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Effects of using arsenic–iron sludge wastes in brick making

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ABSTRACT

The arsenic–iron sludge generated in most of the treatment systems around the world is discharged into the nearest watercourse, which leads to accumulative rise of arsenic and iron concentrations in water. In this study, attempts were made to use the arsenic–iron sludge in making bricks and to analyze the corresponding effects on brick properties. The water treatment plant sludge is extremely close to brick clay in chemical composition. So, the sludge could be a potential substitute for brick clay. This study involved the addition of sludge with ratios 3%, 6%, 9% and 12% of the total weight of sludge–clay mixture. The physical and chemical properties of the produced bricks were then determined and evaluated and compared to control brick made entirely from clay. Results of different tests indicated that the sludge proportion and firing temperature were the two key factors in determining the quality of bricks. The compressive strength of 3%, 6%, 9% and 12% sludge containing brick samples were found to be 14.1 MPa, 15.1 MPa, 9.4 MPa and 7.1 MPa, respectively. These results indicate that the compressive strength of prepared bricks initially increased and then decreased with the increase of sludge proportion. Leaching characteristics of burnt bricks were determined with the variation of pH at a constant temperature. The optimum amount of sludge that could be mixed with clay to produce good bonding of clay–sludge bricks was found to be 6% (safely maximum) by weight.

1. Introduction

The serious arsenic as well as iron contamination in groundwater of Bangladesh has come out recently as the biggest natural calamity in the world. The people in 59 out of 64 districts comprising 126,134 km^2 of Bangladesh are suffering due to the arsenic contamination in groundwater (Safiuddin and Karim, 2001). Seventy-five million people are at risk and 24 million are potentially exposed to arsenic contamination. Most of the recognized stages of arsenic poisoning have been identified in Bangladesh and the risk of poisoning in the population is increasing day by day (Safiuddin and Karim, 2001). The millions of shallow and deep wells that had been sunk in various parts of the country are dispensing their own special brand of poison. In consequence, a large number of populations in Bangladesh are suffering from the toxic effects of arsenic contaminated water. On the other hand, arsenic in combination with various metals such as iron causes serious environmental problems which adversely affect the health of millions of people in Bangladesh. The data collected by the governmental bodies, NGOs and private organizations reveal that a large number of populations in Bangladesh are suffering from melanosis, leucomelanosis, keratosis, hyperkeratosis, dorsum, non-petting oedema, gangrene and skin cancer (Karim, 2000). To minimize these adverse effects available technologies and water treatment have been made which helps to remove arsenic and iron from drinking water (Hassan et al., 2010). Therefore, a sludge is got that will contain this arsenic and iron. So far, most of the focus has been given on awareness building and the development of water treatment system removing arsenic from drinking water. The disposal of arsenic rich sludge generated from the treatment processes is one of the issues that have received little attention from the sponsors of the technologies and the users (Eriksen and Zinia, 2001). At present, 18 large scales arsenic and iron treatment plants are working actively in Bangladesh. Each treatment plant generates about 170 m^3 arsenic-laden sludge per year (Basak and Islam, 2008). They have sufficient removal capacity (>80–90%) for iron as well as arsenic (Hemal and Zinia, 2001). Landfills are commonly used technique for the disposal of sludge in Bangladesh. However, rapid urbanization is gradually making it difficult to find suitable landfill sites (Lin and Weng, 2001). In some places, sludge is directly disposed to the nearby rivers or low laying areas, which is likely to pollute surface and groundwater (Sullivan et al., 2010). It has been shown recently that arsenic-laden sludge, when disposed into the soil do release toxic elements which accumulate in plants (Huq et al., 2011). Recently, environmental regulations are becoming more stringent and volume of generated sludge continues to increase, traditional sludge disposal methods are coming under

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increasing pressure to change and therefore, there is a strong demand for environmentally safe reuse and effective disposal methods for iron and arsenic contaminated sludge out of water treatment plants. Incineration is costly and contributes to air pollution while landfill space is becoming scarce. A possible long term solution appears to be recycling of the sludge and using it for beneficial purposes. One technique that is available to treat hazardous waste is solidification that stabilizes and solidifies components of waste. The solidified product could be disposed off to a secure landfill site or be recycled as construction materials like bricks if it meets the specific strength requirements and can be shown to leach toxic pollutants within acceptable limits (Rahmat, 2001).

In this paper, an attempt has been made to use the arsenic–iron sludge for brick making. For thousands of years, bricks have been made from clay. The major chemical compositions of brick clay were found to be silica, alumina, and ferric oxide which indicate the similar compositions of the water treatment plant sludge (Hegazy et al., 2012). So, the sludge could be a potential substitute for brick clay. Use of arsenic–iron sludge in making brick would be one of the low-cost technologies available in Bangladesh which might significantly contribute to reducing the adverse environmental effects of arsenic-laden sludge. Performance of this technology depends on the concentration of arsenic–iron sludge used as brick ingredient and burning temperature and technique for those bricks. This study mainly aims at blending of arsenic–iron sludge waste with clay for making bricks and to study the physical properties and leaching characteristics of the developed bricks for its potential use in construction works.

2. Methodology

2.1. Raw material collection

The arsenic–iron sludge waste used for this study was collected from arsenic–iron removal plant (AIRP) at Manikganj (Fig. 1) in Bangladesh. Manikganj water treatment plant uses to dispose the sludge into the bank of a nearby water body. As a result, during rains, the sludge drains into the water body and increases the concentration of arsenic, iron and other elements. To reduce such contamination in water bodies, the utilization of sludge for producing environmentaly stable products such as brick manufacturing for use in construction works would be very effective. In this study, for producing sludge–clay bricks, clay sample was collected from nearby brick field at Fultola of Khulna district. Khulna, the third largest city of Bangladesh, is located in the southern part of the country and situated below the tropic of cancer, around the intersection of latitude 22.49°N and longitude 89.34°E. The area of Khulna city is 47 square km with a population around 1.5 million (BBS, 2009).

2.2. Sample preparation and testing

The collected sludge samples were brought to laboratory and oven dried for 24 h at 105 °C. Then, the sludge sample and collected brick clay were crushed and sieved in such a way that the soil sample did not contain any foreign matter. Before taking the soil for sampling, large chunks of soil was crushed manually and mixed thoroughly to get a uniform representation. Water was then added slowly to the soil and mixed it thoroughly by hand until a smooth consistency for molding is achieved. After drying and crushing, the moisture content, arsenic and iron of the sludge were determined in the laboratory. Arsenic content of the sludge was determined by field kits (HACH, USA) using color coding. Arsenic determination by HACH kit involves generation of arsine gas (AsH_3) by addition of prepackaged sulfamic acid and zinc powder and its entrapment on a strip of paper impregnated with mercuric bromide, followed by comparison of the color of the orange-brown circle on the strip to a reference scale. The iron content was determined by Phenanthroline Method using Spectrophotometer (DR 4000, HACH, USA). The quality assurance/control of samples (QA/QC) were done using reference materials (spike samples), sample replicates (3 samples) and prepared blanks. The detection limits for the determination of both arsenic and iron was 0.01 mg/L.

For the manufacture of bricks, a specific dimension of mold was utilized. In this study, the specific dimension of brick was 250 mm × 125 mm × 75 mm. Two wooden frames were used for molding of bricks. The side walls of the mold was 12.5 mm thick. The lower end of the mold was fixed with a plate of wood to facilitate the pouring process. A total of 4 brick samples for each sludge–clay mixture proportion of 3%, 6%, 9% and 12% were prepared in the laboratory. For the preparation of bricks, the sludge–clay mixture was placed into the mold and then compacted well to get the desired strength. Drying and burning of the brick sample was done in three stages. At first, the sample was oven dried at a temperature of 105 °C for 2 days. Secondly, the oven dried brick was burnt into a laboratory furnace at 500 °C for 12 h. Finally, the temperature was increased to about 1000 °C and in this stage the sample was burnt for 12 h. In this study, 3-stages burning process was applied to avoid firing shrinkage of the brick samples. Furthermore, for firing of bricks, the temperature had been raised uniformly @ 100 °C. The actual temperature within the laboratory furnace for brick burning was monitored using a simple dilatometer (thermometer). However, a detailed differential thermal analysis was not done in this study. It was observed from previous studies that sudden rise in burning temperature is responsible for fracturing the surface of brick sample. After the completion of burning process, the furnace was switched off and the bricks had not been been removed until they become cool to room temperature. The prepared bricks were then taken to laboratory for the determination of various physical and chemical properties. Various laboratory tests such as moisture content, specific gravity, water absorption capacity and compressive strength of bricks were performed to investigate the physical properties of the prepared sludge–clay bricks. In this study, leaching characteristics of sludge–clay bricks were investigated with the variation in sludge concentration and pH at a constant temperature. Typically, the leaching test removes the mobile component of any analyte present in the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste (USEPA, 1992). Three different conditions were selected to analyze the leaching characteristic. These conditions were acidic condition, alkaline condition and neutral condition. Particle size of waste materials will surely impact the leachability due to variation in surface area of the solid phase. Once these arsenic-laden sludge–clay bricks will be used in the construction industry, they will break, construction waste and demolition waste containing these bricks will have various particle sizes and varied leachability. In this study, each of the prepared sludge–clay brick was cut into 6 (six) equal pieces for the determination of arsenic and iron leachability. Triplicate samples were tested for leaching behavior of each mix with sludge and the average values were reported for the assessment.

3. Results and discussion

After the collection of sludge sample, various chemical characteristics such as pH, arsenic and iron content were determined in the laboratory. This study found that the arsenic and iron content of the sludge sample were very high (arsenic 0.5 mg/L and iron 7.5 mg/L). The sludge had a pH value of 6.5, indicating that the sludge can be treated as neutral material. When desired bricks were