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Research paper

Middle Eocene clay from Goset Abu Khashier: Geological assessment and utilization with drinking water treatment sludge in brick manufacture

MA Tantawy [a,*], Ramadan SA Mohamed [b]

[a] Chemistry Department, Faculty of Science, Minia University, Egypt
[b] Geology Department, Faculty of Science, Minia University, Egypt

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ABSTRACT

This investigation aims to study the physico-ceramic properties of bricks that were made from the Goset Abu Khashier clay (Qarara Formation, Middle Eocene deposits, El-Minia, Egypt) replaced with 15–60 wt% drinking water treatment sludge (DWTS). The Qarara Formation deposits located in the east bank of the Nile River between Beni Suef and El-Minia Governorates, belong to the Middle Eocene deposits. The Qarara Formation deposits in the Goset Abu Khashier area contain several million tons of clay deposits. The Qarara Formation is composed of a grey to green shale (silty clay) grading upward to marl and limestone. The clay contains kaolinite (29 wt%), montmorillonite (20 wt%), albite (27 wt%) and quartz (23 wt%). The clay contains a high content of silica (49.41 wt%) and a low content of alumina (19.77 wt%) with considerable amounts of Fe_2O_3 (11.37 wt%) and fluxing oxides (3.7 wt%). Clay bricks containing 15–60 wt% DWTS were fired at a temperature of 700–1000 °C. The ceramic properties of bricks were determined according to the ASTM specifications. The phase composition of bricks was determined by XRD, FTIR and SEM techniques. It was investigated that the incorporation of DWTS in the body of clay bricks moderates the ceramic properties of fired bricks to be in agreement with the limiting values that were recommended for traditional bricks. XRD results illustrated that dehydration of kaolinite and the formation of metakaolinite facilitates vitrification and contributes to brick densification. FTIR results showed the formation of a wollastonite phase and indicated that increasing DWTS content facilitates the persistence of a vitrified phase. SEM micrographs illustrated that the porosity and densification of brick matrix was affected by the formation of amorphous vitreous phases and decreased with DWTS contents. It is recommended that the replacement of examined clay by 15–30 wt% of DWTS is considered as the appropriate percentage for building bricks production and minimizes environmental impacts due to DWTS disposal into water bodies.
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1. Introduction

Clay bricks are traditionally made by shaping, drying and firing mixture of clay and sand to a temperature in the range of 900–1100 °C (Jackson, 1984). The ceramic properties of clay bricks are primarily determined by the mineralogical composition of raw clay and fired clay bricks (Janos, 1971; Galal et al., 1985). Abbuoda (1991) and Kamel et al. (1995) studied the Middle Eocene clay deposits, in east Beni Mazar and in east Maghagha, El-Minia, Egypt. They recommended that these clay deposits were suitable for the manufacturing of clay bricks (Abbuoda, 1991; Kamel et al., 1995). The physico-ceramic properties of the Qarara Formation clay deposits in El-Mohasham area, Middle Eocene, Middle Egypt, El-Minia were investigated (Othman et al., 2003). The results obtained indicated that the deposits consist of low grade clay that can produce heavy bricks with relatively low mechanical properties. This limits the utilization of the Qarara Formation clay in the field of clay brick manufacture (Abdel Ghafour, 1995; Ramez and Ramchandran, 1993). Hence, much effort must be conducted to find suitable additives that must be added to the Qarara Formation clay to improve the mechanical properties of clay brick. After the innovation of high performance concrete, traditional clay bricks no longer satisfy the requirements of modern, sustainable building technology, because of its heavy weight and limited thermal insulation properties (Bories et al., 2014). Many additives have been added to clay to improve certain properties of clay bricks (e.g. reducing brick weight and increasing its thermal insulation ability). According to Chiang et al. (2009), the amount of brick inner pores is a controlling factor. The nature and amount of the additives have a direct impact on the physical properties of the bricks. Lightweight bricks were usually manufactured by adding combustibles as pore forming agents and agricultural wastes (e.g. corn cob (Nkayem et al., 2016), seeds (Saiah et al., 2010), grass (Demir, 2008), olive mill solid residue (La Rubia-García et al., 2012), sunflower seed shell (Banhidi and Gomze, 2008), rice husk (Chiang et al., 2009), rice husk ash (Sutas et al., 2012) and rice peel (Banhidi and Gomze, 2008)) as well as industrial wastes (e.g. sawdust (Demir, 2008), bagasse

* Corresponding author.
E-mail address: matantawy75@yahoo.com (M.A. Tantawy).

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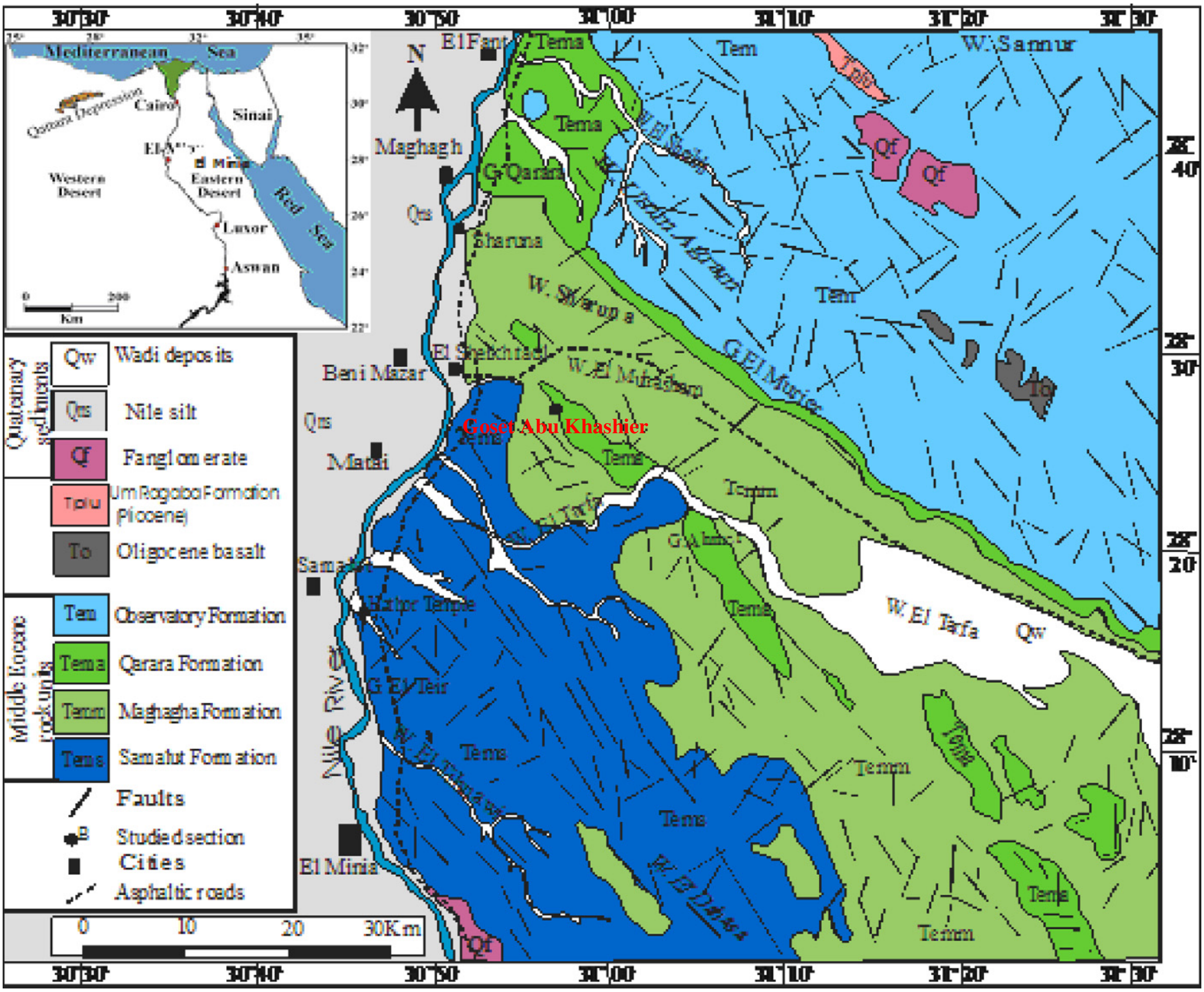

Fig. 1. The geologic and location map of the studied area (modified after EGPC-Conoco, 1987).

(Eliche-Quesada et al., 2011), kraft pulp residues (Demir et al., 2005), recycled paper processing residues (Sutcu and Akkurt, 2009), polystyrene (Veiseh and Yousefi, 2003) and sewage sludge (Weng et al., 2003)). It is necessary to find a compromise between its thermal and mechanical properties in order to produce a good quality lightweight brick (Bories et al., 2014). DWTS is a waste of drinking water treatment industry that uses alum coagulant in clarification of raw water (Goosens, 1996). The amount of DWTS reaches about 5 wt% of the total untreated water quantity (Vaebi and Batebi, 2001). DWTS composes of inorganic substances (e.g. silica, aluminum and iron hydroxides) and organic substances (Miroslav, 2008). The common practice in handling with DWTS in developing countries is disposing it to the nearest water stream. This practice has an adverse impact on the environment due to rising the concentrations of aluminum and heavy metals in raw water (Prakhar and Arup, 1998). The problem of DWTS disposal can be resolved by reusing DWTS as an additive in brick making (Elangoven and Subramanian, 2011; Hegazy et al., 2012; Anyakora, 2013). The aim of this work is to study the physico-ceramic properties of bricks that were made from the Goset Abu Khashier clay, replaced by 15–60 wt% of DWTS and fired at 700–1000 °C as well as the determination of crystalline phases composition of bricks by XRD, FTIR and SEM techniques. Other works (Elangoven and Subramanian, 2011; Hegazy et al., 2012 and Anyakora, 2013) measured only the ceramic properties of fired bricks without analyzing fired bricks. In the present study the DWTS addition will be raised to 60% and the ceramic properties of fired bricks will be aided and explained by XRD, FTIR and SEM analyses of fired bricks.

2. Location and geological setting

The outcrops of Middle Eocene deposits were exposed in the east bank of the Nile River between Beni Suef and El-Minia Governorates. This area displays a complex variation in lithology and hence has been given formational names (e.g. Samalut, Maghagha, Qarara, and El-Fashn Formations) (Bishay, 1966; El-Ayyat, 1998). The term "Qarara Formation" was described as the succession that underlies the El-Fashn Formation and overlies the Maghagha Formation at Gebel Qarara that forms the Northern boundary of Maghagha district and extends to Gebel Merier and Wadi Tarfa in the Eastern Desert (Bishay, 1966). According to a recent investigation, the Qarara Formation was described as the succession that overlies the Samalut Formation and underlies the building stone horizon (the Observatory Formation) (El-Ayyat, 1998). The Qarara Formation clay deposits, which cover more than 200 km^2, are composed of grey to green shale at its base and grading upward to marl and limestone at the top. Representative clay samples were collected from the Qarara Formation shale deposits in Goset Abu

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