ESTIMATION OF EFFICIENCY OF REGENERATED GRANULAR ACTIVATED CARBON BY DIFFERENT METHODS

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ABSTRACT:

In this study regeneration process was carried out for exhausted activated carbon, which has been used for adsorption process of furfural from its solution by three different methods (washing with dilute alcohol ethanol 20%, washing with boiled distilled water at 100C^{o}؛ and thermal process at (200 – 900) C^{o}؛. The regenerated activated carbon has been reused in the column system of fixed – bed in order to estimate the adsorption quantities and comparing the value with adsorption quantity of original activated carbon under same condition (furfural with concentration 0.2 kg/m³, bed depth 5 cm, flow rate of liquid 16.16 × 10^{-5} m³/min and particular size of activated carbon (1.5-0.5) mm) in order to estimate the regeneration efficiency for each method which ranged (60-90)%.

الخلاصة:

في هذه الدراسة تمت عملية تنشيط لفحم مستهلك بعد أن تم استخدامه في عملية الامتزاز لمادة الفورفورال من محلوله المائي وتم استخدام ثلاث طرق مختلفة (الغسل بكحول اثيلي مخفف 20% والغسل بماء مقطر مغلي لدرجة 100 م؛ واخيراً عملية الحرارية الجافة بدرجة حرارة متصاعدة من (200-900) م؛ . الفحم المعاد التنشيط تم استخدامه في عملية الامتزاز في عمود ذو حشوة ثابتة لغرض احتساب الكمية الممتزة للمادة ومقارنتها بالقيمة المستحصلة من استخدام فحم غير مستخدم وتحت نفس الظروف (تركيز الفورفورال 0.2 كغم/ م³ ، عمق الحشوة 5 سم ، معدل جريان 16.16 × 10 $^{-5}$ م³ / دقيقة و أخيرا حجم الحبيبات للفحم (0.5 – 1.5) ملم لغرض احتساب كفاءة التنشيط لكل طريقة والتي تراوحت من 60-90 %.

KEY WORDS:

Activated carbon, regeneration efficiency, thermal process, adsorption quantity, break point time.

INTRODUCTION:

Activated carbon is used as adsorbent in the process of the adsorption in order to control the odor or amount of organic compound because of its large surface area, it is used as powdered or granular while the last is more useful in the continuous process when waste water is purified by passing through bed of granular activated carbon (Rao1994, Casey 1992). In every small plant, it

may be feasible to use granular carbon for one time but for economical concernment the activated carbon must be regenerated (Culp and Gorden 1971).

Four general methods for reactivation granular carbon are solvent wash, acid or caustic wash, steam reactivation and thermal regeneration (Culp and Gorden 1974). Regeneration efficiency by boiling water method was achieved after 4.5 hr for phenol as (adsorb ate) with activated carbon as (adsorbent) was 90% (Martine and Ng. 1984,1985).

CALCULATION OF REGENERATION EFFICIENCY:

The efficiency of the regerant is judged on the adsorption quantity of activated carbon the efficiency can be calculated by using the following equation of calculation was employed (Martin & Ng. 1984).

$$\text{Regeneration Efficiency (RE \%)} = \frac{q_r}{q_o} \times 100\ \% \qquad \text{.....(1)}$$

Where:

q_o = quantity of solute (adsorb ate) adsorbed per unit weight of adsorbent (original activated carbon) and q_r is quantity of adsorbed solute per unit weight of adsorbent (regenerated carbon) during the passing of solution through fixed – bed column.

$$q_r \,\&\, q_o = \int_{t=0}^{t=t_s} [\,(C_o - C\,) / m\ .\ Q\ .t\,] \qquad \text{.....(2)}$$

EXPERIMENTAL WORK:

The physical properties of Granular activated carbon manufactured by (unicarbo co. Italy) are listed in **table (1).** The exhausted carbon from experiments of fixed – bed column adsorption of furfural. From waste water which was obtained from Al- Dora refinery plant after the stage of primary treatment contaminated with furfural ($C_5H_4O_2$) molecular weight (96.06 gm/mole) (OSHA 2000).

Table (1) properties of activated carbon

Item of analysis	specification
Dimensions (granular)	12 × 40 mesh (0.4- 1.6 mm)
Surface area (m^2 / kg)	1100 – 1130
Bulk density (kg / m^3)	460 – 480
Ash (%)	5 (max)

REGENERATION OF ACTIVATED CARBON:

Regeneration of exhausted activated carbon was carried out in the laboratory using the following methods (Martine and Ng. 1984, Clup and Gorden 1971).

WASHING WITH ETHANOL 20 %:

50 gm of the exhausted carbon was weight by electric balance (type, mattler, AE200, Swiss) and mixed with 600 ml of (20%) ethanol in Pyrex beaker of 1 liter. Agitating the mixture by using magnetic stirrer (type, prolabo, 2204) at 800rpm for 4 hr at 25 C˚. The washing liquid was changed three times during the process. The mixture was filtered and the activated carbon washed by

distilled water and dried in electrical oven (type, memmert, 8840, West Germany) at 200 C˚ for 3 hr.

WASHING WITH BOILED DISTILLED WATER:

50 gm of exhausted carbon with boiled distilled water in Pyrex beaker of 1 liter and heated at 100 C˚ with agitating at speed 800 rpm for 6 hr with change the boiled distilled water during the process in order to achieve the adsorption of adsorb ate (furfural). The mixture was filtered and the activated carbon was washed by distilled water and dried at electrical oven at 200 C˚ for 3 hr.

THERMAL PROCESS:

50 gm of exhausted activated carbon was washed by distilled water and dried in an oven at 100 C˚ for 1 hr and at 200 C˚ for 2 hr, after that the activated carbon was heated in an electrical furnace (type, Heraeus., Germany) at temp. 600 C˚ for 1.5 hr and the temperature was raised to 900 C˚ for 1.5 hr.

After each experiment the activated carbon was screened to remove the ash and granular with size less than 0.5 mm to be ready for using in adsorption experiment by fixed – bed column.

CONTINUOUS ADSORPTION SYSTEM:

The equipment are shown in **Fig (1)** were used for investigating the adsorption of furfural from the aqueous solution onto (original or regenerated activated carbon) and these equipment are consisted mainly from a vertical Polyvinylchloride (PVC) column fixed – bed with inner diameter 4 cm and 100-cm height, the samples were taken at internal time of 15 min from the bottom of the column. The analysis was carried by calorimetric (type, Jenway, 6030.UK) at wave length 430 nm. (Foste and Lesile 1971). **Table (2)** shows the experiment condition, which were carried out for using original and regenerated activated carbon.

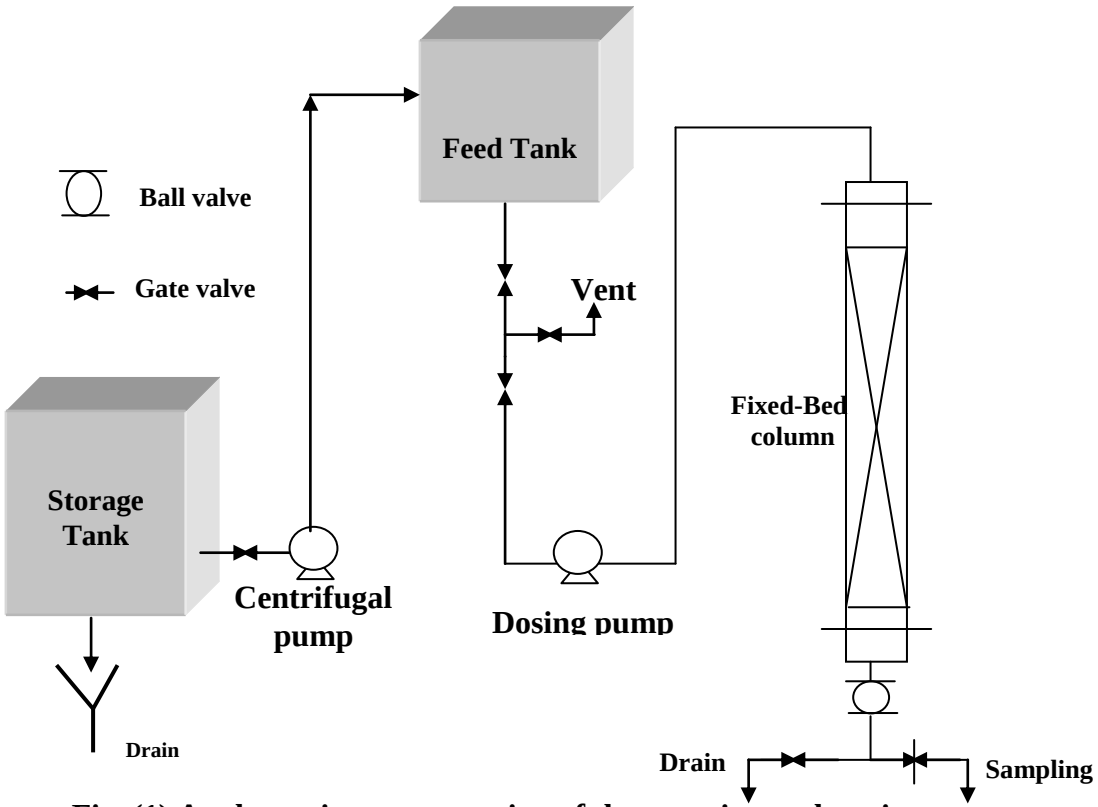

Fig. (1) A schematic representation of the experimental equipment

Table (2) Experiment information data.

experiments	Co (kg/m^3) $\times 10^{-3}$	d.p. mm	Q (m^3/min) $\times 10^{-5}$	Bed depth cm	Carbon mass in gm
Original gran activated carbon (GAC)	200	0.5 – 1.5	16.16	5	28.9
Regenerated(GAC) by alcohol	200	0.5 – 1.5	16.16	5	28.9
Regenerated(GAC) by boiled distilled water	200	0.5 – 1.5	16.16	5	28.9
Regenerated(GAC) by thermal process	200	0.5 – 1.5	16.16	5	28.9

RESULT AND DISCUSSION:

The break through curve **Fig (2)** showed the time required for break point and **Fig (3)** showed the adsorption quantity vs. time. Both above figures showed that the break point time and total adsorption quantity respectively decrease for regenerated activated compared with the original one **Table (3 and 4).**

Table (3)

Kind of bed	Break point time (min)	Total adsorption quantity (kg/kg)
Original (GAC)	**120**	**23.49**
Reg. (GAC) by alcohol	**35**	**14.3**
Reg. (GAC) by boiled distilled water	**60**	**18.4**
Reg. (GAC) by thermal process	**75**	**21**

Examining **Tables (3 and 4)** it can be seen that the removal of furfural from activated carbon using the washing with dilute alcohol Ethanol 20% is less effective compared with other methods as well as with an undiluted organic with water (Foste and Esile 1971). It is likely that bonding between the organic regenerant and water hinders the regeneration process, and the regeneration efficiency increases with increasing alcohol percent in the solution of regeneration (Martine and Ng 1984).
Using equation (1) to calculate (RE%) of the regenerated (GAC) by dilute ethanol was:
RE % = (14.3 / 23.49) × 100 = 60.80 %
This value of RE % is low compared with other methods, Table (5). This is due to the low solubility of furfural in water at 25 C˚ while its very soluble in pure alcohol (ethanol).
The regeneration by boiled distilled water shows to be an attractive form of regeneration knowing that solubility of furfural in water increases with increasing the temperature (Al-Saady, 2000). This indicates that it is acceptable to use steam in the regeneration in fixed bed adsorbers. The value of RE% by using equation (1) is 78.27%.
Using thermal process indicated that it is more effective process compared with the other methods because the high temperature will let the furfural molecules in the microspores be evaporated but this method leads to high percent of ash as a result of combustion of exhausted (GAC). The value of RE% is 89.4% and percentage of ash was 17%. **Table (5)** shows the efficiencies of the three methods.

Table (5) Regeneration efficiencies

Regenerated GAC	q_o	q_r	RE%
Washing by ethanol 20%.	23.49	14.3	60.8
Washing by boiled distilled water 100 C˚	23.49	18.4	78.27
Thermal process (200-900) C˚	23.49	21	89.4

CONCLUSION:

- Pure organic chemical regenerant, which has high solubility for furfural is more effective in regeneration process than the dilute one.
- Adsorption of furfural onto activated carbon is consider physical adsorption.
- Boiling water proved to be a very successful regenerant due to the process of adsorption is more effective when temperature is increased.
- High temperature of thermal process considered more effective method which help the molecules of adsorb ate release from the micro pores of adsorbent but leads to high percentage of ash formation due to the high temperature of heating.

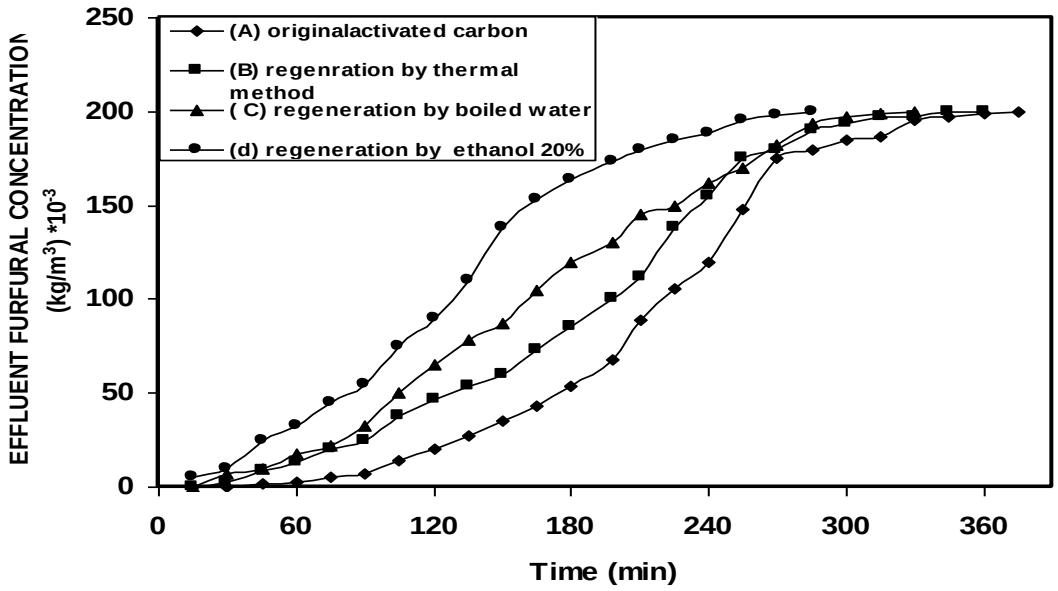

Fig.(2):Break through curves of isotherm adsorption for regenerated activated carbon by different methods comparison with original activated carbon.

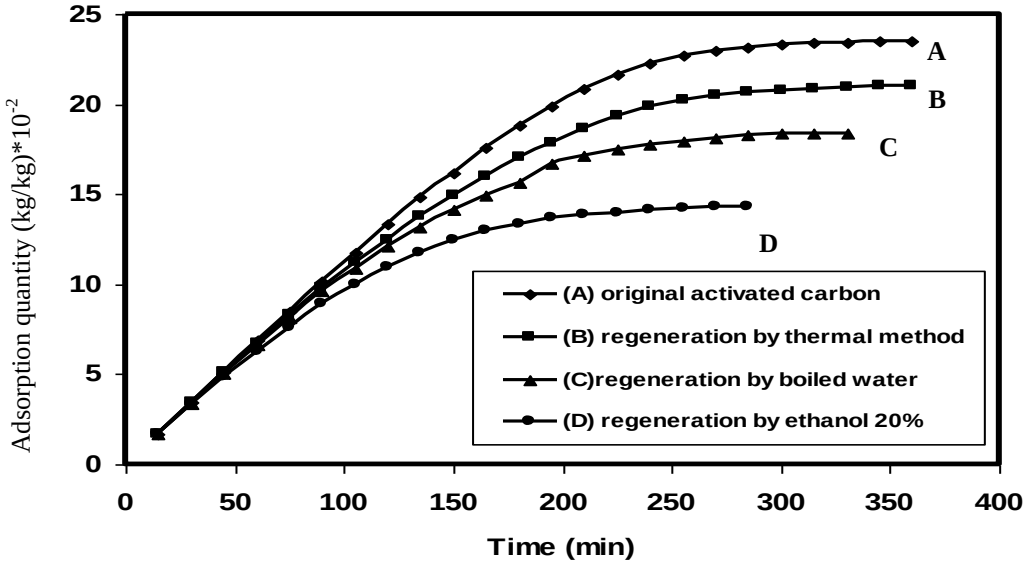

Fig. (3) Adsorption quantities curves of the regenerated activated carbon by different method comparison with original one

Table (4) break through and adsorption rate data for different regeneration methods
Where: C (kg/m^3) X10^{-3} and q (kg/kg)X 10^{-2}

Time min	Original activated carbon		Thermal regeneration		Boiling water method		20%ethanol washing method	
	C	q	C	q	C	q	C	q
15	0	1.72	0	1.72	0	1.72	5	1.69
30	0	3.44	3	3.44	7	3.44	10	3.334
45	2	5.15	9	5.09	10	5.04	25	4.85
60	3	6.85	13	6.708	18	6.617	33	6.3
75	5	8.5	20	8.265	22	8.16	45	7.64
90	7	10.16	25	9.78	33	9.6	55	8.9
105	14	11.78	38	11.18	50	10.9	75	10
120	20	13.32	47	12.5	65	12.07	90	10.95
135	27	14.8	54	13.703	78	13.125	110	11.72
150	35	16.2	60	14.92	87	14.1	138	12.421
165	43	17.56	73	16	105	14.922	153	12.95
180	54	18.8	85	17.01	120	15.614	164	13.36
195	68	19.9	100	17.88	130	16.2	177	13.67
210	89	20.85	112	18.64	140	16.7	180	13.87
225	106	21.65	138	19.33	150	17.133	185	14
240	120	22.3	155	19.87	162	17.46	189	14.13
255	148	22.74	175	20.26	170	17.72	195	14.25
270	175	22.95	180	20.5	182	17.936	198	14.3
285	180	23.12	190	20.67	191	18.126	200	14.3
300	185	23.3	194	20.8	194	18.325		
315	187	23.4	197	20.88	197	18.37		
330	195	23.45	197	21.93	198	18.4		
345	197	23.48	200	21	200	18.4		
360	199	23.49	200	21				
375	200	23.49						

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NOMENCLATURE:

C = Concentration of adsorbent at given time (kg / m^3).
C_o = initial concentration of adsorbent (kg/m^3).
d = bed depth (cm).
d_p = diameter of carbon particle (mm).
GAC = granular activated carbon.
m = mass of carbon (gm).
q = flow rate of waste water (m^3/ min).
q_o= adsorption quantity of original GAC.
q_r= adsorption quantity of regenerated GAC.
RE = Regeneration efficiency.
t = time (min).
t_s = time of bed saturation (min) .