Regeneration of Carbon Saturated with ethylene Glycol by Electrochemical Method

Huda Abdul Razzaq Younis
Technical Institute, Mosul, Iraq

Abstract:

The regeneration of carbon saturated with ethylene glycol was systematically investigated by electrochemical method under different operating conditions. The effects of several operating parameters on the electrochemical regeneration efficiency were measured at room temperature. The experimental results show that the electrochemical method can be used to regenerate the activate carbon exhausted with ethylene glycol. The electrochemical regeneration efficiency can reach 85% and depends on several operating variables such as electrolyte type, concentration and regeneration time.

Introduction:

Adsorption can be used for removal of organic pollutants from aqueous streams. The polluting molecules accumulate on the inner surface of a porous solid phase therefore depleting the liquid phase. Adsorption is often the last stage of a water treatment (1) because it is more effective when pollutants concentration is low. The material mostly used as adsorbent is activated carbon (AC) (2).

For their situ regeneration the carbon remains inside the column, the process is divided into two cycles. In the adsorption cycle the column removes pollutants from the waste stream. It is followed by the desorption cycle where the column is regenerated. There are five processes available for the in situ regeneration of spent carbon (3):

1.Desorption by an inert stream or low pressure stream.
2. Desorption at high temperature.
3.Desorption due to a changing affinity between adsorbate and adsorbent.
4.Desorption by extraction using suitable solvents.
5.Removal of adsorbates by decomposition.

Method 1 and 2 are used for gas phase operation only (physical adsorption). The other three methods are applicable for liquids. All methods can restore only part of the adsorption capacity because they are not powerful enough to change the adsorption equilibrium much. The regenerative performance gets worse for multi-component systems. For better results two methods can be combined as is done in steam regeneration where a high temperature and an oxidizing environment are applied (4).

Electrosorption is short for electrochemically influenced sorption. It basically deals with the effects that an applied electrical potential has on the sorption behavior. Two effects can be identified. For low potentials the adsorption equilibrium of molecules is a function of the solid-liquid potential drop, even if they are not charged. This rules out simple coulombic interaction as mechanism. by changing the applied potential one is able to change the adsorption equilibrium (method 3). When the applied potentials are higher, electrochemical faraday reactions occur in additions to equilibrium changes. By exchanging electrons with the electrode, adsorbed molecules can be oxidized or reduced, converting them to less adsorbable components or even to carbon dioxide and water (method 5). Electrosorption is a hybrid process that combines elements from adsorption and electrochemistry. Electrochemical principles dictate that the system must contain at least two electrodes that are connected via an external electrical circuit. Both most be in contact with an electrolyte (4).

By chemical methods, the exhausted carbon may not be returned for regeneration and carbon loss could be neglected. The regeneration efficiency by chemical methods depends on the types of organic pollutants. Alcohol compounds are raw materials and/or basic products of the chemical industry. As a result, they are widely found in the effluents of these industries or reach the surface or ground water via use by consumers. They are considered as water pollutant (as glycol which is completely soluble in water) due to its, ability to form hydrogen bonds with water molecules (5).

The electrochemical regeneration mechanism was investigated by different researchers (6,7). The regeneration efficiency by electrochemical methods can be conveniently operated in-situ, and reach as high as 80-95% (8).

Zhange and Narbaitz studied regeneration of exhausted carbon with phenol, and the regeneration efficiency can reach over 80%. Desorption and destruction of phenol adsorbed on granular activated carbon could be greatly enhanced in an electrochemical reactor (9, 10).

The aim of this research is to investigate the regeneration mechanism for the exhausted carbon that is regenerated by fixing activated carbon on electrodes under different operating conditions.

Materials and methods:

The granular activated carbon used was supplied by (Riedel-De Haeu AG, Seelze-Hannover). Its iodine adsorption value is **(**1096 mg/g**),** and its particle size is (10*20 mesh). The wastewater containing ethylene glycol in the experiments was prepared from the chemical agent and purified water.

The regeneration experiments of granular carbon were carried out in an electrochemical batch reactor (Analysis omnimeter model OM-1B, TOA Electronics Ltd.), that consisted of two platinum electrodes shown in Fig.[1] (11), one is anode and another is cathode, both have an area of (2 cm X 4 cm), and there was a fixed distance of (2.5 cm) between anode and cathode in those experiments. The activated carbon was used to adsorb ethylene glycol so as to be saturated at 25°C. Then it was put onto the batch reactor and regenerated again under the same conditions.

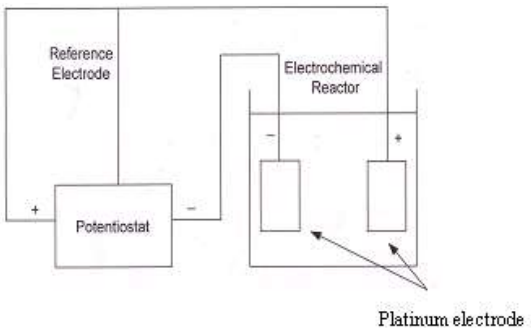

Fig. (1): The electrochemical reactor of regeneration activated carbon

The saturated adsorption values of activated carbon in this paper were denoted by the equilibrium adsorption values of ethylene glycol on activated carbon under (1.0 g/l) ethylene glycol solution concentration except for the adsorption isotherms. The regeneration efficiency was computed comparatively to the saturated adsorption of fresh activated carbon under the same equilibrium solution concentration.

Experimental results and discussions:

The regeneration efficiency of carbon contaminated with ethylene glycol on electrolyte type, electrolyte concentration, and regeneration time. These variables were investigated in this paper to assess the electrochemical regeneration process so as to improve the operation performance and to understand the regeneration mechanism.

1. Regeneration of depleted carbon

Spent carbon saturated with ethylene glycol was placed in the electrochemical reactor where to be regenerated with regeneration current of (11.5 mA) and (2.5 cm) distance between electrodes. The electrolyte was sodium chloride and its concentration was (3%) in the solution of (500 ml), the regeneration time was (4 h). The regeneration efficiency of carbon was computed according to its saturated adsorption capacity before regeneration.

When regeneration was processed a large amount of fog-like gases are formed to gather on the surface of electrolyte solution. Bubbles raised mainly from the cathodic plate like air mist in the liquid. The research results for the reaction mechanism of ethylene glycol oxidation by electrochemical oxidation indicated that during the reaction processes, under the influence of the electric field, the ethylene glycol first became di-sodiumethoxide then was oxidized into carbon dioxide and water. The experimental phenomena like liberation of hydrogen at cathode and the liberation of chlorine gas at anode, were conformable to the above-mentioned results.

The electrochemical regeneration mechanism (12) of carbon saturated with ethylene glycol shows that ethylene glycol is firstly desorbed from the activated carbon surface, then oxidized by electrochemical active chlorine or oxygen (13, 14). Under the influence of the electric field the Na+ ions move to cathode to make ethylene glycol in activated carbon be easily desorbed in the cathode zone because the Na+ ion reacts with ethylene glycol into disodiumethoxide which is very difficult to be adsorbed in activated carbon. Meanwhile the pH value at the cathode zone increases with the movement of the Na+ ions to the cathode. The equilibrium adsorption capacity of ethylene glycol in activated carbon increases in acidic solution. The desorbed ethylene glycol is easily oxidized in the anode by electrochemical active chlorine or oxygen. So the concentration polarization can take place because of mass transfer resistance (10).

2. Electrolyte type

Several kinds of electrolytes such as sodium chloride, sodium carbonate, sodium bicarbonate and sodium sulfate with the same concentration of (3%) were tested. In each test, the spent activated carbon was regenerated in electrolyte solution of (500 ml) with (11.5 mA) current density for (4 h). The fixed distance between electrodes was (2.5 cm). The experimental data are presented in Fig. (2). The result demonstrates that sodium chloride solution is the best electrolyte in that it has high regeneration efficiency and low residual ethylene glycol among the limited examinations in the research.

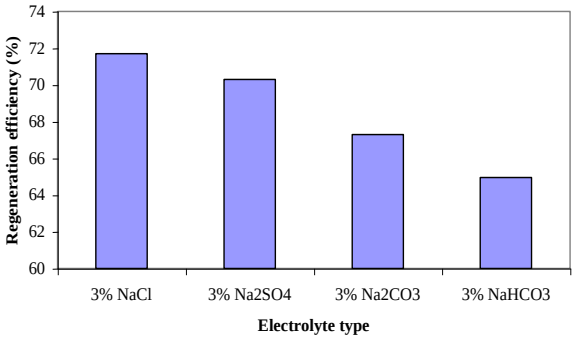

Fig 2. Regeneration efficiency of activated carbon in different electrolyte solutions

3. Electrolyte concentration

As the concentration of NaCl increases from 0.5 to 3%, its effect on regeneration efficiency becomes significant. The regeneration time and regeneration current are (1h) and (11.5 mA), respectively. The regeneration efficiency increased when the electrolyte concentrations are changed from 0.5 to 3% of NaCl solution. It nearly keeps the same after that. The experimental result is shown below in Fig. (3).

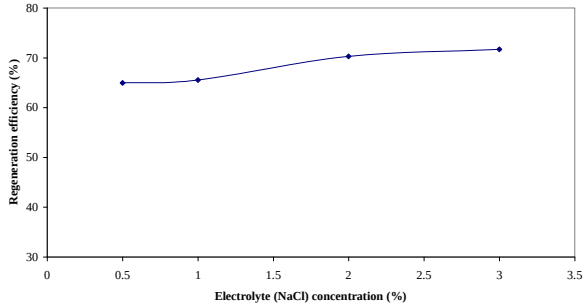

Fig 3. Regeneration efficiency of activated carbon in different electrolyte concentration

4. Regeneration time

The regeneration efficiency of activated carbon was measured at different time keeping other experimental conditions constant. The results are shown in Fig.(4). It is obvious that the regeneration efficiency increases with regeneration time. The change of regeneration efficiency

could be neglected after regeneration for (4h) which was chosen in other experiments.

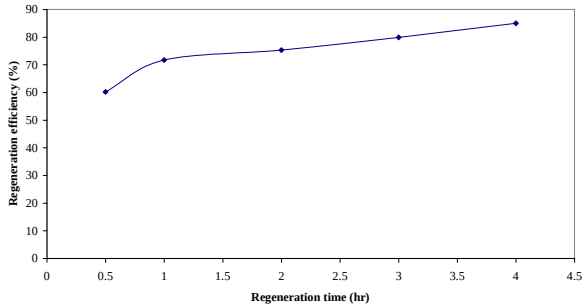

Fig 4. Effect of time regeneration efficiency

Conclusions:

The electrochemical method is very effective for the regeneration of exhausted carbon with ethylene glycol, and the regeneration efficiency can reach 85%. Desorption and destruction of ethylene glycol adsorbed on granular activated carbon could be greatly enhanced in an electrochemical reactor. Sodium chloride is the best choice to be used as electrolyte compared with other electrolytes. The regeneration efficiency of carbon adsorbing ethylene glycol increases along with the increase of electrolyte concentration in the range of lower concentration. It also increases along with regeneration time, but it basically has no change after the regeneration time reaches (4 h). The regeneration efficiency can reach (85%). This method indicates an increasing importance and wider application prospects.

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إعادة تنشيط الكربون المشبع بالأثيلين كلايكول بواسطة الطريقة الكهروكيمياوية

هدى عبد الرزاق يونس البكري

المعهد التقني، الموصل، جمهورية العراق

الملخص:

تم إختبار عملية تنشيط الكاربون المشبع بالآثيلين كلايكول بواسطة الطريقة الكهروكيمياوية وتحت ظروف تشغيل مختلفة. وقيس تأثير العوامل التشغيلية على كفاءة عملية إعادة التنشيط الكهروكيمياوية بدرجة الحرارة الإعتيادية. أوضحت النتائج المختبرية نجاح الطريقة الكهروكيمياوية في إعادة التنشيط للكاربون المشبع بالأثيلين كلايكول. لقد وصلت كفاءة إعادة التنشيط إلى ٨٥% والتي تعتمد على عدة عوامل منها نوع الإلكتروليت، تركيزه، وزمن إعادة التنشيط.