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Decolorization of Reactive Dyes, Part II: Eco-Friendly Approach of Reactive Dye Effluents Decolorization Using Geopolymer Cement Based on Slag

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Abstract

We carried out this study in order to reduce pollution rates by treating the water produced from dyeing operations using reactive dyes, by removing the color from the liquid wastes of yellow 145 using two different types of slag-based geopolymer. The factors affecting the decolorization were optimized according to various parameters such as the dose of adsorbents, treatment time, at different pH and dose of the dye used.

Keywords: Reactive dyes, Geopolymer, Slag.

1. Introduction

Cement and concrete are broadly used in building and construction material in the world. Manufacture of Portland cement consumes huge amounts of energy and raw materials and emits a lot of CO_2 which responsible for global warming. Global annual cement production is predicted to be 5.9 billion tons with more than 4.8 billion tons CO_2 production by 2020[1]. The alkali activation of waste materials has become an important area of research because of the possibility for using industrial wastes like ground granulated blast furnace slag (GGBFS), fly ash and metakaolin, to convert them to useful environmental friendly, inexpensive, technologically advantageous cementitious materials with the added advantages of low carbon-dioxide emissions[2,3].Geopolymer was described by Davidovits [4] as a type of amorphous alumino-silicate cementitious material which prepared from natural aluminosilicate or industrial by-product such as metakaolin, fly ash and ground granulated blast furnace slag. It is produced by the alkali activation of aluminosilicate raw materials by polymerization in presence of high pH environment. The polymerization reaction includes the formation of three-dimensional polymeric chains by Si-Al minerals to form a ring structure which consist of Si-O-Si bonds [5]. These binders may resolve the problems of construction industry. Geopolymer cements GPC reduces 80% CO_2 and is more economical and at the same time uses industrial/agricultural wastes [1,6]. Pozzolanic materials must contain of siliceous or a combination of siliceous and aluminous material in a very finely divided form, and they react with calcium hydroxide in the presence of moisture at ordinary temperatures, to form compounds have comparable performance to ordinary Portland cements OPC. Several studies suggested that various industrial waste materials have been used as a source of alumina and silica for the preparation of geopolymers[1,7,8]. Ground granulated blast furnace slag) GGBFS) is a pozzolanic material and can be identified as a by-product obtained in the manufacture of pig iron in the blast furnace and is formed by the combination of iron ore with limestone flux. GBFS used as a base material consists of aluminosilicate raw material that can be activated by alkali hydroxide and silicate. Alkali activation of slag leads to a reaction product similar to calcium silicate hydrates (C-S-H) gel (a major product of OPC hydration)[7]. Many researchers examined the incorporation of slag with industrial waste products such as fly ash (FA) ,cement kiln dust CKD and silica fume SF [9 – 12]. Geopolymers can be used in different applications

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such as refractory and heat resistant coatings and adhesives, pharmaceutical applications, new adhesives for refractory fiber composites, removal of toxic and radioactive waste, and new cement materials for concrete. Recently, geopolymers have become one of the important adsorbents due to their low cost, simple preparation, and their unique three-dimensional network structure, with fixed-size pores that can be used to remove pollutants (such as dyestuffs and hazardous materials) from the environment [13]. Recent studies have suggested the use of geopolymer cements as adsorbents for the removal of different types of dyes [14-16]. The high demand for dyes for the textile industry over the last decade indicates that they are likely to be toxic substances. It is estimated that about 30-40% of the dye remains in the waste water during the dyeing process. The most common dyes are reactive dyes because they have many advantages such as stable structure, bright color and function under mild conditions. Various physical and chemical decolorization processes such as adsorption, precipitation, oxidation, coagulation, reduction, electrolysis, and membrane extraction are used to remove the dye [17-25]. The ideal process for treating small amounts of wastewater is the adsorption process [26-35]. The aim of this study is to remove the color of the reactive yellow dye 145 residual in the dyeing bath instead of dumping this hazardous waste without treatment by using slag-based geopolymer cement as a new approach that is environmentally safe and inexpensive.

Materials and Methods

2.1. Materials

Reactive yellow 145 was utilized for the decolorization studies. The structures of this dyes is shown.

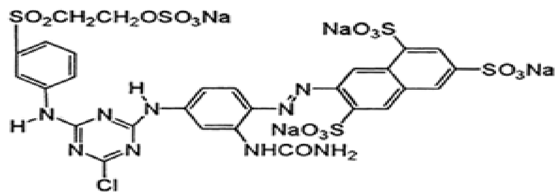

Figure 1. C.I. Reactive Yellow 145

2.2 Preparation of Hydrolyzed Reactive Dye

Hydrolysis of the reactive dyestuff was accomplished by the addition of 3 mL/L sodium hydroxide solution (33%) and 5 g/L sodium carbonate and heating under stirring for 2 h at 80°C. Finally, the hydrolyzed dye was cooled and neutralized with dilute sulfuric acid [28].

2.3 Adsorbent preparation

2.3.1 Starting materials

•Ground granulated blast-furnace slag (GGBFS) and fly ash (FA).

•The alkaline activator in this study was sodium hydroxide (NaOH) and liquid sodium silicate (Na_2SiO_3).

•Ground granulated blast furnace slag is obtained from the Egyptian iron & steel of Helwan Company. The chemical oxide composition is given in Table (1).

•Fly ash (FA) is supplied from Sika Chemical Company, Burg Al-Arab, Egypt. Its chemical oxide composition is given in Table (1).

•The NaOH flakes are obtained from EL-Goumhouria chemical company, Cairo, Egypt with purity 99%. Commercial liquid sodium silicate (LSS) is obtained from Silica Egypt Company, Burg Al-Arab, Alexandria, Egypt.

•The chemical composition of liquid sodium silicate is 11.7 wt% Na_2O, 32.8 wt% SiO_2, and 55.5 wt% H_2O and silica modulus SiO_2/ Na_2O equal 2.80. The chemical compositions of the starting materials are given in Table (1).

2.3.2. Geopolymer Synthesis

Preparation of specimens:

Each of the considered additives (GGBFS and FA) are firstly mixed thoroughly in the dry state to attain complete homogeneity. The composition of the various mixes in addition to, the water/solid ratio which gave standard consistency and setting times are given in Table (2).

S & SF1 samples are prepared by using 100% GGBFS and mixing it with 10% of Fly Ash respectively as shown in Table (2).

In the first the alkali activator (AA) is prepared by mixing sodium silicate liquid (SSL) and sodium hydroxide pellets (SH) then stirred them, initially the temperature of the mixture was quite high then left few minutes to reach to room temperature before the proceeding. Then by the addition of different mixing ratio of alkali activator solution to each dry mix and mixing them on a smooth and non absorbent surface for about 5 minutes. After complete mixing we confirm the water consistency of the geopolymer pastes by standard Vicat apparatus. Then the pastes are put in stainless steel moulds of one-inch dimension (cubic-shaped molds); the moulds are kept under relative humidity 100% for the first 24 hours to attain the final setting and getting hard. After molding the cubes demolded and kept under relative humidity 100% for 7 days of hydration.

2.4. Methods of Investigation

2.4.1.Water of consistency:

The standard water of consistency are determined according to ASTM specification using VicateAapparatus [38]. The quantity of liquid required to produce a paste of standard consistency