Environment Protection Engineering

Vol. 30 2004 No. 4

ZYGMUNT DĘBOWSKI*, MAGDALENA MADEŁA*

ADSORPTION OF PHENOL AND BIOREGENERATION OF GRANULAR ACTIVATED CARBONS

A removal of phenol from water by granular activated carbons WD-extra and WG-12 was investigated. The results of phenol removal were estimated based on adsorption isotherms and then interpreted based on the Freundlich and Langmuir equations. Our test prove that carbon WG-12 is characterized by a greater adsorption capacity than WD-extra. Both activated carbons tested were regenerated in oxidizing atmosphere in the presence of bioproduct. Concentration of bioproduct ranged from 1 to 4 g/dm^3. The results obtained show that the degree of regeneration depends heavily on the time of contact of activated carbon with bioproduct, and in a small degree on its concentration.

1. INTRODUCTION

Phenols in surface water come from both natural humification processes and anthropogenic activities. Phenols as well as their secondary derivatives can be effectively removed by activated carbon. After saturation of activated carbon the problem of its regeneration arises. In literature, the process of biological regeneration is widely described and has fundamental significance in the case of activated carbons used in water conditioning and wastewater treatment [4], [7]. During water purification biological film is formed on the surface of activated carbon. Microorganisms inhabiting beds with activated carbon are able to biodegradate partially organic compounds. This process considerably prolongs operation of a filter with activated carbon. Among microorganisms inhabiting surface of activated carbons predominantly occur bacteria belonging to *Pseudomonas*, *Acinetobacter*, *Flavobacterium* as well as *Bacillus* spp. [1], [3].

CHUDYK and SNOEYINK [2] studied bioregeneration degree of granular activated carbon during water conditioning. They observed an improvement of adsorption properties of activated carbons saturated with phenol as a result of microbial activity.

* Technical University of Częstochowa, Institute of Environmental Engineering, ul. Brzeźnicka 60a, 42-200 Częstochowa, Poland. Phone: (034) 325 09 17; fax: (034) 372 13 04, e-mail: madelam@is.pcz.czest.pl.

2. MATERIALS AND METHODS

Two types of activated carbons, i.e. WD-extra and WG-12, produced by GRYFSKAND in Hajnówka were used in the experiment. Technical characteristics of both carbons are presented in table 1. The values of the coefficients given were estimated according to norms [8], [10].

Table 1

Characteristics of the activated carbons tested

Parameters	WD-extra	WG-12
Bulk density, lb/cu ft	25.8	26.1
Specific surface, m^2/g	756	1000
Mechanical resistance, %	91	95
Methylene number, LM	24	30
Iodine adsorption, mg/g	927	1050
Phenol adsorption, %	4–5	4

In the first stage of investigations, the time of dynamic equilibrium for model water was established at the phenol concentration of 1000 mg/dm^3 and the dose of carbon of 5 g/dm^3 (1 g per 200 cm^3). The process was carried out in oxidizing atmosphere at the temperature of ca. 25 °C. When the time of contact of model water with activated carbon was fixed, the adsorption isotherms were determined. They were plotted as follows: 200 cm^3 of phenol solutions of different concentrations were mixed with 1 g of activated carbon previously dried at the temperature of 145 °C [6]. The content of phenol in solution after adsorption was measured spectrophotometrically by monitoring the absorption at 254 nm on the basis of the standard curve prepared earlier [9].

The bioproduct labelled as BIO ACTIV PH was used for the biodegradation of phenol present on the surface of activated carbon. The bioproduct used in the treatment of industrial wastewater is selective in biodegradation of phenols.

When phenol adsorption from its solution of the concentration of 1000 mg/dm^3 on activated carbons was completed, the bioproduct solution of different concentrations (1, 2 and 4 g/dm^3) was poured into the samples. All samples were kept at room temperature. The time of contact of activated carbons with bioproduct was different (2, 4, 8 and 24 h). In order to determine the number of microorganisms, the measurements after 4 h and 24 h of the sample contact with bioproduct were carried out selectively. The number of microorganisms inhabiting activated carbons was counted as follows: samples of activated carbons were mixed with 20 cm^3 of distilled water, then shaken and heated in water bath at 40 °C for 30 min, and 1 cm^3 of suspension was taken. The solution of suspension was diluted in the solution of physiological salt, transferred to Petri dishes covered with agar medium and incubated for 24 h at the temperature of

37 °C. The results of counting are given as a number of microorganisms in 1 cm^3 of suspension [5].

Regenerated samples of carbon were rinsed with 200 cm^3 of distilled water. Then they again adsorbed phenol from solution, also in concentration of 1000 mg/dm^3. Adsorption capacity of regenerated active carbon was determined. The degree of regeneration was expressed as the ratio of adsorption capacity of regenerated carbon to adsorption capacity of fresh carbon.

3. RESULTS AND DISCUSSION

The time of attaining an equilibrium dynamics for model water is shown in figure 1.

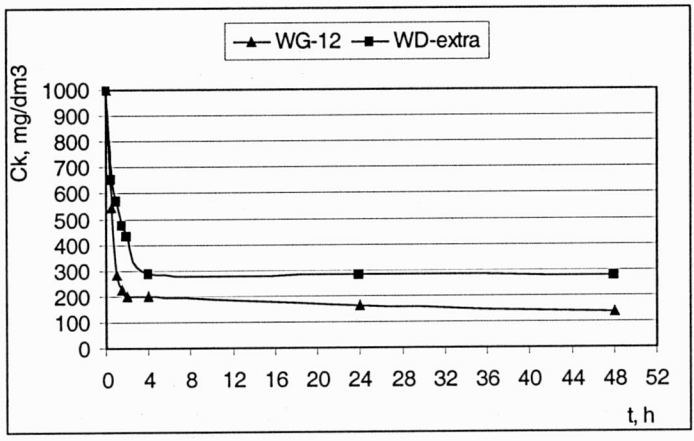

Fig. 1. The effect of contact time of water with active carbon on phenol adsorption

At a 0.5 h contact of water with carbon, 45.8% of phenol were removed from water on carbon WG-12; however, only 34.6% on carbon WD-extra. After 4 h, the degree of removal increased to 80.1% and 71.1%, respectively. Further lenghtening of the contact time resulted in insignificant phenol removal, which after 24 h was equal to 83.8% for WG-12 and for 71.6% WD-extra. For estimation of adsorption isotherms 24 h contact time was accepted in further investigations.

The experimental data fit the Langmuir and Freundlich equations. Isotherms of adsorption representing carbon WD-extra and WG-12 are presented in figure 2. The constants estimated of these equations are shown in table 2.

The isotherms show that carbons WG-12 and WD-extra differed in their ability to adsorb phenol under static conditions. The higher the initial phenol concentration, the greater the difference in the adsorption efficiency of both carbons.

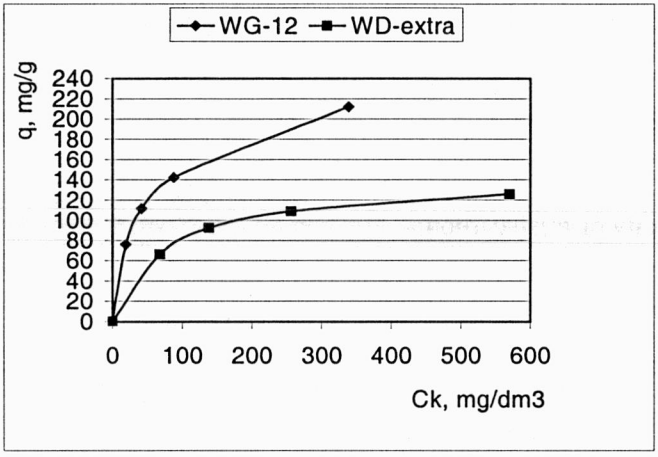

Fig. 2. Isotherms representing adsorption of phenol on carbons WG-12 and WD-extra

Table 2

The constants of the Freundlich and Langmuir isotherms representing phenol adsorption

Carbon	Freundlich isotherm			Langmuir isotherm		
	K_F, mg/g	n	R^2	$q_{,m}$, mg/g	K_L	R^2
WG-12	26.64	0.365	0.99	208.30	0.013	0.98
WD-extra	20.14	0.296	0.95	142.85	0.029	0.99

On the basis of the Freundlich constant K_F and the constant q_m (estimated from the Langmuir equation), it is possible to conclude that carbon of WG-12 adsorbed phenol better than WD-extra, which was expressed by its maximal adsorption capacity of 208.3 mg/g. Adsorption isotherms of both activated carbons show a good correlation with the Freundlich and Langmuir equations.

Table 3

The number of bacteria in the samples of activated carbons (in $1cm^3$ of suspension), depending on biodegradation improvement

Sample	4 h		24 h	
	WG-12	WD-extra	WG-12	WD-extra
Concentration of bioproduct, 1 g/dm^3	$5.8 \cdot 10^1$	$4 \cdot 10^1$	$7.5 \cdot 10^4$	$0.5 \cdot 10^4$
Concentration of bioproduct, 2 g/dm^3	$5.2 \cdot 10^2$	$2 \cdot 10^1$	$9 \cdot 10^5$	$4 \cdot 10^5$
Concentration of bioproduct, 4 g/dm^3	$4.1 \cdot 10^3$	$5 \cdot 10^2$	$1.59 \cdot 10^5$	$4.5 \cdot 10^5$

Quantitative analysis of microorganisms inhabiting activated carbons is presented in table 3.

The highest number of microorganisms ($9 \cdot 10^5$ in 1 cm^3 of suspension) was measured at the biocompound concentration of 2 g/dm^3 and 24 h contact time for carbon WG-12.

Regeneration degree of activated carbon determined as a rate of adsorption capacity of regenerated activated carbon to adsorption capacity of fresh carbon is presented in table 4. The highest degree of bioregeneration was obtained for carbon WG-12 after 8 h contact of carbon with bioproduct solution at the concentrations of the latter of 1 and 2 g/dm^3. The values obtained were similar and equal to 56.4%. The degree of WD-extra regeneration was the highest after 4 h and approached 55%. The differences in regeneration degrees between both carbons were insignificant. However, at the bioproduct concentration of 4 g/dm^3 bioregeneration was the weakest, which could be caused by an intensive overgrowth of carbon pores with microorganisms. Also adsorption of metabolic products of microorganisms on carbon can negatively affect the process of bioregeneration.

Table 4

Bioregeneration degree of activated carbons [%], depending on their contact time with bioproduct

Time h	Concentration of bioproduct					
	1 g/dm^3		2 g/dm^3		4 g/dm^3	
	WD-extra	WG-12	WD-extra	WG-12	WD-extra	WG-12
2	50.00	44.77	48.07	42.44	51.92	41.27
4	55.77	44.18	54.80	43.02	53.84	40.70
8	46.15	56.39	50.00	56.40	50.00	52.90
24	50.00	51.74	50.00	53.48	42.31	50.58

In previous investigations, bioregeneration of carbon WD-extra was carried out at considerably longer contact time. The best regeneration, i.e. 44%, was obtained after 21 days at the concentrations of phenol and bioproduct equal to 2 and 5 g/dm^3, respectively [6]. Comparing the results of experiments, we can conclude that more effective is shorter time of contact of carbon with bioproduct.

4. CONCLUSION

Based on the results obtained we can state that carbon WG-12 shows better adsorption abilities to remove phenol from water in comparison with carbon WD-extra. Carbon WG-12 displays the adsorption ability on average by ca. 40% higher.

The efficiency of regeneration depends on the contact time of carbon with bioproduct solution, and in a small degree on biopreparat concentration. The best values of phenol adsorption from water on regenerated carbons were equal to 97 mg/g for WG-12, and 58 mg/g for WD-extra.

The most promising time of carbon regeneration at bioproduct concentration of 1 g/dm^3 was 4 h in the case of WD-extra and 8 h for WG-12.

REFERENCES

[1] BUITRON G., GONZALEZ A., LOPEZ-MARIN L.M., *Biodegradation of phenolic compounds by an acclimated activated sludge and isolated bacteria*, Wat. Sci. Tech., 1998, 37, 4–5, 371–378.

[2] CHUDYK W., SNOEYINK V.L., *Bioregeneration of activated carbon saturated with phenol*, Environ. Sci. Tech., 1984, 18, 1–5.

[3] HA S., VINITNANTHARAT S., OZAKI H., *Bioregeneration by mixed microorganisms of granular activated carbon loaded with a mixture of phenols*, Biotechnology Letters, 2000, 22, 13, 1093–1096.

[4] IVANCEV-TUMBAS I., DALMACIJA B., TAMAS Z., KARLOVIC E., *Reuse of biological regenerated activated carbon for phenol removal*, Wat. Res., 1998, 32, 4, 1085–1094.

[5] ŁEBKOWSKA M., WĄSOWSKI J., WOJSA-ŁUGOWSKA W., *Zastosowanie analizy mikrobiologicznej do oceny biologicznej aktywności węgli aktywnych*, Ochrona Środowiska, 1997, 3(66), 43–46.

[6] MADEŁA M., *Sorpcja i biodegradacja fenolu na węglach aktywnych*, Inżynieria i Ochrona Środowiska, 2000, 3(3–4), 469–475.

[7] ORSHANSKY F., NARIKS N., *Characteristics of organics removal by pact simultaneous adsorption and biodegradation*, Wat. Res., 1997, 31, 3, 391–398.

[8] PN-82/C-97555, *Węgiel aktywny. Metody badań.*

[9] PN-84/c-04572, *Oznaczanie zawartości rozpuszczonych związków organicznych w wodzie metodą spektrometrii w nadfiolecie.*

[10] PN-90/C-97554, *Węgiel aktywny formowany.*

SORPCJA FENOLU I BIOREGENERACJA GRANULOWANYCH WĘGLI AKTYWNYCH

Badano usuwanie fenolu z wody na granulowanych węglach aktywnych WD-extra i WG-12. Rezultaty usuwania fenolu oceniono na podstawie izoterm adsorpcji, a zinterpretowano je, korzystając z równań Freundlicha i Langmuira. Stwierdzono, że węgiel WG-12 ma większą pojemność sorpcyjną niż węgiel WD-extra. Przeprowadzono regenerację badanych węgli aktywnych w warunkach tlenowych z wykorzystaniem biopreparatu. Zastosowano różne stężenia biopreparatu w zakresie od 1 do 4 g/dm^3. Okazało się, że stopień regeneracji zależy przede wszystkim od czasu kontaktu węgla aktywnego z biopreparatem, a tylko w niewielkim stopniu od jego stężenia. Najkorzystniejszy czas regeneracji dla węgla aktywnego WD-extra wynosi 4 h, natomiast dla węgla aktywnego WG-12 – 8 h.