludge are susceptible of agricultural use, we would reach about 500,000 tons of agriculturally composted sludge suitable per year (Bigeriego, 1993). At present, the disposal of these wastes takes place by three ways such as land or sea dump-

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ing, recycling or utilization with agricultural purposes, and finally incineration. Therefore, it is necessary to investigate for new applications for this type of waste.

Usually, the sewage sludge is a heterogeneous solid material which composition is quite variable depending not only on the origin of the effluent to be treated, but also on the technology used during its treatment. These processes will determine the different quantities of the sludge inorganic compounds (Sommers, 1977), and thus the extent to which those compounds are associated to the sludge organic fraction (Clapp et al., 1986). There are many reviews that develop statistical researches on the sludge composition. It is about a sludge rich in organic matter and in some elements such as N and P. On the other hand, the sewage sludge despites a high electric conductivity due to its high salt concentration (Davis, 1989; Dondi et al., 1997; Navarro Pedreño et al., 1997). The origin of the effluent will determine the presence of toxic elements and agents. Sludge coming from wide urban areas with a substantial industrial influence, usually show higher concentrations of metals typical of factories such as Cr and Ni. The treatment that the sewage receive during the purifying process may increase the existence of certain compounds in the sludge, specially ferric or aluminium salts added in order to favour the flocculation processes.

On the other hand, during the firing process of ceramic pastes takes place a series of reactions and transformations in the phyllosilicates and accompanying minerals like quartz, feldspar, calcite, dolomite and hematite, which will be decisive to establish the final properties of the ceramics products (Real, 1977; Jordán et al., 1999). The crystalline structures exceed its limits of stability and they partially decompose simultaneously that other phases are formed. But the destruction of the pre-existing structures is not an instantaneous effect (Jordán et al., 1999). There is a huge amount of literature on the disappearance and the neomineralization of clay bodies by firing. Clays for porous ceramic bodies were the subject of a study by Peters and Jenny (1973) and Pollifrone and Ravaglioly (1973). González-García et al. (1990) studied the formation of gehlenite and anorthite in calcareous clays which were originally composed of illite, kaolinite, quartz and calcite. Jordán et al. (1993, 1994, 1995) and Almendro et al. (2001) studied the Cretaceous clays from Castellon and their behaviour when they were heat treated by fast firing. This study specifically discusses the behaviour of two calcareous clays from the areas around Agost (Alicante) and La Rioja (Spain) mixed with different quantities of sewage sludge. The geological and mineralogical characterisation of some ceramic pathologies in this ceramic clays were also carried out by Almendro et al. (2002), Jordán et al. (2002) and Miralles et al. (2002).

The aim of this work is to study the effect of the substitution of clay for sewage sludge in different proportions on the technological properties of a ceramic material.

2. Materials and methods

2.1. Characterisation of raw materials

Two standard ceramic clays (RM1 and RM2) and three samples of sewage sludge (A, B and C) coming from three different sewage plants were selected. Tables 1 and 2 show the chemical composition (wt.%) of the samples by X-ray fluorescence. Soluble SO_4^{-2} and Cl^- (expressed in ppm) have been analysed by gravimetry and titration respectively. The total organic matter by calcination at 500 °C while the loss of mass by calcination at 1000 °C (Fernández,

Table 1
Chemical analysis of clays used as raw materials

Parameter	Units	RM1	RM2
O.M. 500 °C	%	1,96	2,56
Deads (1000 °C)	%	12,23	12,98
$CaCO_3$	%	21,00	19,89
$SO4^{-2}$ (solubles)	ppm	4358	2089
Cl^- (solubles)	ppm	212,85	156,40
SiO_2	%	52,69	51,02
Al_2O_3	%	17,85	21,31
Fe_2O_3	%	7,15	6,92
CaO	%	11,29	12,97
MgO	%	4,24	2,72
Na_2O	%	0,394	0,757
K_2O	%	4,23	4,21
TiO_2	%	0,868	0,827
MnO	%	0,0502	0,0809
P_2O_5	%	0,195	0,275
Total SO_3	%	0,570	0,120