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Research Paper

# Utilization of water treatment plant sludge in structural ceramics bricks

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ABSTRACT

The main aim of this study is to assess the effect of incorporating water treatment sludges (WTS) of plant Bouregreg on the properties and microstructure of clay used for raw material.
This work proposes to test the clays used in the manufacture of a ceramic that could incorporate alumina sludge. The raw materials, alumina sludge and clay, were mixed together in different proportions, were prepared by incorporating from 5 to 30%. Specimens of these mixtures were then fired at 800, 900, and 1000 °C. In order to determine the technological properties, such as bulk density, linear shrinkage, water absorption, compressive strength, X-Diffraction, and Scanning Electron Microscopy. The results obtained showed that the samples tested are dense and have high mechanical resistance, without deformation or defects.
These clay materials may be used for the production of terracotta products and also for the formulation of low porosity raw material.



## 1. Introduction

A water treatment plant produces large quantities of sludge as a result of treatment processes of raw water such as flocculation, filtration and coagulation. According to regulations, drinking water sludges are classified as “non-hazardous waste” also known as “banal industrial waste” (BIW). That implies that they are not submitted to the heavy constraints of “hazardous waste” (Miroslav, 2008). This sludge can be dewatered further by thickening, centrifugation and filtration operations in order to recover water and minimize the volume of the waste stream is commonly to dewater the sludge up to about 30% dry matter(DM) and then pay to send it to a commercial landfill (Benlalla et al., 2015).

However, this practice is becoming more and more expensive. Consequently, National Office of electricity and drinking water of Bouregreg initiated a research project on alternative methods for utilization of mill sludges. Questions have been raised in regard to the potential environmental impacts of the sludge when used.

The recycling of such waste to fabricate structural ceramics can be technologically, economically, and environmentally attractive because it produces materials with greater flexural strengths and provides for adequate treatment of the water treatment plant (WTP) sludge. Therefore this technological innovation for manufacturing news products was able to minimize the impacts of WTP residues and can be seen as an environmental performance of industrial solid waste from WTP.

The sludge produced by WTP can be used like additive to produce high-alumina refractory ceramics, lightweight aggregate (LWA), Glass-ceramics, and finally as a prime material for clinker manufacture (Ferreira and Olhero, 2002; Huang and Wang, 2013; Toya et al., 2007; Husillos Rodríguez et al., 2011).

The sludge produced by WTP can also be a potential substitute for brick clay because its chemical composition is very close to that of brick clay (Hegazy et al., 2012). In addition, the use of sludge in the construction industry is considered to be an economic and environmentally sound option (Ramadan et al., 2008). The concentration of sludge that can be incorporated into clays in order to produce bricks depends partly on the sludge properties (grain-size distribution and chemical and mineral composition) but even more so on the properties of the raw materials used (Teixeira et al., 2011). Using bench-scale experimentation, (Alleman and Berman, 1984), showed that conventional clay and shale ingredients for bricks could be partially supplemented with sludge. They called this clay product “biobrick”. Bricks manufactured from dried sludge collected from an industrial wastewater treatment plant were investigated by (Lin and Weng, 2001; Weng et al., 2003b). These reports showed that the sludge proportion and the firing temperature were the two key factors determining brick quality (Liew et al., 2004). In accordance with a previous study, bricks produced from sewage sludge of different compositions were investigated by incorporating WTP sludges with different proportions that can reduce the cost due to the utilization of waste and, at the same time, it can help to solve an environmental problem (Pereira et al., 2000). The utilization of WTP sludge in brickmaking eliminates an environmental problem, several economies related to the replacement of a natural raw material are generated, leading to environmentally friendly practices (Beretka, 1975).

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**Table 1**
Chemical compositions of raw materials determined by XRF.

| Raw materials | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | CaO | MgO | $Na_2O$ | $K_2O$ | $P_2O_5$ | LoI | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WTP sludge | 27.12 | 62.66 | 1.16 | 0.16 | 1.25 | 0.37 | 0.24 | 0.83 | 0.19 | 5.11 | 99.09 |
| Clay | 54.17 | 15.27 | 6.81 | 0.91 | 10.88 | 7,74 | 0.76 | 2.85 | 0.12 | 10.29 | 99.51 |

LoI: loss Ignition.

Utilization of water treatment sludge in the industry of construction products is promising and economically reasonable, and the products produced are not contaminated with hazardous impurities (Liew et al., 2004). Therefore, the objective of the research is to determine the influence of drinking water treatment sludge, which is composed from a large amount of $Al_2O_3$, on physical and mechanical properties, structural parameters, mineralogical composition of the ceramic body burned at 800 to 1000 °C temperatures. In addition, the possibility to utilize this additive in the production of ceramic products was studied.

## 2. Experimental

This section describes the materials and methods used to investigate the feasibility of using WTS for brick production and characterize the structural properties of the resulting bricks.

### *2.1. Sludge and clay samples*

The sludge used in this work was collected from the water treatment plant of Bouregreg located in the city of Rabat (Morocco). In this industry, the water is treated with aluminum sulfates, and cationic polyelectrolytes. The sludge was collected from thecoagulation/flocculation tank once a week during 12 months. The material was sun-dried during 72 h and stocked after each collection. All the collected materials were homogenized. The dried materials were then milled and passed through a 0.6 mm sieve before use. The used clays were supplied by a local bricks industry (Rabat. Morocco). The samples of clay were also sun-dried during 72 h and sieved to 0.6 mm particles. In order to get a uniform particle size. Both sludge and clay were dried with an electric heater during 48 h at 105 °C in order to remove moisture, to get a representative samples for a number of chemical–physical analyses.

### *2.2. Characterization of raw materials*

Tables 1 and 2 show the chemical composition by XRF and a range of metals including Pb, Cd, Cu, Cr, Zn and Ni analyzed using ICP. All of these metals and their concentration in the sludge is an important indicator for the quality for sludge. It can be seen that Alumina is the most abundant element in the sludge, which also contains a significant amounts of Silica, as well as minor amounts of Fe2O3, CaO, MgO, Na2O and K2O. Environmental safety testing based on heavy metals concentration in WTS tested shows the satisfactory in comparison to the permitted standards (TCVN 5945–2005: Fe < 5, Ni < 0.5, and Cr6 + < 0.1 ppm) (Degirmenci, 2008).

### *2.3. Preparation blocks sludge bricks*

Bricks containing 5 to 30% WTS by weight were produced in accordance with the mix compositions as shown in Table 3. The mixture of brick clay and WTS slurry was placed in a commercial kitchen mixer (20 L capacity) and mixed for 60 min while water was added after 10% moistening by weight. The plastic mixtures prepared in this way were stored in plastic bags for one day to achieve a homogenous distribution of moisture.

The plastic mixtures were molded in a pilot scale screw mold of size 80 × 30 × 20 mm. the shaped samples were held for one day and then dried in an oven at 105 °C until constant weight was achieved. The dried samples were then fired in an electric furnace at three different test temperatures; 800 °C, 900 °C and 1000 °C at an average heating rate of 5 °C/min with a 2 h soaking time at the respective peak temperatures. The samples were furnace cooled for further experiments. Fig. 1 shows aspect of raw samples and fired at 800 to 1000 °C.

### *2.4. Brick testing method*

Because water content is an important factor affecting the quality of the brick, tests compaction, and Atterberg limits were conducted, to obtain the plastic nature of the sludge–clay mixtures and to determine the optimum moisture content (OMC) in the brick manufacturing process. Using this OMC, the mixtures with various proportions of sludge and clay were prepared in batches. The methylene blue value (BV) reflects the activity of the clay fraction, thus, it gives an indication of the mineralogy of this fraction and the cation exchange capacity (CEC) of clay minerals. Methylene blue tests performed in this study are based on the French standard Norme Française NF P 94–068 AFNOR (1993). This procedure is continued by adding further 5 mL portions of the methylene blue solution to the clay suspension until a halo of light blue dye surrounds the dark blue spot on the filter paper (Türköz and Tosun, 2011).

The produced bricks then underwent a series of tests including firing shrinkage, weight loss on ignition, water absorption, bulk density, and open porosity were conducted according to ASTM C373-88 (ASTM C373-88, 2006a; ASTM C674-88, 2006; ASTM C326-03, 2006), and compressive strength to determine the quality of bricks. As the major properties of the ceramics materials are intimately connected to their mineralogical composition, the samples were finely crushed and analyzed by X-ray diffraction. The different phases formed after firing at 1000 °C were identified using the XPERT DATA COLLECTER software. The samples microstructure was evaluated using scanning electron (SEM).

## 3. Results and discussion

### *3.1. Atterberg limits of clay–sludge mixtures*

Atterberg limits are an important indicator for several properties of clayey soils: plasticity, sensitivity, consistency and shrinkage/swelling potential. Their determination gives a first insight for the mineralogical composition of clays. The liquid and the plastic limits are highly and

**Table 2**
Concentrations of main heavy metals of WTP sludge determined by ICP (*ppm on dry material).

| Element | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|
| Sludge | ˂5 | 31 | 17 | 15 | 36 | 35 |

* ppm: parts per million.

**Table 3**
Samples of bricks masses with WTP sludge (wt.%).

| Firing temperature | Formulations of mixtures containing WTP sludge | | | | | |
|---|---|---|---|---|---|---|
| | 5% | 10% | 15% | 20% | 25% | 30% |
| 800 °C | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ |
| 900 °C | $S_A$ | $S_B$ | $S_C$ | $S_D$ | $S_E$ | $S_F$ |
| 1000 °C | $S_G$ | $S_H$ | $S_I$ | $S_J$ | $S_K$ | $S_L$ |