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Decolorization of Reactive Dyes, Part VIII: Eco-Friendly Approach of Reactive Red 195 Dye Effluents Decolorization Using Geopolymer Cement Based on Metakaolin backed by slag

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Abstract

We did this study to use two different types of geopolymers based on metakaolin or metakaolin combined with slag to decolorize the colour from the dyeing bath leftovers from the liquid waste of reactive red dye 195 in an effort to reduce pollution and protect the environment. The findings demonstrated that this technique offered colour reduction as a low-cost and affordable option.

***Keywords*:** Dyeing, Reactive dyes, Slag.

1. Introduction

On account of water pollution, the release and discharge of dye in industrial waste becomes a critical serious issue [1]. Due to complex contaminants and high dye intensity, dyes are difficult to degrade, even over the long period of biodegradation, and are hence a common component of liquid industrial wastes [2]. About 15% of the dyeing process in the textile business is wasted since it doesn't even adhere to the cloth fibers. There is an urgent need to have a solution to get rid of dye waste because of the wastewater contamination issue [3]. Several methods, including adsorption [4-8], electrochemistry [9], coagulation, exchange ions [10], photocatalytic degradation [11-13] and photocatalytic sterilization [14], have been developed to eliminate dye waste. The adsorption process is one of the most common ways to treat dye waste since it is inexpensive, simple to use, energy-free, non-toxic, and takes a significant amount of time [15]. Numerous researchers have established adsorbent material from industrial waste, such as geopolymer, which is the best choice. Geopolymer can be used as a substitute for Portland cement because of its advantages in terms of energy conservation and environmental protection. Its production results in energy savings of 43%–59% when compared to conventional concrete as well as its superior mechanical properties, which include fire resistance and acid resistance [16]. Geopolymerization is the synthesis of geopolymer binders which is caused by interaction of silicon (Si) and aluminium (Al) in natural source materials like metakaolin (Mk) or in by product materials like fly ash with alkali activators [17]. Geopolymers can be applied to several fields as construction materials, protective coatings for aircraft, and the immobilization of hazardous elements in trash [18]. Geopolymers demonstrated that it can create better adsorption capabilities [2,19]. Kaolin [18], fly ash [2], [20-22], metakaolin [23], slag [24]and red mud [25] are all elements that may be easily acquired and used to create geopolymers. Metakaolin, by calcination at a moderate temperature, is made from natural clays (kaolin). Typically, a mix of either sodium hydroxide and sodium silicate or potassium hydroxide (KOH) and potassium silicate (K_2SiO_3) which are two types of alkali activators that are used in geopolymer mixes. In order to better understand how the geopolymerization process and alkaline solutions interact, studies on MK-based geopolymer have mostly focused on mortars and pastes [26-28] and the effects of curing techniques

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including temperature and/or time on mechanical characteristics [29,30]. Using metakaolin-based geopolymer and slag-based geopolymer cement to remove the colour of the reactive dye that is still present in the dyeing bath was recommended by Elapasery*et a*l. [31-34] as opposed to letting this hazardous waste go untreated. Numerous investigations have demonstrated that geopolymers with metakaolin as its main component are efficient adsorbents for a variety of water contaminants, including those containing heavy metals and dyes [35-39].Blast furnace slag (BFS) is made up of the inorganic, non-ferrous portions of the raw materials needed to make iron (iron ore, coal/coke, and fluxes, including limestone) that are left over after the iron is extracted from the ore [40]. The major chemical components of BFS are calcium and silica oxides, together with additional oxides like aluminium oxide and magnesium oxide, and other metallic elements including Fe, Ti, and Mn [41]. The grade of the iron ore and the smelting fluxes employed affect the chemical makeup of BFS [41], while the rate at which the slag cools affects its structural phase. BFS is now mostly taken into account for civil engineering projects and the manufacturing of cement [42]. BFS has also been considered for the adsorption of wastewater pollutants such phosphates [43] and metal ions [40], and it has been discovered that it may be successfully used for the treatment of industrial wastewater. Industrial wastewater also includes different types of dyes, where BFS can be used in other situations.

In this study, rather than simply disposing of this hazardous waste without treatment, we compare the adsorption of one mixture containing metakaolin and slag-based geopolymer (MK-S2) to the adsorption of metakaolin-based geopolymer alone (MK). The goal is to find the best mix that can remove a high percentage of the color of the reactive red 195 dye effluents in the dyeing process.

2. Materials and Methods

2.1 Materials

A. Reactive red dye 195

The structure of reactive red 195 which was utilized is showed in figure 1.

B. Preparation of Hydrolyzed Reactive Dye

Hydrolysis of the reactive dyestuff was accomplished by heating 5 g/L sodium carbonate and 3 mL/L sodium hydroxide solution (33%) at 80°C for 2 hrs under stirring. Then, cooling and neutralization (with dilute sulphuric acid) were accrued [44-51].

C- Starting Materials

Materials utilized in this study included:granulated blast furnace slag (GBFS) was acquired from the Helwan Company of Egyptian Iron & Steel. Metakaolin (MK) was obtained from Hemts Construction Chemical Company, Cairo, Egypt. The chemical compositions of metakaolin (MK) and granulated blast furnace slag (GGBFS) were presented in Table 1.

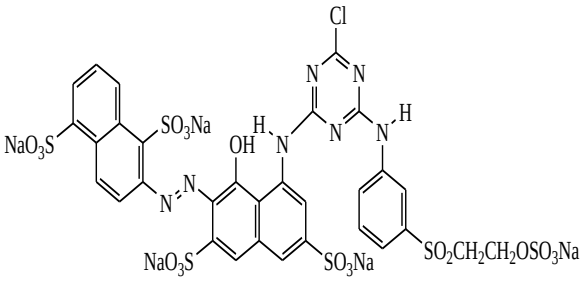

Figure 1. C.I. Reactive Red 195

Table1:Chemical oxide composition of starting materials in mass (%).

Oxide constituents (%)	*Type*	
	MK	*GGBFS*
SiO_2	*64.8*	*32.86*
CaO	*0.52*	*42.56*
MgO	*----*	*11.58*
Al_2O_3	*30.1*	*7.02*
Fe_2O_3	*0.55*	*1.14*
K_2O	*-----*	*0.15*
P_2O_5	*0.06*	*----*
SO_3	*0.13*	*2.5*
Na_2O	*0.1*	*0.29*
TiO_2	*2.7*	*----*
Cl -	*-----*	*----*
L.O.I	*0.73*	*0.93*
Total	*99.69*	*99.03*

The alkaline activator was a solution of sodium hydroxide and sodium silicate .The industrial liquid sodium silicate (Na_2O 11.7 wt%, SiO_2 32.8 wt%, and H_2O 55.5 wt%) was manufactured by Silica Egypt Company, Burg Al-Arab, Alexandria, Egypt. and SiO_2/Na_2O has a silica modulus of 2.80.The sodium hydroxide flakes with 99% purity were purchased from EL-Goumhouria Chemical Company in Cairo, Egypt.

2.2. Geopolymer synthesis

2.2.1. Specimens preparation

The sodium hydroxide (10M sodium hydroxide) and liquid sodium silicate are mixed in a predetermined ratio to create the alkali activator,

which is then shaken until a clear gel is produced. Then, after adding varying amounts of alkali activator solution to each dry mix, we added them to a smooth, non-absorbent surface to mix them for about five minutes. After the mixing was finished, we used a standard Vicate apparatus to check the water consistency of the geopolymer pastes.

The freshly prepared pastes are then placed in one-inch dimension (cubic-shaped) stainless steel moulds. In order to achieve the final setting and hardening, the moulds are kept at 100% relative humidity for the first 24 hours after the cubes were demolded and held at 100% relative humidity for seven days of hydration. Finally, the specimens were taken out and crushed following the curing process. To stop further hydration, the resulting crushed specimens were mixed with an alcohol/acetone hydration-stopping solution (1:1)[52].The mix compositions of the investigated mixes are shown in Table (2).

2.3 Adsorption experiments

A specific amount of the adsorbent was shaken with 50 mL of the dye solution at 30 ºC and 140 rpm. Filtration was used to separate the sample solutions' supernatant. It was possible to determine absorbance at the maximum wavelength (max = 504 nm for reactive red 195) using the calibration curve and Shimadzu spectrophotometry. Using a mass balance relationship, the amount of dye that was adsorbed onto the adsorbent, qe (mg/g), was estimated.

$$q_e = (C_o - C) V/W$$

Co is the initial dye concentration in milligrammes per litre (mg/L), W is the weight of the adsorbent, V is the solution volume in litres (L), C is the equilibrium liquid-phase dye concentration in mg/L.

$$\text{Removal efficiency \%} = 100 (q_e/ C_o)$$

Table 2: Mix composition of the investigated mixes, liquid/solid (L/S) ratio

Mix	MK (%)	GGBFS (%)	Na_2SiO_3: NaOH ratio	L/S ratio
MK	100	0	2.5 :1	0.56
MK-S2	70	30	2.5:1	0.47

3.Results and discussion

3.1.1 Effect of pH

Figure 2 offers us multiple examples of the change in removal efficiency% when using the dye leftovers of the reactive red dye 195at various pH values in the adsorption solution. For a geopolymer based on metakaolin mixed with slag MK and MK-S2 dye-treated, the optimal pH value, ranging from 2 to 10, was investigated.

The findings in Figure 2 unambiguously demonstrate that for all wastewaters, the percentage efficacy of colour removal decreases with increasing pH.The best decolorization efficacy for both geopolymer mixtures (MK and MK-S2) was at pH 2. The highest results for MK and MK-S2 were 34.35% and 50%, respectively.

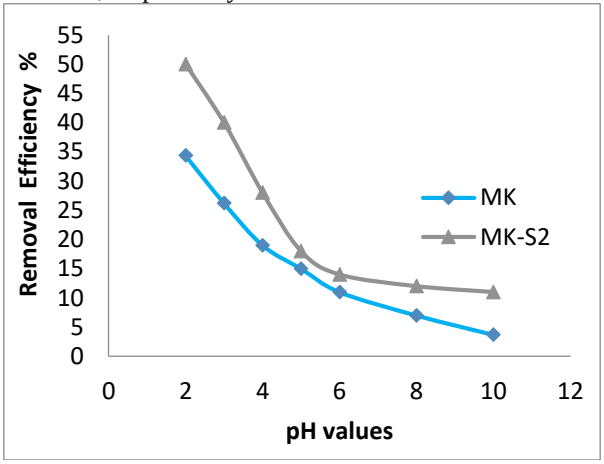

Figure 2. Effect of pH on dye removal efficiency % (Time 2hrs, Temperature 30ºC, wt. of adsorbent 0.01g, concentration of dye 20 mg/L)

3.1.2 Effect of adsorbent dosage

The results of Figure 3 clearly show the relationship between the outcomes of the adsorption concentration and the removal efficiency percentage, which is an essential point to make. The adsorption of the dye under study was tested at various concentrations (0.01-0.1 g/50 ml) of geopolymer cement for two hours using reactive red dye 195dye waste.

The dye concentration for MK and MK-S2 was 20 mg/L at pH 2. The results indisputably show that an increase in removal efficiency is accompanied by a decrease in the weight of the adsorbent. Our calculations showed that the greatest removal efficiency% for MK was 34.35% at 0.01g/100ml for geopolymers combinations and for MK-S2 was 57.7% at 0.02g/50ml for geopolymers combinations.

3.1.3 Time's impact

In order to establish the appropriate period of reaction of the reactive dye with geopolymer cement materials, the removal of the reactive dye was evaluated at various time intervals ranging from 1 to 5 hours.

We can also state that the results shown in Figure 4 demonstrate, in a very precise scientific manner, that the colour removal efficiency rises as the adsorption time is extended until it reaches a duration of five hours, reaching a maximum colour removal efficiency of 65.2% for the MK geopolymer mixture and 68.6% at three hours for the MK-S2 geopolymer mixture.

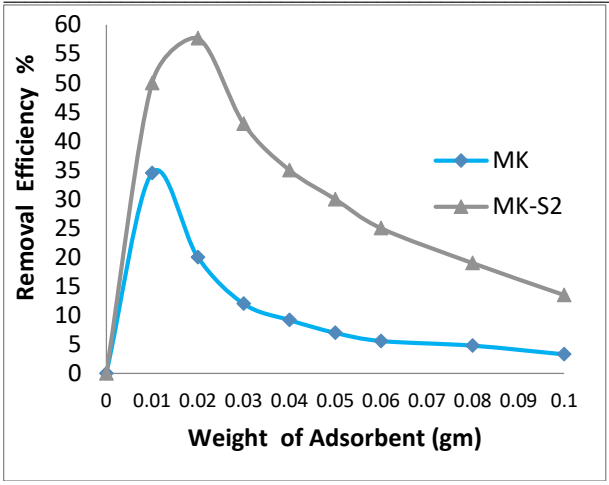

Figure 3. Effect of adsorbent weight on the removal efficiency % (Time 2hrs, Temperature 30°C, concentration of dye 20 mg/L, pH 2)

3.1.4 Effect of Dye Concentration

When using the constant weight of the cured geopolymer combination MK and MK-S2 with time and the proper pH, the results shown in Figure 5 provide us with a clear and comprehensive scientific picture of the relationship between the influence of the dye concentration on the colour removal efficiency percent. In order to study the dye's absorption, several dye concentrations (5–100 mg/L) were used. For MK, the greatest removal effectiveness percentage was 65.2% with the dye concentration (20 ppm) at pH 2 and 5 hours. The target was also reached at the same dye concentration and pH levels, but it took 3 hours for the MK-S2 geopolymer mix, with a removal efficiency percentage of 68.6%.

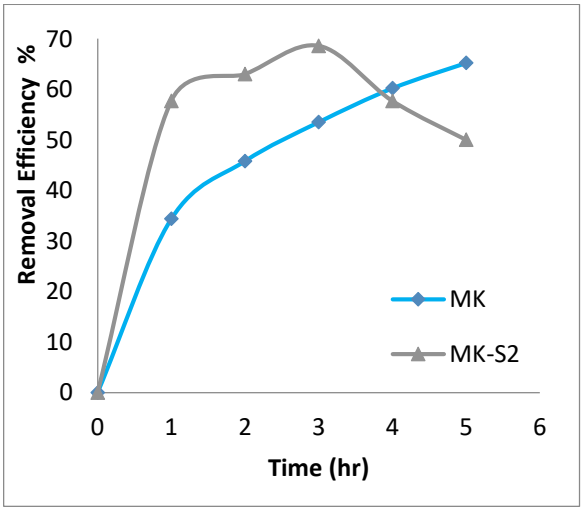

Figure 4. Effect of time on the removal efficiency % (Weight of adsorbent 0.02g, for Mk and 0.01 for MK-S2, Temperature 30°C, concentration of dye 20 mg/L, pH 2

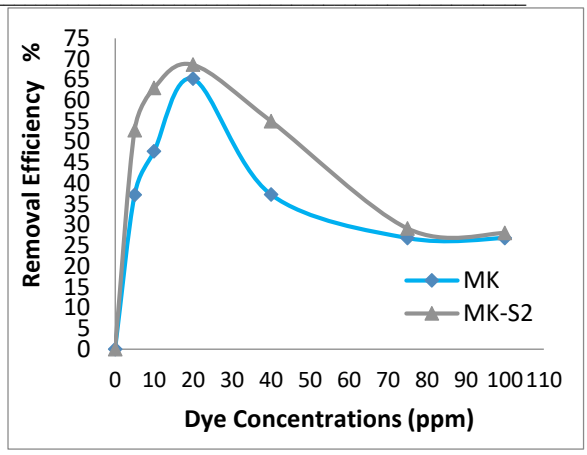

Figure 5. Effect of dye concentration on the removal efficiency % (Weight of adsorbent 0.02g, for Mk and 0.01 for MK-S2, Temperature 30°C , pH 2, Time 5 hours for Mk and 3 hours MK-S2)

4. Conclusion

We could succinctly state that our findings support the feasibility of utilising a geopolymer based on metakaolin MK or a mixture of metakaolin 70% and slag 30% MK-S2 to remove any remaining colour from the reactive red dye 195 dyeing pools. Additionally, we can state that the maximal absorption capacity of the reactive red dye 195 utilising slag-based geopolymer and metakaolin was superior to geopolymer based solely on metakaolin, indicating that the 30% slag content was advantageous for colour removal.

5. Conflicts of interest

"There are no conflicts to declare".

6. Acknowledgement

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7. References

[1] Lei S., Wang S., Gao B., Zhan Y., Zhao Q., Jin, S., Song G., Lyu X., Zhang Y., Tang Y., "Ultrathin dodecyl-sulfate-intercalated Mg-Al layered double hydroxide nanosheets with high adsorption capability for dye pollution", Journal of Colloid and Interface Science,2020, 577, 181–190

[2] Alouani M. E., Alehyen S., Achouri M. E., Hamed T. M., "Comparative Studies on Removal of Textile Dye onto Geopolymeric Adsorbents ", EnvironmentAsia,2019, 12, 143153

[3] Novais R. M., Ascensã G., Tobaldi D. M., Seabra M. P., Labrincha J. A., "Biomass fly ash

geopolymer monoliths for effective methylene blue removal from wastewaters", Journal of Cleaner Production ,2018, 783–794

[4] Bensalah H., Younssi S. A., Ouammou M., Gurlo A., Bekheet M. F., "Azo dye adsorption on an industrial waste-transformed hydroxyapatite adsorbent: Kinetics, isotherms, mechanism and regeneration studies ", Journal of Environmental Chemical Engineering,2020, 8, 103807

5] Hua P., Sellaoui L., Franco D., Netto M.S., Dotto G.L., Bajahzar A., Belmabrouk H., Bonilla P.A., Li Z., "Adsorption of acid green and procion red on a magnetic geopolymer based adsorbent: Experiments, characterization and theoretical treatment", Chemical Engineering Journal, 2020, 383, 123113

[6] Maleki A., Mohammad M., Emdadi Z., Asim N., Azizi M., Safaei J., "Adsorbent materials based on a geopolymer paste for dye removal from aqueous solutions", Arabian Journal of Chemistry ,2020, 13, 3017–3025

[7] Schadeck N. M., Leindcker R.D., Jahn S. L., Stoffels M.E., Luiz D.G., Luiz F.E., "Preparation of a novel magnetic geopolymer/zero–valent iron composite with remarkable adsorption performance towards aqueous Acid Red 97", Chemical Engineering Communications,2020, 207, 1048–1061

[8] Tran V. A., Kadam A. N., Lee S.W., "Adsorption-assisted photocatalytic degradation of methyl orange dye by zeolite-imidazole-framework-derived nanoparticles", Journal of Alloys and Compounds,2020, 835, 155414

[9] Sirés I., Brilla E., "Remediation of water pollution caused by pharmaceutical residues based on electrochemical separation and degradation technologies: A review" Environment international,2012, 212–229

[10] Ahmaruzzama M., "Role of Fly Ash in the Removal of Organic Pollutants from Wastewater", Energy Fuels,2009, 23, 1494–1511

[11] Cai B., Feng J., Peng Q., Zhao H., Miao Y., Pan H., "Super-fast degradation of high concentration methyl orange over bifunctional catalyst Fe/Fe3C@C with microwave irradiation", Journal of hazardous materials., 2020,392, 122279

[12] Hanafi M. F., Sapawe N., "Influence of pH on the photocatalytic degradation of methyl orange using nickel catalyst", Materials Today: Proceedings, 2020,31, 339-341

[13] Yao K., Liu Y., Yang H.,Yuan J., Shan S., "Polyaniline-modified 3D-spongy SnS composites for the enhanced visible-light photocatalytic degradation of methyl orange", Colloids and Surfaces A: Physicochemical and Engineering Aspects,2020, 603, 125240

[14] Yang H., Yuan H., Hu Q., Liu W., Zhang D., "Synthesis of mesoporous C/MoS2 for adsorption of methyl orange and photo-catalytic sterilization", Applied Surface Science,2020, 504, 144445

[15] Bulgariu L., Escudero L.B., Bello O.S., Iqbal M., Nisar J., Adegoke K.A., Alakhras F., Kornaros M., Anastopoulos I., "The utilization of leaf-based adsorbents for dyes removal: A review", J. Mol. Liq.,2019, 276, 728–747

[16] Neupane K., Chalmers D., Kidd P., "High-strength geopolymer concreted properties, advantages and challenges", Advances in Materials,2018,7,15-25

[17] Ma C.K., Awang A.Z., Omar W.," Structural and material performance of geopolymer concrete: a review" Construction and Building Material, 2018,186,90-102

[18] Yan S., Zhang F., Liu J., Ren B., He P., Jia D., Yang J.,"Green synthesis of high porosity waste gangue microsphere/geopolymer composite foams via hydrogen peroxide modification", Journal of Cleaner Production, 2019, 227, 483–494

[19] Khan M. I., Teoh K. M., Azizli K., Sufian S., Ullah H., Man Z.,"Effective removal of methylene blue from water using phosphoric acid based geopolymers: synthesis, characterizations and adsorption studies", RSC Advances.,2015,5, 61410–61420

[20] Adegoke K. A., Oyewole R. O., Lasisi B. M., and Bello .O.S., "Abatement of organic pollutants using fly ash based adsorbents", Water Science and Technology, 2017,76,2580-2592

[21] Dash S., Chaudhuri H., Gupta R., and Nair U. G., "Adsorption study of modified coal fly ash with sulfonic acid as a potential adsorbent for the removal of toxic reactive dyes from aqueous solution: Kinetics and thermodynamics", Journal of Environmental Chemical Engineering,2018, 6, 5897–5905

[22] Novais R. M., Carvalheiras J., Tobaldi D. M., Seabra M. P., Pullar R. C., Labrincha J. A., "Synthesis of porous biomass fly ash-based geopolymer spheres for efficient removal of methylene blue from wastewaters ", Journal of Cleaner Production,2019, 207, 350–362

[23] Zawrah M. F., Abo Sawan S. E., Khattab R. M., Abdel-Shafi A. A., "Effect of nano sand on the properties of metakaolin-based geopolymer: Study on its low-rate sintering", Construction and Building Materials., vol. 246, p. 118486, Jun. 2020.

[24] Yu Q., Li S., Li H., Chai X., Bi X., Liu J., Ohnuki T., "Synthesis and characterization of Mn-slag based geopolymer for immobilization of Co", Journal of Cleaner Production,2019, 234, 97–104

[25] Zhang Y. J. He P. Y., Yang M. Y., Chen H., Liu L.C., "Renewable conversion of slag to graphene geopolymer for H_2 production and

wastewater treatment, " Catalysis. Today,2020, 355,325-32

[26] Weng L., Sagoe-Crentsil K., "Dissolution processes, hydrolysis, and condensation reactions during geopolymer synthesis: Part Idlow Si/Al ratio systems", Journal of materials science,2007, 42,2997-3006

[27] Yao X., Zhang Z., Zhu H., Chen Y.,"Geopolymerization process of alkalie-metakaolinite characterized by isothermal calorimetry",Thermochimica Acta,2009,493,49-54

[28] Yunsheng Z., Wei S., Zongjin L., Yantao J, "Study of polycondensation process of metakaolin-based geopolymeric cement using semi-empirical AM1 calculations", Advances in cement research,2009,21,67-73

[29] Albidah A., Abadel A., Alrshoudi F., Altheeb A., Abbas H., Al-Salloum Y, " Bond strength between concrete substrate and metakaolin geopolymer repair mortars at ambient and elevated temperatures", Journal of Materials Research and Technology, 2020,9,10732-10745.

[30] Rovnanı´k P., "Effect of curing temperature on the development of hard structure of metakaolin-based geopolymer", Construction and Building Material, 2010,24,1176-1183

[31]Elapasery M.A., Ahmed D.A., Aly A.A., "Decolorization of Reactive Dyes, Part II: Eco-Friendly Approach of Reactive Dye Effluents Decolorization Using Geopolymer Cement Based on Slag", Egyptian Journal of Chemistry, 2022, 65, 49-54.

[32]Elapasery M.A., Ahmed D.A., Aly A.A., "Decolorization of Reactive Dyes, Part III: Eco-Friendly Approach of Reactive Dye Effluents Decolorization Using Geopolymer Cement Based on Metakaolin", Egyptian Journal of Chemistry, 2022, 65, 55-60.

[33] Elapasery M.A., Ahmed D.A., Aly A.A., "Decolorization of Reactive Dyes, Part IV: Eco-Friendly Approach of Reactive Red 195 Dye Effluents Decolorization Using Geopolymer Cement Based on Slag", Egyptian Journal of Chemistry, 2022, 65, 121- 127.

[34] Elapasery M.A., Ahmed D.A., Aly A.A., "Decolorization of Reactive Dyes, Part V: Eco-Friendly Approach of Reactive Red 195 Dye Effluents Decolorization Using Geopolymer Cement Based on Metakaolin", Egyptian Journal of Chemistry, 2022, 65, 129-135.

[35] Yu Z., Song W., Li J., Li Q., "Improved simultaneous adsorption of Cu(II) and Cr(VI) of organic modified metakaolin-based geopolymer" , Arabian Journal of Chemistry, 2020, 13, 4811- 4823.

[36] Aly A. A., Mahmoud S. A. and El-Apasery M.A., "Decolorization of reactive dyes, Part I: Eco-friendly approach of reactive dye effluents decolorization using cationized sugarcane bagasse", Pigment & Resin Technology,2018, 47 108-115.

[37] Ahmed D.A., Abdallah S.H., Ragai S.M., "Hydration characteristic and leaching behavior of different mixes of slag based -geopolymer cement in presence of heavy metals", Egyptian Journal of Chemistry, 2022.DOI:10.21608/ EJCHEM.2022.114795.5213In press.

[38]Elapasery M.A., Ahmed D.A., "A Sustainable Approach for Immobilization Dyeing bath Effluents of Reactive Yellow 145 by using Different Types of Eco-Friendly Geopolymer Cement", Journal of Chemistry, 2022. DOI10.21608/EJCHEM.2022.157273.6818In press.

[39] Elapasery M.A., Ahmed D.A., " An Innovative and Promising Facile Route to Remove Heavy Metals and Dyes using Environmentally Friendly Slag-based Geopolymer Cement", Journal of Chemistry, 2022.DOI: 10.21608/ EJCHEM.2022.169221.7099In press.

[40] Wang Z., Huang, G., An C., Li W., Chen L., Zhang Z.," Transport of Reactive X-3B Dye at the Interface between Cationic Surfactant-Modified Water Quenched Blast Furnace Slag and Aqueous Solution,"The Canadian Journal of Chemical Engineering,2018, 96, 1240–1249

[41] Shi J., Kuwahara Y., An T., Yamashita H.,"The fabrication of TiO_2 supported on slag-made calcium silicate as low-cost photocatalyst with high adsorption ability for the degradation of dye pollutants in water,"Catalysis Today, 2017, 281, 21–28

[42]Rivera A.R., Sanjuán M.Á., Martin D.A.,"Granulated Blast-Furnace Slag and Coal Fly Ash Ternary Portland Cements Optimization," Sustainability 2020, 12, 5783.

[43] Yasipourtehrani S., Strezov V., Evans T.J.," Investigation of Phosphate Removal Capability of Blast Furnace Slag in Wastewater Treatment," Scientific Reports, 2019, 9, 7498

[44] Aly A. Hebeish, Amal A. Aly,**"** Synthesis, Characterization and Utilization of Starch Hydroxypropyl Sulphate for Cationic Dye Removal,**"**International Journal of Organic Chemistry,2014,4, 208-217.

[45] Ahmed S.M, Aly A.A, El-Apasery M. A, Ragai S.M, Decolorization of Reactive Dyes, Part VI: Eco-Friendly Approach of Reactive Dye Effluents Decolorization Using Geopolymer Cement Based on Metakaolin backed by slag", Egyptian Journal of Chemistry, 2022, 65,683-688.

[46] Ahmed S.M, Aly A.A, El-Apasery M. A, Ragai S.M, "Decolorization of Reactive Dyes, Part VII: Eco-Friendly Approach of Reactive Dye

Effluents Decolorization Using Geopolymer Cement Based on Metakaolin-Slag mixes", Egyptian Journal of Chemistry, 2022, 65, 689-694.

[47]Hashem, A., Aniagor, C.O., Morsy, O.M., Abou-Okeil, A., Aly, A.A."Apricot seed shell: an agro-waste biosorbent for acid blue193 dye adsorption",Biomass Conversion and Biorefinery , (2022).

[48] Hashem A., Aniagor C.O., Farag, S., Abou-Okeil A.A., Aly, A.A., Amr, A."Lepidium sativum seed powder: A novel biosorbent for acid orange 142 dye uptake", Environmental Processes , 2022 , 9, 56.

[49] Hashem A., Aniagor C.O., Abdel-Halim E.S. , Amr A. , Farag S., Aly A.A."Instrumental characteristics and acid blue 193 dye sorption properties of novel lupine seed powder" , Cleaner Chemical Engineering (2022) 2 , 100011

[50] Hashem A., Aly, A.A., Aly, A.S., Hebeish, A."Quaternization of cotton stalks and palm tree particles for removal of acid dye from aqueous solutions",Polymer - Plastics Technology and Engineering, 2006 , 45 , 389 – 394

[51]Hashem A., Aly A.A., Aly A.S."Preparation and utilization of cationized sawdust" , Polymer - Plastics Technology and Engineering ,2006, 45, 395 - 401

[52] Designation A., 2008. C191: "Standard test method for normal consistency and setting time of Hydraulic Cement", Annual Book of ASTM Standards, 172-174