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Textile sludge management by incineration technique

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Abstract

The rapid growth of textile industry in Bangladesh plays an important role in economic development. The sludge from the wastewater treatment plant in textile units is considered hazardous as it is often contaminated with heavy metals of dyestuffs and chemicals. Currently, land filling is the most common practice for textile sludge disposal. Leaching of heavy metals from textile sludge is a growing concern in Bangladesh. This study attempts to find out an environment-friendly solution for the management of the textile sludge. In this study, sludge samples were collected from treatment plants of various textile units located at Savar, Gazipur and Narsingdi. An electric incinerator was designed, fabricated and installed for the incineration of textile sludge. The sludge samples were incinerated at 500°C, 700°C and finally at 800°C for different time intervals. The volume reduction of the sludge samples was nearly 80% at 800°C. The incineration techniques were used for volume reduction and destruction of the hazardous elements. The oven dried samples were powdered and mixed at various proportions (0%, 10%, 20%, and 30%) with clay for making the ceramic products and also mixed with sand, cement and aggregates for making blocks for the stabilization of heavy metals in sludge. The properties of ceramic products such as firing shrinkage, bulk density, leaching of Heavy metals and the compressive strengths were evaluated. Incinerated ash samples were also used for ceramic tiles and block preparations. The concentrations of heavy metal in leachate from the stabilized sludge samples were very low. The compressive strength, bulk density, water absorption of the stabilized sludge and ash samples were examined and the results showed that up to 10% of the raw sludge and 10-20% ash samples could be used for stabilization and/or solidification and additionally, 80% volume reduction of the raw sludge could be obtained.

Keywords: Sludge; ash; TCLP; compressive strength; incineration

1. Introduction

The growth of textile industry sector in Bangladesh has led to its major economic development. It provides employment and business opportunity to a significant number of people. Currently, the textile industry sector
accounts for 45% of all industrial employment in the country and contributes 5% of the total national income. The number of textile industrial units in 1954 was only 53 but now there are more than 5000 units [1]. A large number of textile dyeing, printing and finishing industries have been built as cluster at Narayanganj, Savar, Demra, Tongi, Joydevpur, Gazipur, Hazaribagh and Tejgaon industrial area of greater Dhaka district.

In dyeing process the dyes are grouped as Acid, Direct, Disperse, Food, Mordant, and Natural, Pigment, Reactive, Sulphur and Vat dyes. Dyes in each group are subdivided as yellow, orange, red, violet, blue, green, and black dyes comprising of complex organic and inorganic chemicals. [2,3]. A significant amount of liquid dye waste is generated in the dyeing process. About 4 liters of wastewater are generated per square meter of cloth dyed and the wastewater contains about 4000-5000 ppm of suspended solids. In wastewater treatment process different chemicals are added and most of the chemicals get settled out during the process. Finally they end up in the sludge and the sludge produced contains hazardous materials like Chromium, Cadmium, Beryllium, Lead, Mercury, Nickel, Aluminium and toxic organic chemicals having high BOD and COD load. They are toxic to both human health and environment [4-6]. It is categorized under toxic substances by statutory authorities.

Textile sludge is an unwanted residual solid generated in the textile wastewater treatment plant and its management is a critical environmental issue. The only option practiced in Bangladesh for sludge disposal is landfilling. The environmental impacts of landfill are the polluting air, water and soil. The uncontrolled production of landfill gases such as methane, carbon dioxide, traces of non-methane and volatile organic carbons leads to global warming. The most serious environmental impact of sludge disposal to landfill is contamination of local groundwater by the generated leachate. The leaching potential of the raw sludge from the effluent treatment plant is very high [7, 8]. Disposal of solid wastes generated in textile dyeing industries located at Savar, Gazipur and Narsingdi areas has led to serious toxicity problem. The contamination of groundwater aquifer by the leachates is of great environmental concern. This study is to investigate the management of sludge using thermal decomposition and heavy metal stabilization and leachability of the treated and stabilized sludge.

2. Materials and methods

Experimental materials and methods are described hereunder for understanding the textile sludge disposal using incineration techniques. Textile wastewater sludge samples were collected from greater Dhaka district. Normally each sample weighing 20 kg was collected at a time. The Grab sampling methods were used for the sampling purpose. Sampling was carried out at location where sludge was routinely removed from the wastewater treatment for subsequent disposal and some cases the sludge samples were not routinely removed, occasionally this was used by the ETP.

All the collected samples were bone dried and kept in air tight plastic container for further analysis. The sludge samples were digested (EPA3050B method) and the digested samples were preserved in disposable small plastic bottles and kept in a cool dry place before analysis. The leachate samples were also preserved in plastic bottles and the analysis was done within a short time after collection of sample for good results. The performance of the incinerator was investigated and the temperature was increased slowly with time. Initially the temperature was set at 200°C for 20 minutes, and in the next 20 minutes the temperature reached 500°C and within 1 hour it was 800°C. The maximum reachable temperature of the electric incinerator was 1000°C. The incineration process was continued up to 800°C and 4 hours. During the incineration process the sludge sample reduces their volume as well as mass. Incinerated ash samples contain heavy metal and the heavy metal analysis was performed by the AAS. The waste water treatment sludge was added in proportion of 5wt%, 10wt%, 20wt%, 30wt% to clay. One batch of 100% clay was prepared for reference purpose. Therefore, a small amount of water was sprayed to add to the moisture of the powder. The moisture content of the mixture must be above 2% so that the samples are not brittle when formed and samples were produced by using manual press operated at 90psi. The samples were dried in an oven at 80°C for 18 hours. Drying is necessary to avoid warp and cracks in the samples due to the variations in the moisture during high temperature firing stage. Then, the samples were fired at 1200°C by natural gas. This is the process where the sample gains strength, hardness and reduced porosity. The fired samples were tested for strength, water absorption,
shrinkage and density.

Fig. 1. Photographs of the collected sludge samples wastewater treatment plant.

3. Results and Discussion

During the past three decades textile has emerged as the biggest manufacturing sub-sector and achieved remarkable growth in Bangladesh. A large quantity of textile sludges are produced from the textile wastewater treatment plants. The sludge samples were analyzed for selected industrial units for determining sludge characteristics in terms of their physical and chemical constituents. The parameters analyzed included: pH, alkalinity, percent organic, sulphate, nitrate, chloride, silica and the heavy metals. The sludge samples were incinerated and stabilized with clay or cement.

Table 1. Results of Preliminary Analysis of Textile Sludge.

| Parameter                | S1   | S2   | S3   | S4   | S5   | S6   |
|--------------------------|------|------|------|------|------|------|
| pH                       | 6.56 | 7.82 | 6.5  | 6.6  | 6.25 | 6.63 |
| Alkalinity as CaCO₃ (mg/kg) | 98.66 | 107.7 | 98.2 | 96.33 | 93.33 | 100  |
| Chloride (mg/kg)         | 112  | 121.6| 112  | 111.5| 108.8| 98.5 |
| Sulphate (mg/kg)         | 3400 | 4700 | 3540 | 4522 | 4508 | 5105 |
| Nitrate (mg/kg)          | 302  | 162  | 302  | 270  | 290  | 211.8|
| Silica (mg/kg)           | 157  | 212  | 157  | 187.3| 172.3| 189  |
| Moisture Content %       | 90   | 89   | 90   | 91   | 90   | 90   |
| Organic Content %        | 67.6 | 68   | 67.3 | 76   | 69   | 69   |
| Ash                      | 19   | 17.6 | 19   | 15.5 | 17.9 | 18.5 |

Table 2. Heavy metal Concentrations in Sludge Sample.

| Sample No. | Unit, mg/kg | As   | Cr     | Cd     | Cu    | Pb    | Zn    | Hg    | Ni    |
|------------|-------------|------|--------|--------|-------|-------|-------|-------|-------|
| S1         |             | 1.6  | 382.3  | 19.43  | 265   | 189.4 | 328   | 0.9   | 66.2  |
| S2         |             | 1.45 | 392.3  | 14.43  | 211   | 109.4 | 348   | 0.7   | 54.9  |
| S3         |             | 1.6  | 451.1  | 18.8   | 145.1 | 192.6 | 317.28| 0.1   | 65.1  |
| S4         |             | 1.1  | 367    | 5.3    | 130   | 113   | 229   | 0.12  | 229   |
| S5         |             | 1.8  | 301.8  | 10.8   | 210   | 28.9  | 390   | 0.1   | 65    |
| S6         |             | 1.56 | 285.6  | 9.2    | 140   | 23.2  | 510   | 0.1   | 76    |
Table 3. Heavy metal Concentrations in Ash Sample.

| Sample No. | Unit, mg/kg | As | Cr  | Cd  | Cu  | Pb  | Zn  | Hg  | Ni   |
|------------|-------------|----|-----|-----|-----|-----|-----|-----|-----|
| S1         |             | 0.8| 850 | 9.93| 664.7| 19.1| 980 | 0.08| 168.6|
| S2         |             | 0.79| 1059.2| 7.2| 411.5| 45.2| 761 | 0.07| 126  |
| S3         |             | 0.9 | 1019.2| 4.2| 282.9| 47  | 636 | 0.07| 151  |
| S4         |             | 1.2 | 831.2| 1.3| 249  | 38.5| 480.9| 0.01| 186  |
| S5         |             | 1   | 685 | 3.1| 410.5| 14.9| 764 | 0.01| 155  |
| S6         |             | 1.2 | 648.3| 4.6| 273  | 12  | 1126| 0.01| 175  |

The effect of temperature on sludge sample is very important and it depends on the composition of the sludge sample. If the wastewater treatment plant is a biologically treatment plant then the sludge sample contains organic compound, and the decomposition of sludge sample is very high.

From figure 2 it is observed that the percent of weight loss of powder material was higher than the 2 mm and 6 mm particle size sludge sample. Initially the weight loss for the three samples are very close but at the temperature above 800°C, the percent weight loss is 80% of the powder material. The powder sludge sample was kept in the incinerator and the temperature was increasing and the time was 2 hours, 4 hours and 6 hours, the weight loss is high at the 6 hours time and at 1000°C. From figure 3 it is shown that the leaching of heavy metal of Cr, Pb, Cd and Hg of sludge sample at high temperature are lower than the lower temperature. At 800°C the leaching of the heavy metal was less than the Land Disposal Restrictions (LDR) limit.
The quality of tiles can be assured according to the degree of firing shrinkage. Normally for a good quality clay brick the firing shrinkage is 14-15%. Firing temperature is an important parameter affecting the degree of shrinkage. The firing temperature and the proportion of sludge or ash in the mixture are the factors controlling the ceramic shrinkage during the firing process. In the figure 4 a linear relationship between the shrinkage and the ash proportion was observed. An addition of ash to the mixture should narrow the degree of firing shrinkage. Density goes on reducing with increase in percentage of sludge. This is because of increasing the temperature there is significant weight loss due to burning of organic matter present in the sludge. It is seen that the density of Ceramics from the ash samples is higher than the ceramic made from the sludge sample.

From figure 6 it is observed that the addition of ash the compressive strength is increasing but at the 30% ash addition the compressive strength is decreasing. Ash has cementing property for bonding. Addition upto 20% ash the ash sample shows its cementing property and the chemical bonding is strong but when added more ash it does not shows the bonding property better, so the compressive strength decreases. From figure 7 it is seen that the compressive strength is higher for the 28 days and is lower for 30% sludge addition.
The figure 8 shows the results of compressive strength of Blocks made from Ash+cement and Sludge+cement. The compressive strength of the blocks made from sludge is lower because the sludge samples contain lot of organic compounds so the bonding is not strong.

4. Conclusion

Textile sludge management in Bangladesh is a challenging task for the industries which are producing waste water treatment residue such as sludge. As mentioned in the earlier chapters the traditional means of disposal of sludge has been either by open dumping, land filling or dumping near the river. Incineration is an important disposal method for the large volume of sludge produced by industrial and municipal wastewater treatment. The Toxicity Characteristics Leaching Procedures (TCLP) test results of leachate and heavy metal concentration of sludge leachate are higher than the US EPA LDR limit. The high temperature operation decomposes the hazardous and toxic organic compounds in the sludge. The compressive strength test results of the block without addition of sludge and ash is 6000 Psi and shows that use of sludge and ash is possible for its preparation within certain limits. Ten percent sludge and 10-20% ash can be used as a cement replacement for block preparation.

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