4th European BioRemediation Conference

ID 021

SOLIDIFICATION OF DRIED ACTIVATED SLUDGE IN CERAMIC MATERIALS

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ABSTRACT

A sustainable sludge management plan targeting in resource recovery, minimization of secondary pollution and reduction of treatment cost is necessitated. Addition of sewage sludge in ceramics is an interesting alternative for sludge reuse and the production of material with distinguished physical properties. The objective of this paper was to identify mechanical properties and heavy metal leachability of ceramics materials constructed using mixtures of conventional soil and powder activated sludge (PAS) the latter varying from 0, 2, 4, 6 and 8% per weight. Addition of more than 2% PAS leads to weight reduction by 4-7 % and increase in porosity by 10-15%. According to preliminary leaching studies with deionised water, the PAS percentage had no significant influence on the mobility of heavy metals. Most of the metals concentrations were below the EU limits except for Pb. The results of this work demonstrate the feasibility of re-using sewage sludge in ceramic materials.

1. INTRODUCTION

Approximately 10 Mtn dry mass of sewage sludge originating from conventional activated sludge wastewater treatment plants, are produced annually in the EU [1]. This material contains both important resources (organic matter, macro- and micro-nutrients) as well as hazardous materials (micro-pollutants, heavy metals). In Greece, 90% of the sludge produced is disposed into landfills, despite the fact that European legislation demands the reduction of organic biodegradable solid waste load that is entering at landfills [1]. Therefore, a sustainable sludge management plan is necessitated, targeting in material or/and energy utilization, in minimization of secondary pollution and all with the minimum costs.

Except from landfill disposal, sludge can be reused in agriculture as fertilizer. However, its use is restricted due to the European legislation that determines the maximum annual heavy metal load per surface unit and due to the possible hygiene risks by pathogen load of sludge [2]. Incineration is another possible approach for sludge disposal that, however, is accompanied by gas emissions that leads to expensive off-gas treatment.

Use of incinerated sludge ash as an additive in construction materials, like asphalt concrete, bricks and cement have been widely demonstrated [3-5]. The use of dried sewage sludge as an additive in construction materials appears an equal interesting solution for sustainable sludge management. By this way, sewage sludge is reused and the pollutant content is stabilized, during mixing obnoxious compounds with various binding media.

Aim of this work is to provide an insight of the physical and mechanical properties of ceramic bodies constructed with conventional soil and powder activated sludge (PAS). Furthermore, the paper focuses on the leachability of heavy metals from these materials and the compliance with EU regulations.

2. MATERIALS AND METHODS

2.1 Ceramic samples

Ceramic bodies were produced using as an additive powder activated sludge of 0, 2, 4, 6 and 8% per weight. Sewage sludge was obtained from a municipal wastewater treatment plant after thickening and dewatering. Sludge drying was accomplished in two pilot-scale greenhouses. A schematic diagram of the proposed method is shown in Figure 1. In this work, the clay:sludge mixtures were fermented and casted manually, then dried at 100 ^{o}C for 24 h and heated following a protocol of gradual increase of temperature up to 900 ^{o}C. The final product is shown in Figure 2.

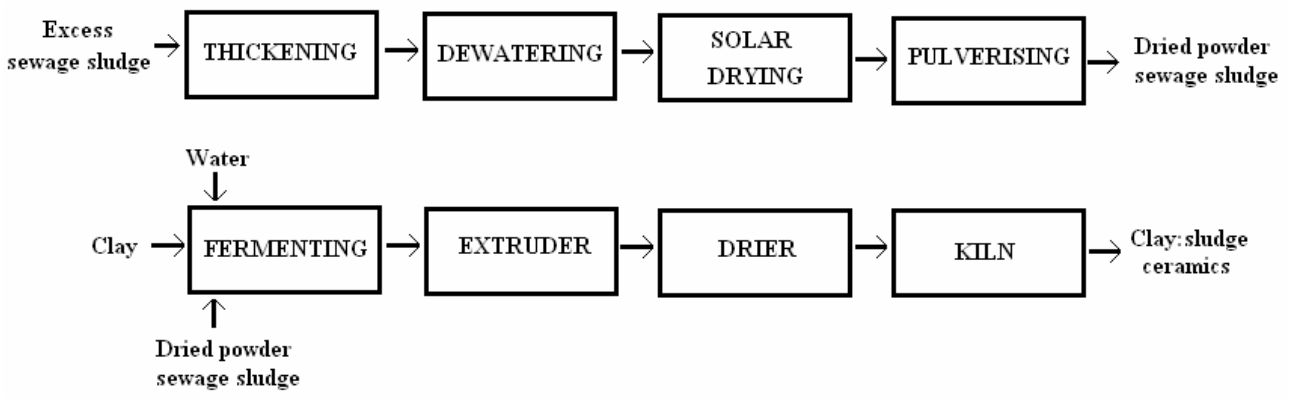

Figure 1. Schematic diagram of the process for the production of ceramics by using waste activated sludge

2.2. Testing procedures

The ceramic specimens were tested for definition of physical, mechanical and chemical properties. Physical properties comprise density, water absorption and porosity, the later being mainly controlled by the voids left as the sewage sludge becomes ash during the heating phase. Among the mechanical properties, tensile strength was chosen as the prominent one to identify the impact of sludge percentage on its deterioration. Leachability of heavy metals in deionized water (200ml/20g) was tested in batch stirred vessels using crushed ceramic bodies (5-15 mm). After 24 h the water was separated from the ceramic materials using vacuum filtration with 45 μm mixed cellulose membranes. The filtered leachates were transferred to glass flasks, pH was measured and the solution was acidified with nitric acid to pH 2. The samples were condensed by evaporation and consequently analyzed for heavy metals (Cd, Cr, Cu, Pb, Fe, Mn, Zn) using an Atomic Adsorption instrument (Varian) by employing standard methods of analysis.

Figure 2. Samples of final ceramic bricks prepared using different percentages of clay and powder activated sludge.

3. RESULTS AND DISCUSSION

3.1 Mechanical properties

In Figure 3 the porosity, weight reduction and tensile strength of ceramic specimens prepared with different PAS percentages is presented. According to these results addition of more than 2% of dry sewage sludge leads to weight reduction 4-7 % and an increase in porosity by 10-15%. However, in order to maintain similar mechanical properties with common clay ceramics, the percentage of sludge must not exceed 4%.

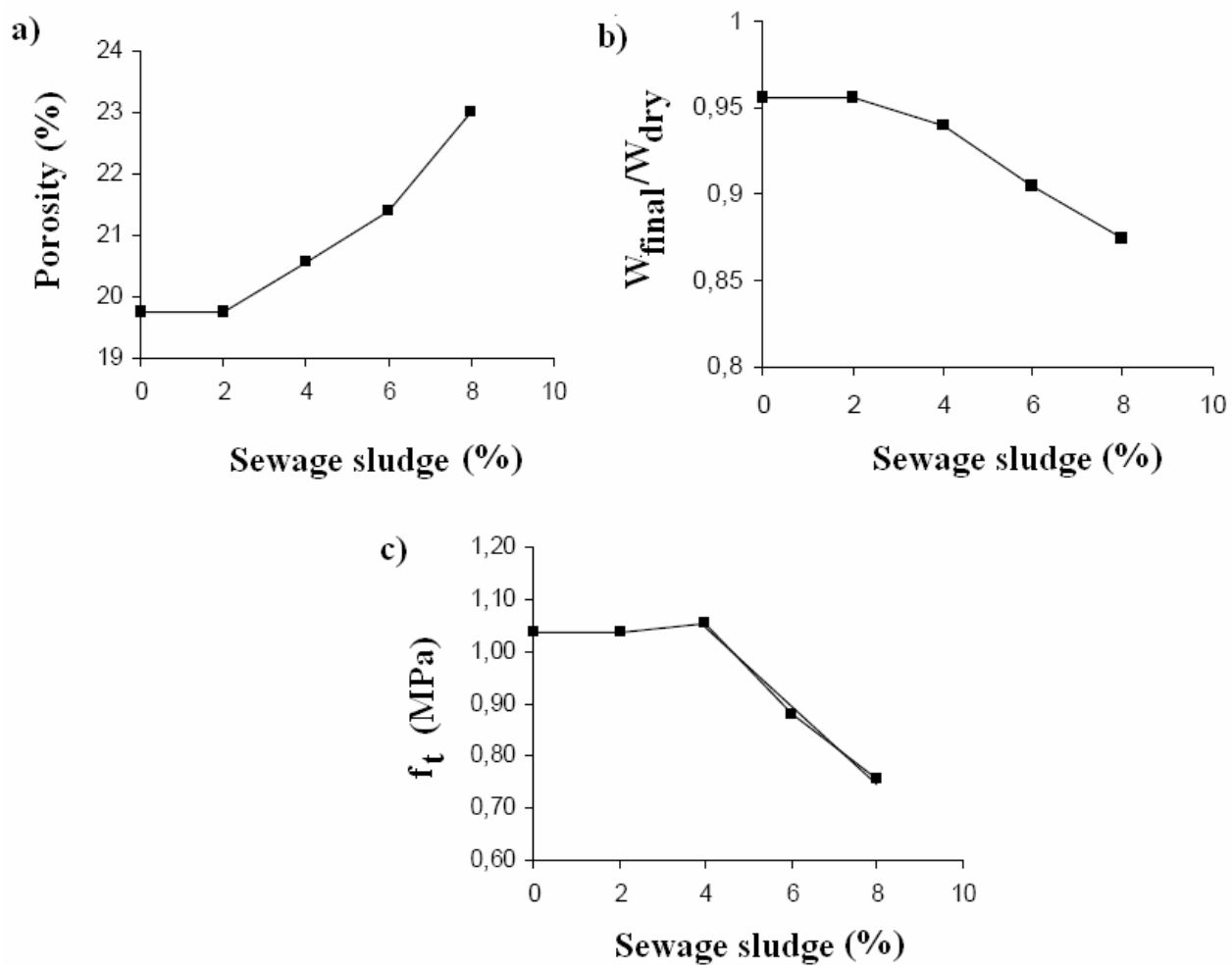

Figure 3. Effect of PAS percentage on (a) porosity, (b) weight loss and (c) tensile strength of ceramic bodies.

3.2 Leachability of heavy metals

Based on the leaching studies it can be concluded that the content of the examined metals follows the order Zn > Pb > Fe > Ni > Mn > Cd > Cr. The concentrations of Pb and Mn revealed a strong correlation with sludge content in contrast to the concentrations of Ni and Zn that were found to be lower, for sludge content up to 6%, than the respective of the control ceramics. Despite the fact that increasing sludge content leads to an increased porosity, which is beneficial for capillary water movement, inside the ceramic structure and heavy metal mobility, the increase of sintering temperature due to combustion of sludge organics may be the reason for heavy metals stabilization [6]. The final concentrations in the leachates were below the EU limits in all cases except for Pb.

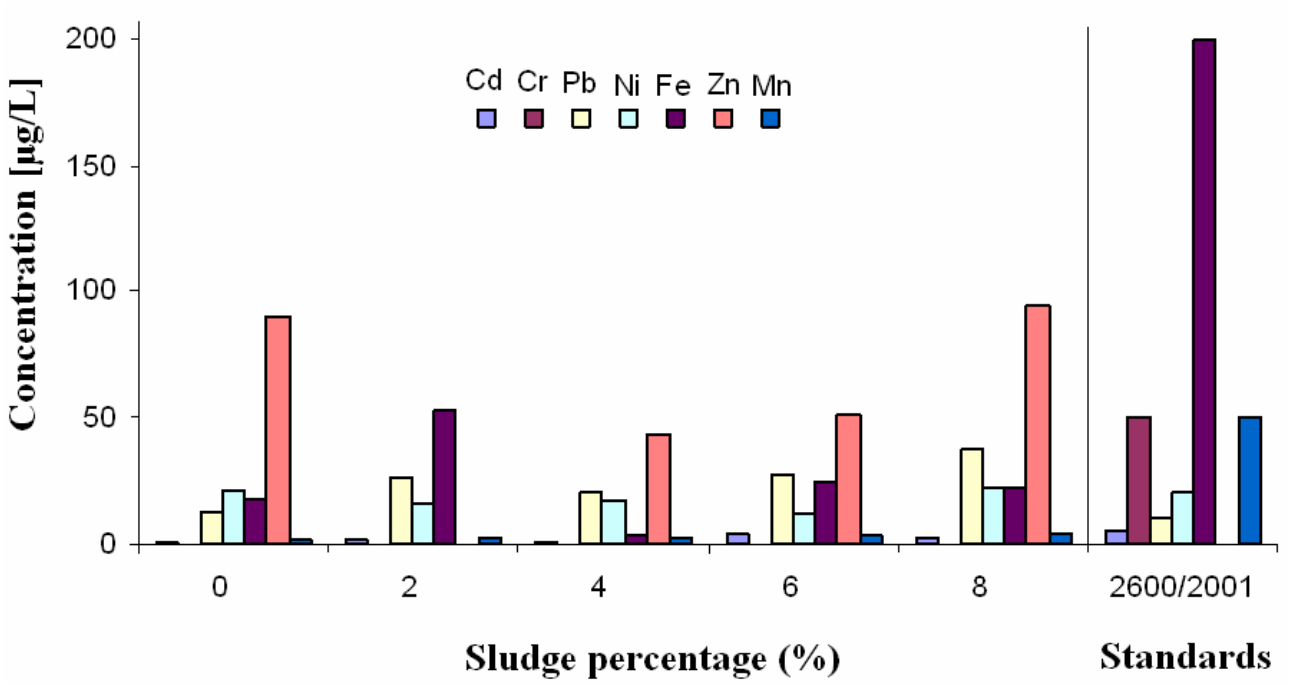

Figure 4.Comparison of the heavy metals content obtained by the leaching test under different sludge percentage and the standards for disposal according to the EU Directive 2600/2001.

4. CONCLUSIONS

Powder activated sludge (PAS) can be directly re-used for the production of light-weight ceramics. The percentage of PAS had a significant influence on physical and mechanical properties of laboratory made ceramics such as porosity and tensile strength. The mobility and leaching behavior of heavy metals in clay:sludge ceramics is slightly affected by PAS percentage between 2-8%.

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