

## Use of arsenic contaminated sludge in making ornamental bricks

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**ABSTRACT:** Arsenic contaminated sludge can be substantially found from the treatment of arsenic contaminated ground water. Lack of proper management and reuse of this sludge can create further environmental problem as there is probability of mixing with soil and water. In this paper, effort is taken in order to use of such waste. Here, effectiveness of using this sludge during the process of making ornamental brick has been analyzed and justified. The detailed study was made upon the suitability of sludge in making bricks. Results of different tests indicate that sludge proportion is the key factor for determining the quality of ornamental bricks/tiles. The compressive strength of ornamental bricks mutually decreases with increase of sludge proportion. This study showed that arsenic contaminated sludge could be used safely up to 4 % for making ornamental bricks. Because upper than this limit, the quality of bricks or tiles may be fallen considerably.

**Keywords:** *Compressive strength, cubes, firing shrinkage, tapper tiles, dulpori*

### INTRODUCTION

Arsenic in ground water was first detected in Bangladesh at Barogharia union of Chapai Nawabgonj district in 1993 (Ahmed and Rahman, 2000). Since then, arsenic contamination problem has been reported from almost every part of the country. 80 % of Bangladesh land and 35-40 million people are at risk of arsenic poisoning-related diseases because the ground water in these wells is contaminated with arsenic (Alam *et al.*, 2002; Smith *et al.*, 2000). The three major adverse biochemical actions of arsenic are coagulation of proteins, complexation with co-enzymes and uncoupling of phosphorylation (De, 1994). It is also evident that the arsenic contaminated water also contains ample amount of Iron that is also not good for health or other purpose. Using the available (oxidation, co-precipitation and adsorption onto coagulated flocs, adsorption onto sorptive media, ion exchange and membrane technique) technologies,

arsenic and iron can be removed from drinking water. Therefore, a sludge is got that will contain this arsenic and iron. Most of the focus has been 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 (Akhtar *et al.*, 2000; Dutre and Vandeeasteele, 1995; Eriksen and Zinia, 2001; Kameswari *et al.*, 2001). The solidification or stabilization process would be the best practical technology to treat the arsenic waste (Artiola *et al.*, 1990; Leist *et al.*, 2003; Vandeeasteele *et al.*, 2002; Voigt *et al.*, 1996). It is found appropriate by many investigators in treating arsenic contaminated waste (Fuessle and Taylor, 2000; Pal, 2001; Sanchez *et al.*, 2003; Shih and Lin, 2003). Also another study found that the recommended proportion of contaminated

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sludge in brick making is up to 15%-25% by weight (Rouf and Hossain, 2003).

Coagulation is the most common arsenic removal technology (Johnston and Heijnen, 2001). At present, 18 large scales arsenic and iron treatment plants are working actively in Bangladesh. Each treatment plant generates about 60000-cft arsenic rich sludge per year (Basak and Islam, 2008). They have sufficient removal capacity (> 90%) as well (Hemal and Zinia, 2001). Landfills are commonly used for disposal of sludge in Bangladesh. But rapid urbanization is gradually making it difficult to find suitable landfill sites (Lin and Weng, 2001). At some places, it is disposed off to nearby rivers or low laying areas, which is likely to pollute surface and groundwater.

As environmental regulations become more stringent and volume of generated sludge continues to increase, traditional sludge disposal methods are coming under increasing pressure to change. Incineration is costly and contributes to air pollution and landfill space is becoming scare. 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 is disposed off to a secure landfill site or it can be recycled as construction material like bricks if it meets the specific strength requirement and can be shown to leach toxic pollutants within acceptable limits (Rahmat, 2001). In this paper, an attempt is taken to find a way to use the arsenic-iron contaminated sludge. All the tests were performed in the laboratories of the Department of Civil and Environmental Engineering and the Department of Chemistry, Shahjalal University of Science and Technology, Sylhet, Bangladesh. The time of completion of all the tests was from April to August, 2008.

#### *Use of arsenic*

Arsenic has found widespread use in agriculture and industry to control a variety of insect and fungicidal pests (Leist *et al.*, 2000). Arsenic tri-oxide is used in manufacturing of agricultural chemicals (pesticides), glass and glassware, industrial chemicals, copper and lead alloys and pharmaceuticals. In agriculture, arsenic compounds such as lead arsenate, copper aceto arsenite, sodium arsenate, calcium arsenate and organic arsenic compounds are used as pesticides. Substantial amount of methyl arsenic acid

and diethyl arsenic acid are used as selective herbicides. Chromate copper arsenate, sodium arsenate and zinc arsenate are used as wood preservatives. Some phenyl arsenic compounds such as arsenal acid are used as feed additives for poultry and wine. Small amount of arsenic compounds continue to be used as drugs in some countries. As medicine arsenic is used since the fifth century BC, when hypocrites recommended the use of an arsenic sulfide for the treatment of abscess. Arsenic preparation was used for the treatment of skin disorder, tuberculosis, leukemia, asthma, leprosy, syphilis, amoebic dysentery, etc. Homeopaths are also using arsenic as drug. Besides, arsenic is used in the preparation at dyes, poisonous gas and transistor, as a component of semiconductor, as a preservative in tanning and in the industry of textile and paper, etc. (Dhaka University Hospital, 2003). After treating, the arsenic contaminated water sludge of arsenic-iron is produced. In another study, it was found that the recommended proportion of this contaminated sludge in brick making is up to 15 %-25 % by weight. (Rouf and Hossain, 2003)

Arsenic contaminated groundwater is used extensively in Bangladesh to irrigate the staple food of the region and paddy rice (*Oryza sativa* L.). To determine whether this irrigation is good for environment or not, a survey on arsenic levels in paddy soils and rice grain was undertaken. It showed that arsenic levels were elevated in zones where arsenic in groundwater used for irrigation was high and where these tube-wells have been in operation for the longest period of time. (Meharg and Rahman, 2002). The total arsenic content of 150 paddy rice samples were collected from Barisal, Comilla, Dinajpur, Kaunia and Rajshahi districts of Bangladesh. It was found that arsenic concentrations varied from 10 to 420 µg/kg at 14 % moisture content. Rice yields and grain arsenic concentrations were 1.5 times higher in the boro (winter) than the monsoon (summer) season, consistent with the much greater use of groundwater for irrigation in the boro season. Mean values for the boro (winter) and aman season (monsoon rices) were 183 and 117 µg/kg, respectively (Duxbury *et al.*, 2003).

#### *Objective of the research*

Keeping the above factors in mind, the research work was carried to use this contaminated sludge in making a product, which has some economic values. Therefore, it will definitely reduce the pollution of surface water,

ground water and the environment from uncontrolled disposal of arsenic-iron contaminated sludge.

*Ornamental brick*

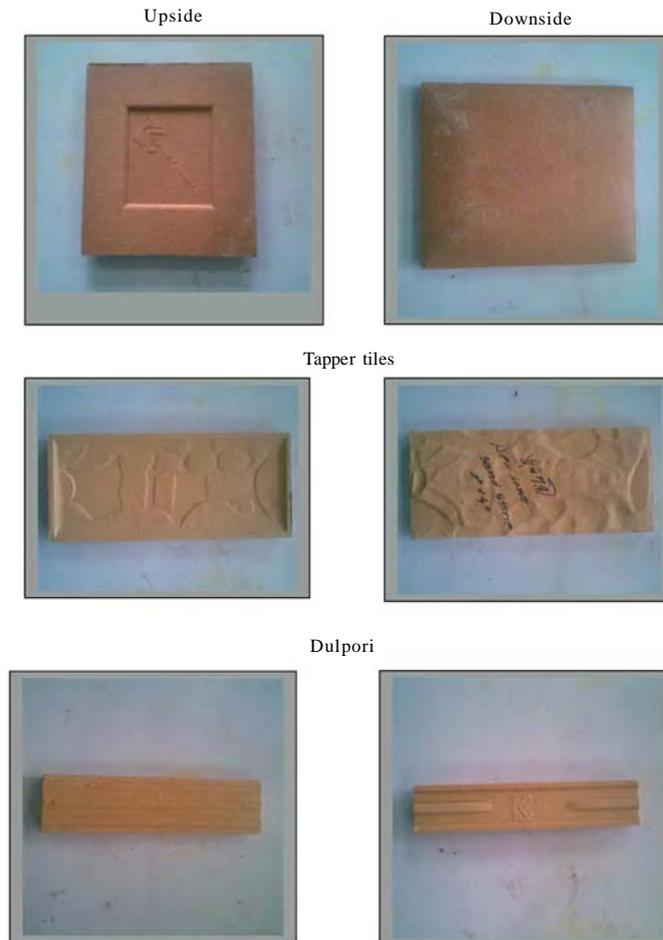
Ornamental bricks are special types of bricks. These are used for decorative work. Real estate companies use ornamental bricks according to the requirements of customer. Different types of ornamental bricks, which are made in the Khadim Ceramic Industry for this research purpose, are shown in Fig 1.

**MATERIALS AND METHODS**

The raw material (arsenic sludge) used for this study was collected from arsenic- iron removal plant (AIRP) of Manikganj sadar of Manikganj District near the pourashava office (Fig. 2). Then the basic

physicochemical characteristics were examined. It includes determination of moisture content and pH. Heavy metal content, i.e. the concentration of arsenic and iron (Table 2) was determined by acid digestion with a HNO<sub>3</sub>: HCl volume of ratio of 1:3 (aqua-regia).

Mortar in cube 6 shape is a measure to get compressive strength. The mortar used in manufacturing of cube is the mixture of cement, sand and water with a ratio of 1: 2.75: 0.485. In the work, various proportion of oven dried sludge (0.5 %, 1.0 %, 1.5 %, 2.0 %, 2.5 %) were mixed with sand by basis weight. But total proportion of sand in manufacturing ratio of concrete was not changed. After 24 h, the moulds were stripped off and the cubes are further cured in water for 7 days. After 7 days, the cubes were tested to check the crushing strength. Three cubes of each proportion of sludge were



C.T.-5

Fig. 1: Different types of ornamental bricks



Fig. 2: Sludge collection area

made and took the average of crushing/compressive strength value. Three standard cube samples were also made without using contaminated sludge, only with cement, sand and water maintaining the same ratio of 1: 2.75: 0.485. They were made following the same procedure. Compressive strength of these cubes was also measured for comparison of compressive strength.

The clay sample for ornamental bricks was collected from Khadim ceramic limited (KCL) located at Khadim Nagar in Sylhet. At first, various proportion of sludge was mixed with clay soil on basis weight (2 %, 4 %, 5 %, 6 %, 8 % and 16 %) and clay was prepared in batches (3 samples for each proportion). After complete mixing, the clay soil was taken to the brick manufacturing machine. In this research, four types of ornamental bricks e. g. Tapper tiles, Dulpori, CT-5 and 1" × 6" are studied. All the ornamental bricks are produced following the

standard rule of KCL. Again, standard samples of those four types of ornamental bricks were also made. The ornamental bricks were then tested for compressive strength. Three bricks of each proportion of sludge were tested and took the average crushing/compressive strength value. This was done to compare the compressive strength of ornamental bricks which have different sludge proportions with the standard ornamental bricks to identify the safe numerical percent value for practical use. The total methodology of manufacturing ornamental bricks is represented in Fig. 3.

## RESULTS AND DISCUSSION

### *Sand property analysis*

For concrete sand, FM range is 2.3-3.1 (Mobasher, 1999). The sand used in making the cubes was subjected to different experimental procedures, which gives the

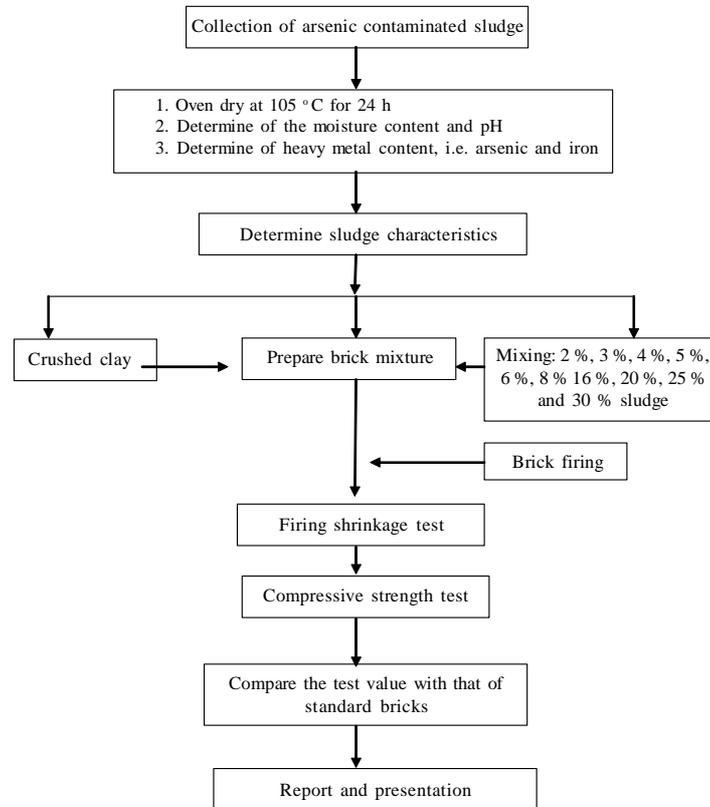


Fig. 3: Flow chart describing methodologies

unique values to define the sand to a specified category. Table 1 represents the various physical properties of Sylhet sand.

#### Sludge property analysis

The specified physicochemical properties associated with the suitability of sludge in use of manufacturing of ornamental bricks were determined and the findings are represented in Table 2.

#### Density of ornamental bricks

The density of ornamental bricks decreases with the increase of sludge addition. Table 3 shows the comparison between the densities of ornamental bricks made without sludge and those made using different proportion of sludge. From the figures, it can be concluded that up to 4% sludge addition, the density of ornamental bricks is not much affected. But when sludge addition is more than 4%, then the quality of ornamental bricks may be affected.

#### Firing shrinkage of ornamental bricks

Shrinkage during firing is unavoidable. The quality of brick can be assured according to the degree of firing shrinkage. From the data analysis, it is seen that the percentage of shrinkage increases as the amount

Table 1: Physical properties of naturally iron-rich Sylhet sand

| Serial No. | Physical property parameter       | Unit | Values |
|------------|-----------------------------------|------|--------|
| 1          | Fineness modulus                  |      | 2.42   |
| 2          | Effective size (d <sub>10</sub> ) | mm   | 0.19   |
| 3          | Effective size (d <sub>30</sub> ) | mm   | 0.32   |
| 4          | Effective size (d <sub>60</sub> ) | mm   | 0.74   |
| 5          | Uniformity coefficient, Cu        |      | 3.89   |

Table 2: Physico-chemical properties of arsenic-iron contaminated sludge

| Serial No. | Physicochemical property parameter | Unit | Values |
|------------|------------------------------------|------|--------|
| 1          | Moisture content                   | %    | 73.43  |
| 2          | pH                                 | -    | 7.78   |
| 3          | arsenic                            | mg/g | 0.0076 |
| 4          | iron                               | mg/g | 15.6   |

Table 3: Comparison of density (gm/cm<sup>3</sup>)

| Sludge in mixture (%) | Tapper tiles | Dulpori | C.T- 5 | 1"× 6" |
|-----------------------|--------------|---------|--------|--------|
| 0                     | 0.47         | 0.50    | 0.29   | 0.39   |
| 2.0                   | 0.47         | 0.51    | 0.31   | 0.40   |
| 4.0                   | 0.46         | 0.50    | 0.27   | 0.39   |
| 5.0                   | 0.41         | 0.48    | 0.26   | 0.37   |
| 6.0                   | 0.40         | 0.45    | 0.23   | 0.36   |
| 8.0                   | 0.37         | 0.41    | 0.20   | 0.34   |
| 16.0                  | 0.35         | 0.35    | 0.17   | 0.31   |

Table 4: Comparison of firing shrinkage (%)

| Sludge in mixture (%) | Tapper tiles | Dulpori | C.T- 5 | 1"× 6" |
|-----------------------|--------------|---------|--------|--------|
| 0                     | 5.37         | 5.52    | 4.85   | 4.08   |
| 2.0                   | 4.23         | 4.85    | 4.55   | 4.01   |
| 4.0                   | 5.72         | 5.65    | 4.9    | 4.87   |
| 5.0                   | 6.25         | 4.89    | 7.21   | 5.64   |
| 6.0                   | 6.18         | 5.41    | 11.76  | 10.07  |
| 8.0                   | 10.14        | 9.77    | 13.23  | 18.03  |
| 16.0                  | 12.08        | 10.83   | 14.75  | 18.18  |

Table 5: Compressive strength of cubes

| Sludge in mixture (%) | Compressive strength (psi) |          |          |         |
|-----------------------|----------------------------|----------|----------|---------|
|                       | Sample 1                   | Sample 2 | Sample 3 | Average |
| 0                     | 2864                       | 2812     | 2825     | 2834    |
| 0.5                   | 2460                       | 2381     | 2406     | 2416    |
| 1.0                   | 2303                       | 2351     | 2367     | 2340    |
| 1.5                   | 2268                       | 2287     | 2706     | 2278    |
| 2.0                   | 2161                       | 2025     | 2146     | 2111    |
| 2.5                   | 1822                       | 1772     | 1308     | 1797    |

Table 6: Comparison of compressive strength (psi)

| Sludge in mixture (%) | Tapper tiles | Dulpori | C.T- 5 | 1"× 6" |
|-----------------------|--------------|---------|--------|--------|
| 0                     | 128.17       | 194.04  | 285.21 | 304.3  |
| 2.0                   | 128.33       | 194.36  | 285.17 | 304.2  |
| 4.0                   | 128.17       | 194.31  | 285.54 | 303.63 |
| 5.0                   | 119.27       | 194.04  | 280.43 | 297.60 |
| 6.0                   | 109.46       | 187.77  | 253.43 | 278.37 |
| 8.0                   | 101.12       | 174.60  | 212.93 | 280.6  |
| 16.0                  | 98.23        | 156.78  | 198.46 | 281.36 |

of sludge is added in the mixture. Also, the firing shrinkage increases rapidly adding 4 % or more proportion of sludge to the mixture (Table 4). Since the swelling of the clay is much lower than that of sludge, an addition of sludge to the mixture widens the degree of shrinkage. It can be mentioned that in sludge

proportion of up to 4 %, the firing shrinkage of ornamental bricks is below the bricks made without sludge. But it increases when sludge addition is more than 4 %.

#### Results from compressive strength test of mortar

Presence of arsenic (V) reduces the initial and final settling time of cement. Again, compressive strength of cement increases with increase of arsenic (V) content (Minocha and Bhatnagar, 2007). In this study, cubes made using the arsenic contaminated sludge were tested for compressive strength. From Table 5, it is clear that desired strength was not found when sludge was mixed with clay soil in the manufacture of cubes. Even at small proportion of sludge mixing the compressive strength of the cubes can be hampered. Therefore, it can be concluded that sludge mixing is not recommended in the manufacturing of mortar.

From the Table 6, it was seen that up to 4% of sludge addition, compressive strength of the ornamental bricks made using sludge, is always as high as that of ornamental bricks made without sludge.

The compressive strength of the ornamental bricks made using sludge lost their quality with the addition of more than 4 % of sludge. Thus, the maximum of 4 % of sludge can be mixed as clay material safely.

## CONCLUSION

This work tries to demonstrate a feasible way of using arsenic contaminated sludge as a clay substitute to produce quality ornamental bricks. Different measurements of both clay- sludge mixture and cube and ornamental bricks were carried out to evaluate the factors that could affect the ornamental brick quality. The results of compressive strength tests on the cube shows that desired strength can not be found in cubes when they were manufactured of cubes done using arsenic contaminated sludge, even when just 0.5% sludge was substituted as sand. Based on the results of compressive strength of cube, it can be said that Arsenic sludge is not suitable as raw material in manufacturing of mortar in cube shape.

Use of waste as an aggregate on mortar may be an effective management option. But the required strength value must be maintained. For example, the utilization of waste glass in concrete can cause cracking and weakening due to expansion by alkali-silica reaction (Park and Lee, 2004). Compressive strength of mortar increases with an increase in

cement content and decreases with an increase lime, sand, water or air content (Masonry Advisory Council, 2008). The results of compressive strength tests on the ornamental bricks indicate that the strength is greatly dependent on the amount of sludge substituted as clay soil. The optimum amount of sludge that could be mixed with clay to produce good bonding of ornamental bricks was 4 % (safely maximum) by weight. On the other hand, if 4 % of sludge is mixed to the clay soil, the firing shrinkage of the ornamental bricks would not be affected. But the firing shrinkage starts to vary with the addition of more than 4 % sludge by weight.

Totally, the recommended proportion of sludge in ornamental brick making is 4 % by weight to produce a good quality ornamental brick using arsenic contaminated sludge.

The research evaluates the exact proportion of sludge which will not affect the quality of ornamental bricks. As the objective was one dimensional, thus there may be some limitations.

These may direct the scope of further studies as below:

- This research work was limited to verify the compressive strength and firing shrinkage of bricks. Further study is required for understanding the effect on water absorption.
- Toxicity characteristics leaching procedure (TCLP) test should be performed for further research work.
- Just four types of ornamental bricks were made by using this contaminated sludge. Further study should be conducted to make the other types of ornamental bricks using this sludge.
- The air pollution within the time of brick firing should be measured at further research work.
- Further study may be conducted to determine the strength of ornamental bricks at different firing temperature.
- More research works may be conducted to make hollow bricks or blocks using the arsenic-iron contaminated sludge.

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#### **REFERENCES**

Ahmed, M. F.; Rahman, M. M., (2000). Water supply and sanitation, 1<sup>st</sup> Ed., ITN-Bangladesh, Center for Water Supply

- and Waste Management, 312-313, ISBN 984-31-0936-8.
- Akhtar, H.; Cartledge, F. K.; Miller, J.; Melearn, M., (2000). Treatment of arsenic-contaminated soils, soil characterization. *J. Environ. Eng.*, 126 (11), 999-1003 (5 pages).
- Alam, M. G. M.; Allinson, G.; Stagnitti, F.; Tanaka, A.; Westbrooke, M., (2002). Arsenic contamination in Bangladesh groundwater: A major environmental and social disaster. *Int. J. Environ. Heal. R.*, 12 (3), 235-253 (19 pages).
- Artiola, J. F.; Zabeik, D.; Jhonson, S. H., (1990). In situ treatment of arsenic contaminated soil from a hazardous industrial site: Laboratory studies, solidification or stabilization. *Waste Manage.*, 10 (1), 73-78 (6 pages).
- Basak, R.; Islam, M. S., (2008). A study on the use of arsenic-iron contaminated sludge in making construction materials. B.Sc. thesis, Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet, Bangladesh, 1-2.
- De, A. K., (1994). *Environmental Chemistry*, 3<sup>rd</sup> Ed., New Age International (P) Limited Publishers, New Delhi-110 002, ISBN: 81-224-0648-3, 78-80.
- Dhaka University Hospital, (2003). Arsenik: King of poison. Available from: [http://www.dchtrust.org/arsenic\\_king\\_of\\_poison.htm](http://www.dchtrust.org/arsenic_king_of_poison.htm).
- Dutre, V.; Vandeeastele, C., (1995). Solidification/stabilization of arsenic-containing waste: Leach tests and behaviour of arsenic in the leachate. *Waste Manage.*, 15 (1), 55-62 (8 pages).
- Duxbury, J. M.; Mayer, A. B.; Lauren, J. G.; Hassan, N., (2003) Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice. *J. Environ. Sci. Heal. A.*, 38 (1), 61-69 (9 pages).
- Eriksen, N.; Zinia, B. K. M., (2001). A Study of arsenic treatment technologies and leaching characteristics of arsenic contaminated sludge. In technologies for arsenic removal from drinking water, Proceedings of a BUET-UNU workshop, Bangladesh, 207-213.
- Fuessler, R. W.; Taylor, M. A., (2000). Stabilization of arsenic and barium-rich glass manufacturing waste. *J. Environ. Eng.*, 126 (3), 272-278 (7 pages).
- Hemal, N. E.; Zinia, B. K. N., (2001). A Study of arsenic technology and leaching characteristics of arsenic contaminated sludge, technology for arsenic removal from drinking water. ISBN 984-31-1305-6, 207-208.
- Johnston, R.; Heijnen, H., (2001). Safe technology for arsenic removal, technology for arsenic removal from drinking water. ISBN 984-31-1305-6, 01.
- Kameswari, K. S. B.; Bhole, A. G.; Paramasivam, R., (2001). Evaluation of solidification (S/S) process for the disposal of arsenic bearing sludge in landfill sites. *Environ. Eng. Sci.*, 18 (3), 167-176 (10 pages).
- Leist, M.; Casey, R. J.; Caridi, D., (2000). The management of arsenic wastes: Problems and prospects. *J. Hazard. Mater.*, 76 (1), 125-138 (14 pages).
- Leist, M.; Casey, R. J.; Caridi, D., (2003). The fixation and leaching of cement stabilized arsenic. *Waste Manage.*, 23

- (4), 353-359 (7 pages).
- Lin, D. F.; Weng, C. H., (2001). Use of sewage sludge ash as brick material. *J. Environ. Engin.*, 127 (10), 922-927 (6 pages).
- Masonry Advisory Council, (2008). An overview of the characteristics of mortar: Compressive strength. Available from: <http://www.maconline.org/tech/materials/mortar/comp/comp.html>.
- Meharg, A. A.; Rahman, M. M., (2002). Arsenic contamination of Bangladesh paddy field soils: Implications for rice contribution to arsenic consumption. *Environ. Sci. Tech.*, 37 (2), 229-234 (6 pages).
- Minocha, A. K.; Bhatnagar A., (2007). Immobilization of arsenic (As<sup>5+</sup>) ions in ordinary portland cement: Influence on settling time and compressive strength. *Res. J. Environ. Toxicol.*, 1 (1), 45-60 (16 pages).
- Mobasher, B., (1999). Aggregates: Fineness modulus. Available from: <http://www4.eas.asu.edu/concrete/aggregates/sld013.htm>.
- Pal, B. N., (2001). Granular ferric hydroxide for elimination of arsenic from drinking water. In proceedings of BUET-UNU international workshop on technologies for arsenic removal from drinking water, Dhaka, 5-7 May, Bangladesh University of Engineering and Technology and United Nations University, Bangladesh, 59-68.
- Park, S. B.; Lee, B. C., (2004). Studies on expansion properties in mortar containing waste glass and fibers. *Cement Concrete Res.*, 34 (7), 1145-1152 (8 pages).
- Rahmat, M. N., (2001). Development of environmentally friendly building material: An analysis of the use of solidified industrial waste. Available from: <http://www.unu.edu/env/arsenic/Dhaka2003/15-Rouf.pdf>
- Rouf, M. A.; Hossain, M. D., (2003). Effect of using arsenic-iron sludge in brick making. The international symposium on fate of arsenic in the environment organized by Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh and The United Nations University, Tokyo, Japan with assistance from ITN Centre, Bangladesh.
- Sanchez, F.; Garrabrants, A. C.; Vandecasteele, C.; Moszkowicz, P.; Kosson, D. S., (2003). Environmental assessment of waste matrices contaminated with arsenic. *J. Hazard. Mater.*, 96 (2-3), 229-257 (29 pages).
- Shih, C. J.; Lin, C. F., (2003). Arsenic contaminated site at an abandoned copper smelter plant: Waste characterization and solidification/stabilization treatment. *Chemosphere*, 53 (7), 691-703 (13 pages).
- Smith, A. H.; Lingas, E. O.; Rahman, M., (2000). Contamination of drinking-water by arsenic in Bangladesh: A public health emergency. *Bull. WHO*, 78 (9), 1093-1103 (11 pages).
- Vandecasteele, C.; Dutre, V.; Geysen, D.; Wauters, G., (2002). Solidification/stabilization of arsenic bearing Fly-ash from the metallurgical industry. Immobilization mechanism of arsenic. *Waste Manage.*, 22 (2), 143-146 (4 pages).
- Voigt, D. E.; Brantley, S. L.; Hennes, R. J. C., (1996). Chemical fixation of arsenic in contaminated soils. *Appl. Geochem.*, 11 (5), 633-643 (11 pages).

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