Novel Composite from Glass Waste and Activated Carbon for Heavy Metals Removal from Well Water in Semi-arid Regions

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Abstract: In this study low-cost composite was prepared from glass waste and activated carbon. The developed composite was used for the removal of heavy metals from well water in semi-arid regions. An effective new green composite adsorbent was synthesized by mechanical grinding of glass waste (GP) and activated carbon (AC), after hydrothermal treatment of the waste glass (TGP). Various ratios of AC to TGP composites (1:1, 2:1 and 1:2, respectively) were prepared. The ability of those new composites for heavy metal (Cd,Cu, Fe, Pb and Zn) removal was evaluated. Composite with the ratio AC to TGP (2:1) reveals the highest adsorption of the studied metals, so it was used for the rest of the experiments. The prepared composites were characterized by scanning electron microscopy SEM, XRD and BET surface area measurement. Batch experiments were conducted to test the ability of the new composites for the removal of Cd, Cu, Fe, Pb and Zn from its solution. The experiments of the heavy metals adsorption by the prepared composite were performed at different metal ion concentrations, solution pH, adsorbent dosage, solution temperature and contact time. By application of the new composite in well water, it reveals high removal efficiencies (99- 100%) for all the studied heavy metals at pH 7 contact time 45 min and a temperature of 25 °C.

Key words: Glass waste · Adsorption · Heavy metals · Wastewater · Pollution · Water · Well

INTRODUCTION

The removal of heavy metals from different water sources (natural water, ground drinking water) and wastewater has attracted considerable attention [1]. In recent years, significant research efforts have been developed for the removal of heavy metals from polluted water and wastewater, which including adsorption, chemical precipitation, biosorbtion, solvent extraction, reverse osmosis, ion exchange, membrane separation and flotation [2-4].

Adsorption has been an effective technique for removing heavy metals from polluted waters [5]. Several adsorbents such as activated carbon, silica and graphene were used in the purification of water [6]. In recent years, several studies have been performed to explore the application of mineral materials and solid wastes as adsorbent materials for heavy metals treatment as zeolites [7], diatomite [8], sodium silicat glass powder [9, 2], activated carbon and its composites [10].

Glass beads exhibit great potential in heavy metal adsorption as a result of their high contents of alkaline earth metals, as well as, their ion exchange property with heavy metal ions. The specific surface area of untreated glass powder is small, while most of the active ions inside the glass are not available for exchange with heavy metal ions. In order to better utilize the potential of glass powder, it is useful to prepare porous glass powder with high surface areas [11]. On the other hand activated carbon does not have sufficient functional groups to adsorb heavy metals, so many methods were applied for modifying the activated carbon surface with other supported. Composites of activated carbon supported on glass powder or beads were prepared as an effective adsorbent for heavy metal ions in water. A novel route for the fabrication of silica-carbon composites by introducing a homogeneous layer of carbon to cover the silica pores was studied by Valle-Vigón *et al*. [10].

Activated carbon has shown to be an efficient adsorbent for the removal of a wide variety of inorganic pollutants presented in the aquatic environment. Because

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of its high surface areas (500 to 1500 $m^2 g^{-1}$) it is widely used in the treatment of wastewaters [2]. Effectiveness of activated carbons to act as adsorbents for a wide range of contaminants is well noted [12].

Chitosan supported on porous glass beads as a new green adsorbent for heavy metal recovery was studied by Shen *et al*.[13], in which it showed high adsorption abilities for heavy metal ions with capacities achieving up to 2.47, 7.27, 8.84, 5.15 and 4.29 m mol/g for Ni^{2+}, Cu^{2+}, Pb^{2+}, Ag^+ and Cd^{2+}, respectively.

Karnib *et al*. [14] used activated carbon, silica and silica activated carbon composite for the removal of heavy metals. Batch experiments were studied to test the ability of activated carbon for the removal of lead, cadmium, nickel, chromium and zinc ions from water. Nickel showed the highest removal percentages by activated carbon at all concentrations and the removal percentages decreased as the concentration of heavy metal increased.

This study aims to use a glass waste to prepare low-cost composite prepared from glass waste powder and activated carbon. The prepared adsorbent was applied for the removal of heavy metals (Cd,Cu, Fe, Pb and Zn) from well water in semi-arid regions.

MATERIALS AND METHODS

Sample Collection
Well Water Samples: Well water samples were collected from two different areas from the west and east of the River Nile sides at Qena governorate, upper Egypt, Egypt. One liter of the well water was collected in a clean glass bottle, filtered and stored at -4°C until use. All reagents used in the experiments were of analytical grade.

Waste Glass Samples: Waste glass bottles were collected from the house residues. The bottles were washed with tap water, followed by deionized water, crushed and ground to powder with a laboratory agate mortar and pestle to size -63ìm. The sample was oven dried at 105°C and stored for subsequent use. The collected waste glass sample was made of silicate glass which is a type of glass with the main glass-forming constituent's silica. Typically, the resulting glass (GP) composition is about 59.7 wt.% SiO_2, 25.1 wt.% Na_2O, 9.8 wt.% MgO and 4.9 wt.% CaO.

Preparation of Waste Glass Adsorbent (TGP) by Hydrothermal Treatment: Hydrothermal treatment of waste glass was processed according to Wange *et al*. [15] in which the mixture of the waste glass powder GP

(63µ) (20 g) and the distilled water (30 mL) was transferred into a Teflon container with40% volume filling in the autoclave. The autoclave was put into an oven for heating and hydrothermal reaction was conducted at 180°C for 2 h. The waste glass adsorbent was separated by filtration and washed several times with deionized water.

Surface Activation of the Prepared Adsorbent: The obtained waste glass adsorbent (TGP) was treated with HCl to replace the metal ions contained in the shell part of porous glass with hydrogen ions [15]. For this modification, the obtained adsorbent(TGP) was treated with 500 mL of 0.5 M HCl acid. The mixture was shaken for 12 h at 160 rpm in a temperature controlled shaker at 333° K. The modified TGP was separated from the solution through filtration and washed with deionized water until the of washing water pH became neutral.

Physical preparation of Activated carbon/Glass powder Composite (AC/TGP): A mixture of activated carbon (AC) and modified waste glass powder TGP was grounded in an agate mortar and sieved to the particle size 63µ. The obtained powder was mixed with deionized water and stirred for 24 hrs, after then it was washed with dionized water, filtered, dried at 105°C for two hours and burning at 300°C. The ratio of AC to TGP was adjusted to 1g:1g, 1g:2g and 2 g:1 g. The developed composites labeled P(AC/TGP)1, P(AC/TGP)2 and P(AC/TGP)3, respectively.

Characterization of the Prepared Composite: The surface morphologies of AC/TGP composite were examined by SEM (SEM, JSM-6460LV, JEOL, Japan). FTIR (Perkin-Elmer, USA) spectra in the 4000–400 cm^{-1} region were acquired by using KBr pellets. The specific surface area and pore diameter of the samples were determined by nitrogen adsorption–desorption experiments at a temperature of 77 K with an automated sorptometer (Quantachrome Autosorb NOVA2200e, USA). The X-ray diffraction (XRD, Brukeraxs D8, Germany) using Cu Kα radiation (λ= 0.15405 nm) and a secondary monochromator in the 2θ range from 10 to 70° was used to appreciate the crystalline phase, the phase composition, relative crystallinity and crystallite diameter.

Batch Experiments: The following batch adsorption experiments were carried out to determine the optimum conditions for the adsorption process of the selected heavy metals (Cu^{2+}, Cd^{2+},Fe^{2+}, $Pb^{2+}$and Zn^{2+}). Batch

adsorption experiments included: pH, contact time, adsorbent dose and initial metal concentration.

Effect of pH on metal adsorption: The synthesized absorbent (TGP) was stirred with 50ml of 50mg/l single ion standard solution (Cu^{2+}, Cd^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) for 30 min by electrical motor (500 rpm). Solution pH was varied at 2, 5, 7 and 9 and adjusted using a pH meter and HNO_3 and NaOH solution. The solution was filtrated by Whatman filter paper No 42 and the metal ions in the filtrate were measured by atomic absorption spectroscopy.

Heavy metal removal percentage (R%) was calculated using the following Eq. (1):

$$R = \frac{C_{Asb} - C_{Asa}}{C_{Asb}} \times 100\%$$
(1)

where, C_{Asa}, C_{Asb} are the metal concentration after and before the adsorption through the synthesized absorbent.

Effect of Adsorbent Dose: Different amounts (0.5, 1 and 1.5g) of TGP adsorbent were stirred with 50mL of 50mg/L metal standard solution (Cu^{2+}, Cd^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) at pH 7 for 30 min by electric stirrer (500 rpm). The mixture was filtered off and the metal ions were measured by atomic absorption spectrophotometer.

Effect of Contact Time on Metal Adsorption: 1.5g of TGP adsorbent was stirred with 50 mL of 50 mg/L standard metal solution (Cu^{2+}, Cd^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) at pH7 for different contact times (15, 30 and 45 min). The mixture was filtered off and the metal ions were measured by atomic absorption spectrophotometer.

Effect of Initial Metal Concentration: Because the metal adsorption capacity was initial concentration independent, so results with different initial concentrations are comparable. The effect of intial metal ion concentration was conducted with 25, 50 and 100 mg/L metal standard solution (Cu^{2+}, Cd^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) at constant contact time 45 min and pH7.

Effect of Solution Temperature on Metal Adsorption: The effect of solution temperature on metal adsorption was investigated at 25°C, 30°C and 45°C. 1.5g of TGP was stirred with 50ml of 50mg/L single ions (Cu^{2+}, Cd^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) standard solution at the operating temperatures at constant contact time 45 min and pH7.

The solution was filtrated by Whatman filter paper No 42 and the metal ions in the filtrate were measured by atomic absorption spectroscopy.

Analytical Techniques: A flame atomic absorption spectroscopy (Model 3110 Perkin- Elimer) equipped with digital and direct concentration readout and an air – acetylene burner was used for the element determinations. The instrumental parameters were those recommended by the manufacture. The light source used was a hollow cathode lamp for Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} which used at their recommended wave length and current.

RESULTS AND DISCUSSION

Characterization of the Prepared Adsorbents: Surface area of TGP and AC/TGP were checked by BET measurement. The results (Table 1) showed that the specific surface areas for TGP (13.73 m^2/g) increased to 20 times in AC/TGP composite (225.9m^2/g). Also, average pore volume diameter increase from 10.95 in TGP to 20.39 in AC/TGP.

XRD is an important method to determine the phase of the prepared adsorbents. Figure 1 shows XRD patterns of TGP adsorbent and AC/TGP composite. There is no sharp peak observed and this indicates that both TGP adsorbent and AC/TGP composite are in amorphous phase.

Figure 2 shows SEM micrographs of TGP and AC/TGP surfaces. It is observed that TGP particles is irregular and smooth surface and the surface was exfoliated fragments stuck on the surface with corroded and rough with fine flaky bulges on its surface, which might be crystalline calcium silicate and sodium silicate. AC/TGP composite surfaces show the change of its surface resulted in the variation of specific surface area of TGP.

Comparison Between the Prepared Composites: The percentage removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} after treatment with composites p(AC/TGP)1, P(AC/TGP)2 and P(AC/TGP) 3 were shown in Fig (3). It was observed that

Table 1: Surface areas, average pore sizes and pore volume for both TGP adsorbent and AC/TGP composite

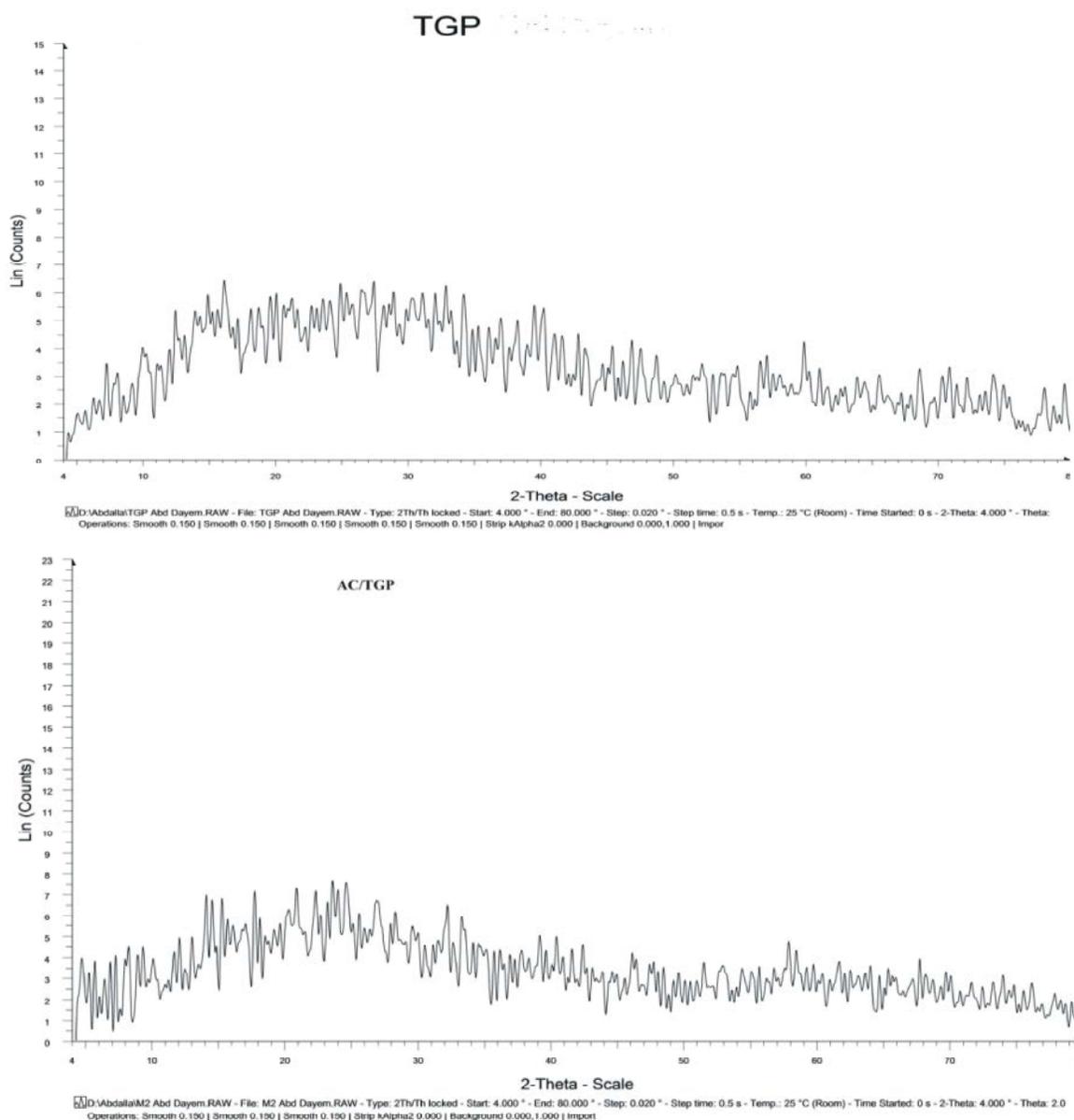| Samples	Surface area (m^2/g)	Average pore diameter	Pore volume (cc/g)
TGP	13.73	10.95	0.0067
AC/TGP	225.9	20.39	0.1151

Fig. 1: X-ray diffraction (XRD) patterns of TGP adsorbent and AC/TGP composite

the composite p(AC/TGP)3 reveals higher removal percent for Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} (03.5%, 91.1%, 91.4%, 91%, 90 %, respectively) than with those on P(AC/TGP)1 and P(AC/TGP)2. The order of the amount adsorbent dose for the removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} follows in order as $p(AC_{(2gm)}/TGP_{(1gm)})$ 3 > p $(AC_{(1gm)}/TGP_{(2gm)})$ 2> $p(AC_{(1gm)}/TGP_{(1gm)})$ 1). The higher the surface area of activated carbon on the surface of the TGP adsorbent the greater the percentage of removal of heavy metals. Thus $p(AC_{(2gm)}/TGP_{(1gm)})$ 3 was selected for the further experiments.

Darvishi *et al*. [16] studied the Pb(II) ions adsorption by Silica nano- powders / alginate composite in aqueous solutions. The optimal value of pH was 5.0 which give the best removal of Pb(II) ions.

Parameters Affecting Adsorption Potential of Metal Ions on the Prepared Composite: Composite p(AC/TGP) was mixed with 50 ml of 50 mg/L of each Cd^{+2}, Cu^{+2}, Fe^{+2}, Pb^{+2} and Zn^{+2} ions. The mixtures were checked for 45min, filtered, washed and the equilibrium concentrations of the studied elements were the estimated in the filtrates using AAS technique.
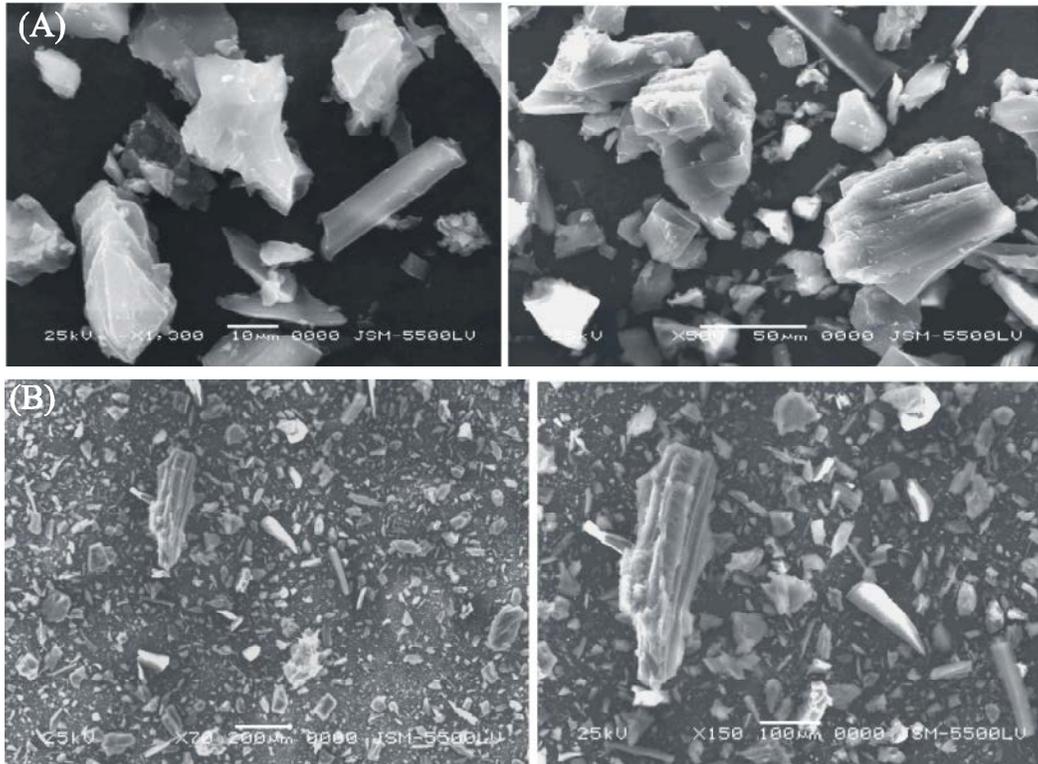
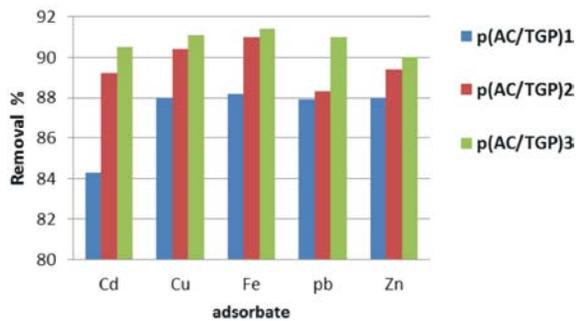Fig. 2: Micrographs of TGP adsorbent (A) and AC/TGP composite (B)

Fig. 3: Comparison of adsorption efficiency between different composites for the removal of the studied metals

Table 2: Effect of pH on the removal percentage of Cd, Cu,Fe, Pb, Zn using P(AC/TGP)3 adsorbent.

pH	Cu^{2+}	Cd^{2+}	Fe^{2+}	Pb^{2+}	Zn^{2+}
2	40%	45%	39.8%	37%	43.4%
5	88.9%	88.5%	87.8%	88.8%	89.7%
7	90.7%	90%	90.5%	90%	91.2%
9	89.7%	88.8%	88%	88.5%	90%

Effect of pH on Metal Adsorption: The pH of the solution plays an important role in the whole adsorption process. The effect of pH on the metals (Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) removal on p(AC/TGP)3 adsorbent is very important parameter. The concentration of the metal ion uptake from the single metal ion solution was examined for different pH values (2,5,7and 9) and the results presented in Table (2).

The results show that the removal percent of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} ions by P (AC/TGP) 3 adsorbent increased with an increase of pH levels in the range from 2 to 9. At acidic pH 2 it shows less removal of metal removal probability due to the competition effect with ion H_3O^+. At pH from 5 to 7, metal adsorption increased until the maximum absorption of the metals at pH 7 (90.7% for Cd, 93 % for Fe, 90 for Cu, 90.5% for Fe and 91.2% for Zn). Over pH 7, metals began to precipitate as metal hydroxides. So, the suitable pH for the maximum adsorption of the studied metal ions was at pH 7. The small adsorption appears at low pH often attributed to a competition between H^+ and metal ion on the same sites [17]. Hence the removal yield of metal ions is very low due to the electrostatic repulsion forces between positively charged $H3O^+$(sorbent surface) and metal ions. The increase of pH, cause the negative charge density on the surface to increase due to the deprotonisation of positively charged groups on the surface (Sorbent surface).
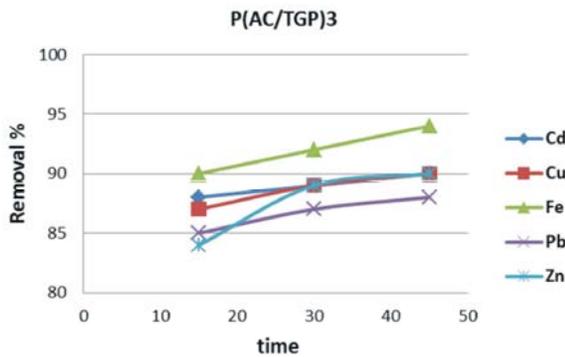
Fig. 4: Removal percentage of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} by P(AC/TGP)3 at different contact time (15, 30 and 45 min)
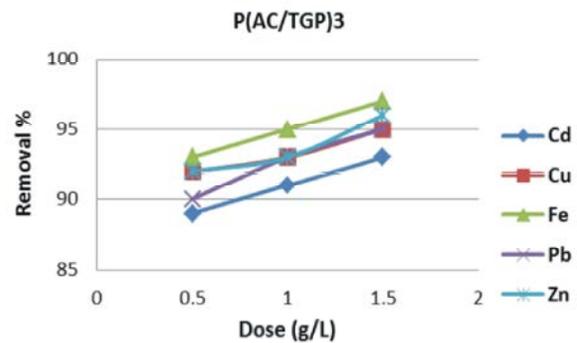
Fig. 5: Removal percentage of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} by P(AC/TGP)3 at different adsorbent doses (0.5, 1 and 1.5g).

Givianrad *et al*. [18] reported that the maximum adsorption of Cd^{2+} ion by a novel composite adsorbent, silica aerogel activated carbon was at pH 6.0. Abed El-Latif *et al*. [19] used magnetic alumina nano composite for the removal Cadmium Ions from aqueous Solutions. Elnasri *et al*. [20] reported that the maximum removal of Fe^{2+} ions by activated carbon was at pH 6.

Mehdinia *et al*. [21] studied the effect of pH on metal adsorption at magnetic amine-functionalized mesoporous silica nanocomposites. They reported that at low pH values the adsorption showed very low removal of lead(II), copper(II) and zinc(II). The removal efficiencies reached to 90% at pH of 6.0 for Pb^{2+}, 88% at pH of 7.0 for Cu^{2+} and 87% at pH of 7.0 for Zn^{2+}.

Effect of Contact Time on Metal Adsorption: Equilibrium time is another important operational parameter for the effectiveness of adsorption, where the adsorbent active sites and the sorbet are in contact to each other for the adsorption to occur. The adsorption data for the removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} by P(AC/TGP)3 adsorbent at different contact times (15, 30 and 45 min) under the same experimental condition parameter (initial concentration; 50 mg/L particle at pH 7) were studied and represented in Fig. (4).

The results reveal that the adsorption of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} increased rapidly from 15 min to 45 min contact time and the maximum adsorption of the metals was at 45 min contact time (89% for Cd, 90% for Cu, 94% for Fe, 88% for Pb and 89% for Zn). This might due to the nature of the sorbent and its available sorption sites that affect the time needed to reach equilibrium [22].

Givianrad *et al*.[18] reported that the maximum adsorption of Cd on nano composite silica aerogel, activated carbon was at 90 minutes. Pandey *et al*. [23]

studied the removal of Cu (II) by ZeoliteNaX from Aqueous Stream and found that Cu removal increased with the time and attains saturation in 60 to 120 min.

Effect of Dose on Metal Adsorption: The adsorption data for the removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} by 0.5g of P(AC/TGP)3) under the same experimental condition parameter (initial concentration; 50 mg/L at pH 7) were studied and represented in Fig. (5). The results show that metal ions were effectively removed from the solution even at small adsorbent doses. With the increase adsorbent dose from 0.5 to 1.5 g/50ml, the metal adsorption increased slowly. The maximum removal percent of metals were at the dose of 1.5g (Cd 89%, Cu 93%, Fe 91%, Pb 92% and Zn 93%). It is shown that fraction removal significantly increases as the adsorbent dose increased until equilibrium adsorption was established at 1.5g/50ml of p(AC/TGP) 3 adsorbent. So the amount of different adsorbent was selected as 1.5 g/50mL for further adsorption experiments.

An increased metal ions (II) removal was noted to increase in the amount of Sorbent. This happens due to the greater availability of the surface area of the sorbent. The increasing in the amount of sorbent enhances the fraction removal of metal ions until it reaches the optimum dose. Also, the increase in removal of metal ions with increasing adsorbent dosage can be explained by the increase in active sites in the higher amount of adsorbent, thus providing easier penetration of metal ions to active sites.

Abd El-Latif *et al*. [19] studied that the effect of adsorbent dose on Cd ion removal from aqueous solutions by varying the amount of MANC from 0.25 to 3.0 g/L, while keeping other parameters (pH, agitation speed, temperature, initial Cd^{2+} ion concentration and

Table 3: The adsorption data for the removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} on P(AC/TGP)3 adsorbent at different initial concentration 25, 50,75 and 100 mg/L

Initial Con. mg/l	Removal %									
	Cd^{2+}		Cu^{2+}		Fe^{2+}		Pb^{2+}		Zn^{2+}	
	Ce	%	Ce	%	Ce	%	Ce	%	Ce	%
25	1.9	92.4	1.5	94	1.60	93.6	1.93	92.3	2.819	94.3
50	5.02	90	4.23	91.5	4.62	90.7	5.11	89.7	4.007	92
75	10.51	86	9.60	87.2	11.52	84.6	10.62	85.8	8.527	86.6
100	17.52	82.5	17.32	82.7	19.77	80.2	17.52	82.5	16.87	83.1
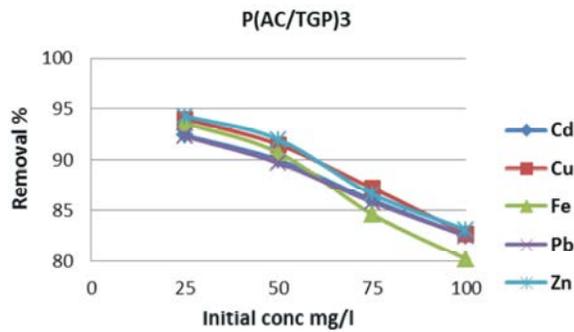
Fig. 6: Removal percentage of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^2 by P(AC/TGP)3 adsorbent at different initial concentration 25, 50, 75 and 100 mg/L.
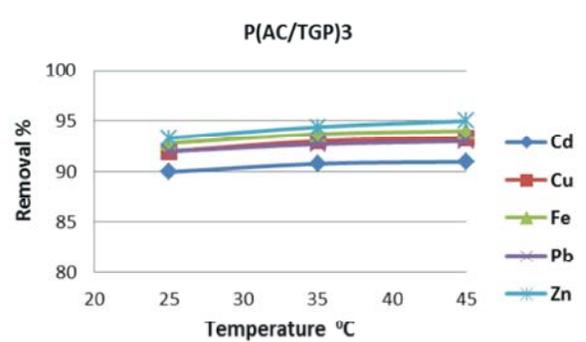
Fig. 7: Removal percentage of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} by P(AC/TGP)3 adsorbent at different temperature 25, 35 and 45°C.

contact time constant, The percentage removal of Cd ion increased from 96.06% to 99.99% with the increase of adsorption dosage from 0.25 to 3 g/L [19]. Kakavandi *et al*. [24] studied the adsorption of Pb^{2+} ions onto a magnetic composite of activated carbon and super paramagnetic Fe_3O_4 nanoparticles. The effect of adsorbent dosage variations on the percentage of Pb^{2+} ion removal of condition (pH 6 and t = 60 min). By raising the adsorbent dosage from 0.5 to 2 g/L, the removal percent of Pb^{2+} ions significantly increased from 41.7 to 92%, while the adsorption capacity was reduced from 41.7 to 22.9 mg/g.

Effect of Initial Metal Concentration on Adsorption: The adsorption data for the removal of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} by P(AC/TGP)3 adsorbent at different initial metal ion concentrations (25, 50, 75 and 100 mg/L) under the same experimental condition parameter (solution temperature 25 °C at pH 7) were studied and represented in Fig. (6) and Table (3).

It was shown from the Table that with increase of metal ion concentration from 25 to 100mg/L the removal efficiency of metal decrease from 92.4 to 82.5% for Cd^{2+},from 94 to 82.7% for Cu^{2+}, from 93.2 to 80.2% for Fe^{2+}, from 92.3 to 82.5%for Fe^{2+}, from 92.3 to 82.5% Pb^{2+} and

from 94.3 to 83.1% for Zn^{2+}. The adsorption decrease at higher metals concentration may due to could lack of the free high energy sites.

Heavy metal Cu^{2+}, Cr(VI), Cd^{2+}, Ni^{2+} and Pb^{2+} ions removal from aqueous solution using magnetite Dowex resin nano composite was studied by Lasheen *et al*., [25]. Metals adsorption percentages decrease with increasing the initial metals concentration to 100 mg/L.

Effect of Solution Temperature on Metal Adsorption: Temperature plays key roles on the adsorption process. First, increasing the temperature decreases the viscosity of the solution which, in turn, enhances the rate of diffusion of the adsorbate molecules across the external boundary layer of the adsorbent and resulted in higher adsorption. Second, changing the temperature may affect the equilibrium adsorption capacity of the adsorbent [26].

The effect of different temperatures (25°C, 35°C and 45°C) on heavy metals (Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} ions) by P(AC/TGP) 3 adsorbent is presented in Fig. (7).

The results reveal that with the increase of solution temperature from 25 to 45 °C no significant effect appeared. High removal percentage of metals appears at 45 °C (Cd^{2+} 91%, Cu^{2+} 93%, Fe^{2+} 92.8%, Pb^{2+} 93% and Zn^{2+} 95%). This could due to the strength of the binding and

Table 4: Physical and chemical analysis for real well drinking water samples before treatment

Well	pH	Cd^{2+} mg/l	Cu^{2+} mg/l	Fe^{2+} mg/l	Pb^{2+} mg/l	Zn^{2+} mg/l
Al-Karaimat	7.4	0.005	0.017	0.679	0.004	0.015
Al-Maharza	7.57	0.007	0.015	0.575	0.004	0.012

Table 5: Removal percent of metal ions (Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}) after treatment of real well drinking water sample

Well	Cd^{2+}	Cu^{2+}	Fe^{2+}	Pb^{2+}	Zn^{2+}
Al-Karaimat	89.5%	90.8%	91.4%	90.7%	91.8%
Al-Maharza	90.8%	93%	94.4%	91.8%	93.1%

attraction between metal ions and active site on the surface P(AC/TGP)3. Also, the increase of metal adsorption at higher temperature attributed to acceleration of some originally slow step, creation of new activation sites on adsorbent surface decrease in the size of adsorbing species, this could well occur due to progressive dissolution of the metal ion as the solution temperature increases. The temperature has two major effects on increase the rate of adsorbate diffusion across the external boundary layer and in the internal pores of the adsorbate particles because liquid viscosity decrease as temperature increase and the other one is that it effects the equilibrium capacity of the adsorbate depending on whether the process is exothermic and endothermic [27].

Our findings are in good agreement with the findings of different researchers [28-30]. Payne and Abdel-Fattah [30] used zeolites as dsorbent and revealed that Pb^{2+} removal increases with temperature in 23-45 °C range. Panida *et al*. [31] studied the adsorption of zinc using the pulp waste. In different of temperatures from (30, 40 and 50° C), the adsorption increased with an increase in temperature from 30 to 40°C.

Application of the Developed Composite for the Removal of Heavy Metal Ions from Real Well Drinking Water Samples: The real well drinking water samples were obtained from two different locations from Abu Tesht (Al-Karaimat well west of Abu Tesht and the well of Marharza east of Abu Tesht) at Quena Governorate, Egypt. Composite p(AC/TGP)3 was applied for the adsorption of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} ions at optimum pH7, contact time 45 min and a temperature of 25 °C) from real well drinking water samples. The obtained result is tabulated in Tables (4-5).

The results show that the removal percent of metal ions Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} with p(AC/TGP)3 adsorbent were highly adsorbed. Al-Karaimat well water shows high removal percent of metal ions (Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+}, 89.5%, 90.8%, 91.4%,90.7% and91.8%, respectively). For the Al-Maharza well water the removal percent of Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} and Zn^{2+} ions were 90.8%, 93%, 94.4%,91.8% and93.1% respectively. So, the

prepared p(AC/TGP)3 adsorbent was effective for higher removal efficiency of heavy metals from well drinking water.

CONCLUSION

Composite p(AC/TGP)3 was successfully prepared from waste glass and activated carbon and characterized by SEM, XRD and BET surface measurement. The developed adsorbent was successfully applied for the removal of heavy metals (Cd, Cu, Fe, Pb and Zn) from well water at the optimum adsorption conditions of pH7, contact time 45 min, adsorbent dose 1.5 g and temperature 25 °C. Glass waste can easily be applied as a cheap adsorbent for heavy metal removal from well water by preparing a new composite with activated carbon.

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