BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 62 (66), Numărul 1, 2016
Secţia
CHIMIE şi INGINERIE CHIMICĂ

PHENOL AND COLOUR REMOVAL FROM WASTEWATER USING TWO COAL-BASED ADSORPTIVE MATERIALS: PRELIMINARY LABORATORY TESTS AND PERFORMANCES

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Received: February 15, 2016
Accepted for publication: March 25, 2016

Abstract. Some preliminary laboratory scale set-up results of adsorption process performance using different types of coal, as carbonaceous adsorbents, meaning powder activated charcoal (PAC), or granular activated charcoal (GAC) and mezotrophic peat (MP), applied for phenol and color removal from different high phenol-containing synthetic and real wastewaters were summarized. The influence of high phenol concentration in some adsorption processes applied for synthetic wastewaters (*i.e.* 10-3,000 mg/L phenol-containing solutions) and real wastewaters (*i.e.* wastewaters produced in manufacturing of wood fibrous plates, in a furniture processing plant, which was contained a known phenol concentration of 3,000 mg phenol/L) were studied in order to obtain a laboratory estimation of highest performance in phenol removal and its discoloration. The highest phenol removal efficiency, working with a dose of 50 g/L PAC, was of 99.875% in the case of 100 mg/L phenol-containing solutions, 80.70% in the case of 278 mg/L phenol-containing solutions with 50 g/L GAC, and 60.42% in the case of 2000 mg/L phenol-containing solutions with 50 mg/L MP. For the studied real wastewater containing around 3,000 mg/L phenol, the highest removal was of 73.46% for color with PAC, and 57.58% with MP, after 60 min (50.83% after 10 min), and of 95.19% phenol with PAC and 63.30% with MP, after 60 min. These data were useful in preparation of future experiments, and

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also of in-deep adsorption mechanism characterization for high phenol-containing industrial effluents, its optimization and industrial applications of adequate operating conditions.

Keywords: adsorption; powder (PAC) and granular (GAC) activated charcoal; mezotrophic peat (MP); phenol and color removal; wastewater treatment.

1. Introduction

Wastewaters are produced in all types of economic and domestic activities (productive or not productive ones). Treatment of these wastewaters becomes a local responsible obligation, and choosing of the most adequate wastewater management strategy will depend significantly of cost-efficiency criteria, among others. The wastewater treatment technology will play also a key role, being greatly influenced by treatment efficiency in each technological step, resulting in removal of polluting species, and also of any additional hydraulic loads.

Adsorption onto activated carbon is still considered a useful and recommended advanced treatment process of wastewaters referring to removal of dissolved organic and inorganic species, especially refractory organic, or persistent organic pollutants with a concentration of chemical oxygen demand (COD) lower than 500 mg O_2/L, in conditions in which the suspended solids, colloids, greases and oils are carefully controlled.

The activated charcoal (activated carbon) is usually obtained by heating at high temperatures, in special oven or stove, of different carbonaceous materials as wood, fossil coal, nut seeds, different types of vegetal materials, etc. The heating is used for elimination of hydrocarbons, working with an insufficient air rate for not favor of solid material combustion, with or without addition of some inorganic substances such as $ZnCl_2$, $MgCl_2$, $CaCl_2$, H_3PO_4, etc., and followed by an activation process using specific activation agents (*i.e.* air, water vapors, carbon oxides, or even Cl_2), with the main role of porous structure formation in the activated charcoal. The activation process contributes to the increasing of specific surface of activated carbon between 500-1000 m^2/g, dimensions of pores being in range of 20 to 100 Å, and porosity of 80%. In wastewater treatment, it can be used activated carbon in three forms: (*i*) granular activated carbon (GAC) with particle diameter of 1-6 mm; (*ii*) powder activated carbon (PAC) with dimensions between 0.1 to 0.5 mm, corresponding to the coal type that can be used in combination with other processes as coagulation-flocculation, biological treatment in the same mechanical agitation system, and (*iii*) biological activated carbon (BAC), having similar structure as GAC, but, because of high retention time of wastewater in column filled with GAC, it forms a biological film (this coal type is developing in parallel both adsorption and biological degradation of organic pollutants from wastewater).

The main factors highly influencing the adsorption process are grouped in: (*i*) adsorbent characteristics (*e.g.*, specific surface of activated carbon, structure of pores and distribution of pores dimensions, size of activated carbon particles, surface polarity, etc.), (*ii*) characteristics of adsorbed organic compounds such as solubility (*i.e.* lower solubility of organic compounds, greater adsorption is), molecular size and structure (*i.e.* it is preferentially favor adsorption of compounds with high molecules and branched structure; being influenced by types of functional groups, meaning the hydroxyl, sulphonic groups decrease, and nitro, aromatic groups increase the adsorption capacity), polarity and ionic character (*i.e.* nonpolar molecules with a low ionization degree are preferentially adsorbed), and (*iii*) wastewater characteristics (*i.e.* temperature - low temperature favors adsorption, because adsorption is, in general, exothermic; pH - varies in each case, being dependent of adsorbing organic compound type, in general adsorption is higher at pH corresponding to the lowest polarity of organic molecule; content of dissolved solids and greases in wastewater, is usually indicated for good adsorption conditions; *e.g.*, for not blocking of activated carbon layer, it is recommended a concentration of dissolved solids lower than 10-70 mg/L, and of oils/ greases lower than 10 mg/L) (Bousher *et al.*, 1997; Chojnacka, 2010; Macoveanu *et al*., 1997; Laohaprapanon *et al*., 2010; Park *et al*., 2010; Suhas *et al*., 2007; Zaharia, 2015).

Adsorption of refractory (or non-biodegradable) organic compounds, included also in the category of persistent organic pollutants (*i.e.* some dyes, pesticides, phenols and poly olefins, industrial effluents from oil refinery, cellulose and paper industry, etc.), is advantageous for concentration until 5,000 mg/L, and can be used before or after biological treatment, in function of wastewater characteristics. Usually, activated carbon is used for drinkable or industrial water treatment, industrial wastewater treatment in secondary (before biological stage, if wastewater contains toxic species for microbial biomass), or tertiary treatment steps (after biological step, for treatment finishing and removal of dissolved organic compounds resulted from biological processes).

This work proposes a brief presentation of some preliminary laboratory control tests referring to phenol removal from different synthetic wastewaters, more exactly different aqueous phenol solutions (with 10 - 3,000 mg/L phenol), and also from a real wastewater containing at least 3,000 mg/L phenol (a quite known quantity, because of corresponding phenol addition in wastewater). In parallel, in the case of real wastewater (from wood fibrous plates manufacturing, in a furniture processing plant), it is also studied the discoloration degree in case of a constant adsorbent dose of 50 mg/L.

2. Experimental

2.1. Materials

Reagents: Phenol (Merck KGaA, Germany), aqueous stock solution of 2,000, or 3,000 mg/L; sulfuric acid (H_2SO_4,) of 0.1N and concentrated (98%, Merck KGaA, Germany); sodium hydroxide (NaOH; Chemical Company, Iași, Romania) of 0.1N; potassium acid phthalate, calibration COD-Cr reagent (Fluka Analytical, Sigma-Aldrich Chemie GmbH); $K_2Cr_2O_7$ (Chemical Company, Romania), aqueous solution of 0.25N; mercury (II) sulfate, specific catalyst ($HgSO_4$, Fluka Analytical, Sigma-Aldrich Chemie GmbH), and silver sulfate, chloride inhibitory (Ag_2SO_4, Fluka Analytical, Sigma-Aldrich Chemie GmbH). All reagents were of analytical purity.

Adsorptive materials: *PAC* - powder charcoal activated for analysis (powder activated carbon-PAC; Merck KGaA, Germany), characterized by a specific surface of 1165 m^2/g (BET method, for benzene adsorption/desorption onto PAC); *GAC* - granular activated coal (from respiratory protection mask), characterized by a specific surface of 128 m^2/g (BET method, for benzene adsorption/desorption onto GAC); *mezotrophic peat* (fertile soil for vegetal plants/crops, characterized by pH = 6.6-7.0, purchased from Matecsa Ker.Es Kért kft, Hungary), prepared in a special mode: (1) it was washed few times with distilled water, followed by solid separation, and dyed at room temperature; (2) it was heated in a oven at 250°C, until a constant mass, and (3) the final solid sample was mortared, and sifted through a sieve of 1 mm mesh.

Real wastewater: real wastewater produced in wood fibrous-based plates manufacturing (*e.g.,* for beech plates manufacturing, in a furniture processing plant), characterized as turbid wastewaters, having yellow-brown color, persistent specific smell of wood, and high organics content (*i.e.* suspended organic solids, organic colloidal dispersion, or dissolved organic species, consisting in phenols and other derivates resulted from lignocellulose-based material degradation and phenol formaldehyde-based resins (as glue) added to wood fibrous mass for manufacturing of wood fibrous plates), and are usually acid. The experimental tests were performed for real wastewaters resulted from thermal treatment of wood for fibrous plates manufacturing, which were enriched or not with added phenol (3,000 mg phenol/L). In this work, there were considered as important pollutants (or wastewater quality indicators) the color and phenol concentration, which influenced also the sum organics concentration, expressed by chemical oxygen demand (COD-Cr, [mg O_2/L]), or biochemical oxygen demand (BOD_5, [mg O_2/L]).

2.2. Analysis Methods

Phenol determination: it was analyzed by the spectrophotometer-based method with p-nitroaniline, without distillation (SR ISO 7167 - 1992) (Musteret *et al.*, 2014; Zaharia, 2014).

Color determination: it was expressed by absorbance related to a blank with distilled water, measured at three standard characteristic wavelengths (SR ISO 7887-97) as: 436, 525, and 620 nm, especially at 436 nm for industrial wastewaters (*apparent color* in supernatant, or *real color* in filtrate), or Hazen color index (Hazen units - HU, *i.e.* an absorbance of 0.069 at 456 nm corresponds to 50 HU) (Musteret *et al*., 2014; Zaharia and Suteu, 2013; Zaharia, 2014). The absorbance measurements were performed at a Drell 2000 (Hach Company, U.S.A.) spectrophotometer.

COD-Cr determination: it was performed with the spectrophotometer-based method, by absorbance measurement at 600 nm (A_{600}) with Drell 2000 spectrophotometer of treated sample by 2h-oxidation at 150°C (oxidation in concentrated H_2SO_4 medium with $K_2Cr_2O_7$ 0.25N, in the presence of specific catalyst- $HgSO_4$, and chloride inhibitory agent - Ag_2SO_4; COD is appreciated with specific calibration curve and liniar regression equation, plotted with experimental results working with potassium acid phthalate as COD-Cr calibration reagent solution (Surpateanu and Zaharia, 2002; Zaharia and Suteu, 2013; Zaharia *et al*., 2012).

BOD_5 determination: it was applied the standard method consisting in calculation of difference between the initial dissolved oxygen concentration and dissolved oxygen concentration after 5 days of wastewater sample incubation (treated with nutrition dilution water – 1 mL of each constituent solution per 1 L of wastewater, consisting in phosphate buffer solution for pH=7.2 (KH_2PO_4+K_2HPO_4+Na_2HPO_4), magnesium (II) sulfate, calcium chloride, ferric chloride, and 1 mL of zoo-technical wastewater), at constant standard temperature. For determination of dissolved oxygen concentration it was applied the standard Winkler method (SR EN 25813:2000), consisting in hydroxide precipitation of manganese species in alkaline condition (NaOH + KI) in presence (as $Mn(OH)_3$), or lack (as $Mn(OH)_2$) of dissolved oxygen in studied wastewater, and its dissolution in acid medium (HCl or H_2SO_4) with I_2 eliberation, and titrimetrically analyzed with sodium tiosulfate in presence of starch (Musteret *et al.*, 2014; Surpateanu and Zaharia, 2002; Zaharia, 2014).

PH measurement: it was done directly at HACH One Laboratory pH meter.

2.3. Working Methodology

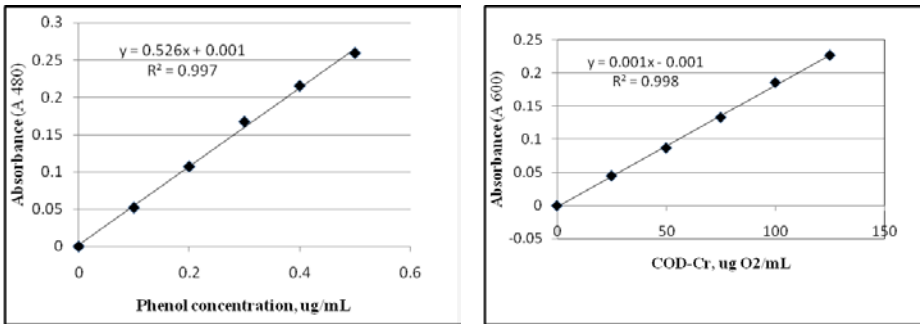
There were performed some control tests of phenol adsorption onto different coals: PAC, GAC, and mezotrophic peat (MP), working with 1g of

adsorbent per each 20 mL of studied synthetic or real wastewaters, meaning a dose of 50 g/L of adsorbent. Only for real wastewater containing 3,000 mg/L phenol added, it was studied the color removal, or its discoloration degree. The wastewater and adsorbent were stirred together for 3 min, and after let to rest and develop 'batch' adsorption for 1 hour, in special test tubes. Further the test tubes were centrifuged at 3,000 rpm in a CM-4 mass centrifuge (Electrotehnica, București, Ro; No.121-characteristics: 220V, 0.6 A, 120W; max 6000 rpm) for PAC, or processed by filtration using simple laboratory funnel with cotton wool as filtering layer, for GAC and mezotrophic peat; the clear phase (supernatant), or filtrate was analyzed further concerning the phenol content and color, among others.

The adsorptive treatment performance was expressed by phenol and color treatment degree, or phenol and color removal (R, [%]) (Zaharia and Suteu, 2011), and also the phenol amount adsorbed onto adsorbent related to the added phenol amount.

3. Results and Discussions

Some important quality indicators (color, phenol, COD-Cr and BOD_5) were analyzed in different synthetic and real wastewaters. The calibration curves used for phenol and COD-Cr determination, together with their liniar regression equations are presented in Figs. 1 *a* and *b*, being performed working according with the analysis methodology described above.



a *b*

Fig. 1 − Calibration curves for phenol concentration (*a*) and COD-Cr (*b*).

The main analyzed characteristics of real industrial wastewater produced at manufacturing of beech wood fibrous plates, alone or with known amount of phenol added in it, are summarized in Table 1.

Table 1
The Main Quality Indicators of Real Wastewater (Without/with Added Phenol)

Wastewater type	Color, [HU]	COD-Cr, [mg O_2/L]	BOD_5, [mg O_2/L]	Added Phenol, [mg/L]
Real industrial WW	1,395.65	544.712	80.8	- (not considered)
Real industrial WW + phenol sol. added	1,176.80	6,847.5	1530	3000

3.1. Control Test of Phenol Adsorption onto PAC from Synthetic Wastewater

Different volumes of phenol stock solution were added in different test tubes and treated each ones with 1 g PAC, working as in the above mentioned 'batch' adsorption methodology (3 min of stirring, 1h-adsorption, followed by S/W separation by 3,000 rpm-centrifugation for 5 min). After separation, the clear liquid phase was analyzed concerning the residual phenol concentration for determination of total phenol removal. Some of experimental results are presented in Table 2 and illustrated in Fig. 2.

Table 2
Phenol Removal from Different Solutions onto PAC

No.	Phenol solution volume, [mL]	Absorbance (A_{480})	Residual phenol conc., [mg/L]	Phenol removal, [%]
1	5	0.048	0.0175	98.78
2	10	0.058	0.0400	87.20
3	15	0.071	0.0713	95.01
4	20	0.215	0.3000	79.02

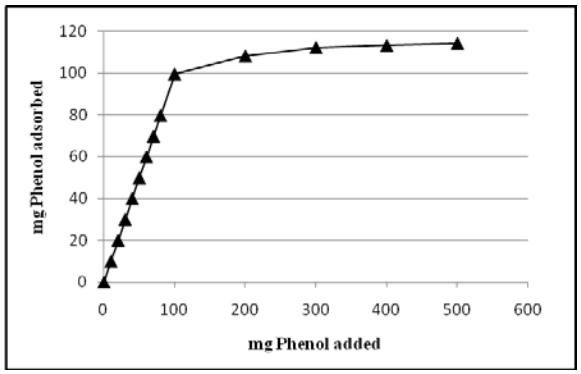


Fig. 2 − Variation of phenol adsorbed amount vs. phenol added amount working with a dose of 50 g/L PAC (1 g/20 mL of aqueous solution).

In solution containing between 10 mg and 100 mg phenol, the removals were between 99.875% and 99.318% with 50 g/L of PAC, but with

increasing of added phenol amount in solution, the phenol removal decreases; *e.g.*, for 200 mg phenol in 20 mL-solution the removal is of 51.0%, and only 22.80% for 500 mg phenol in 20 mL-solution.

It can be also observed that the phenol adsorption capacity onto PAC is of approx. 100 mg phenol/g of adsorbent (PAC), without any adjustment of pH, mineralization level, among others.

3.2. Control Test of Phenol Adsorption onto GAC from Synthetic Wastewater

A quite similar methodology of phenol adsorption control test was applied with GAC adsorbent, meaning that different volumes of phenol stock solution were treated with 1 g GAC in different test tubes, applying the 'batch' adsorption methodology (3 min of stirring, 1h-adsorption, followed by S/W separation by simple filtration onto cotton wool). After separation, the filtrate was analyzed concerning the residual phenol concentration for determination of total phenol removal.

Some of experimental results are presented in Table 3.

Table 3
Phenol Removal from Different Solutions onto GAC

No.	Phenol solution volume, [mL]	Absorbance (A_{480})	Residual phenol conc., [ug/mL]	Phenol removal, [%]
1	4	0.999	0.276	80.70
2	8	1.359	0.752	47.41
3	12	1.608	1.374	3.92
4	16	1.623	1.430	3.007

The results for phenol removal from synthetic wastewaters by adsorption onto GAC (50 g/L of adsorbent) indicate that the used adsorptive material has much reduced adsorption capacity related to phenol adsorption capacity onto PAC, especially for high phenol concentrations in treated synthetic wastewaters (> 100 mg phenol per 20 mL wastewater).

3.3. Control Test of Phenol Adsorption onto Mezotrophic Peat (MP) from Synthetic Wastewater

Different phenol containing solutions were treated with 1 g of mezotrophic peat (MP) in different test tubes, working in a similar mode as in 'batch' adsorption methodology onto GAC (3 min of stirring, 1h-adsorption, followed by S/W separation by simple filtration onto cotton wool). After separation, the filtrate was analyzed concerning the residual phenol concentration for determination of highest phenol removal.

Some of experimental results are presented in Table 4.

Table 4
Phenol Removal from Different Solutions onto Mezotrophic Peat (MP)

No.	Added phenol, [mg]	Phenol conc., [mg/L]	Absorbance (A_{480})	Adsorbed phenol, [mg]	Phenol removal, [%]
1	2	100	0.080	0.50	25.00
2	10	500	0.245	5.42	54.20
3	20	1000	0.438	11.81	59.05
4	30	1500	0.640	18.04	60.13
5	40	2000	0.847	24.17	60.42

The phenol removal by adsorption onto MP is relative reduced, varying around the value of 60% for synthetic wastewaters with 10-60 mg phenol. In comparison with PAC, the adsorption capacity of MP is reduced, but closed in some cases with that of GAC. Therefore, further the adsorption experiments were performed onto only PAC and MP.

3.4. Phenol and Color Removal from Real Wastewaters by Adsorption

Different volumes of real wastewater (rWW) were treated each one with 1 g of adsorbent (PAC and MP), completing each time the sample volume with distilled water until the final volume of 20 mL. A similar working methodology was applied in these studied 'batch' adsorption tests (3 min of stirring, 1h-adsorption, followed by S/W separation by 3,000 rpm-centrifugation for PAC, or simple filtration for MP). After separation, the color and residual phenol concentration in supernatant, or filtrate were determined and also removal efficiency appreciated.

The experimental results are summarized in Tables 5 and 6 for color removal, and Table 7 for phenol removal.

Table 5
Color Removal from Studied Real Wastewater (rWW) onto Coal-Based Adsorbent

No.	rWW, [mL]	Distilled water, [mL]	Initial $A_{456\ nm}$	Initial color, [UH]	Final $A_{456\ nm}$	Final color, [UH]	Color removal, [%]
• *Adsorption onto PAC*							
1	2	18	0.199	144.20	0.148	107.24	25.63
2	4	16	0.371	268.84	0.164	118.84	51.79
3	5	15	0.455	329.78	0.222	160.86	55.21
4	6	14	0.545	394.92	0.232	168.11	57.43
5	8	12	0.780	565.21	0.239	173.18	69.93
6	10	10	0.927	971.73	0.245	178.26	73.46
• *Adsorption onto MP*							
1	5	15	0.455	329.71	0.427	309.42	6.15
2	10	10	0.927	671.71	0.638	462.31	31.17
3	15	5	1.422	1030.43	0.766	555.07	46.13
4	20	0	1.929	1395.65	0.947	686.23	50.83

As shown in Table 5, the real wastewater discoloration by adsorption onto adsorbent (PAC, or MP) was higher as treated real wastewater volume was higher. Also, comparing the results of color removal obtained with PAC and MP, the best performance had PAC (73.46%, dilution 1:1) related to MP (31.17%, same dilution of 1:1). Because the adsorption results concerning the color removal were not good with MP, in future research works, some improvements will need to be found, one of those being the increasing of contact time between the adsorbent and treated wastewater.

Influence of adsorption time onto color removal by adsorption onto MP. The influence of contact time in color removal (no more than 1h, which represents the reported time for establishment of adsorption equilibrium with PAC adsorbent) (Zaharia and Suteu, 2013) was also tested, working with 1g of MP per each sample of 20 mL real wastewater.

The experimental results were presented in Table 6.

Table 6

Influence of Contact Time in Color Removal by Adsorption onto PM Applied for the Studied Real Wastewater

No.	Adsorption time, [min]	Initial $A_{456\ nm}$	Initial color, [UH]	Final $A_{456\ nm}$	Final color, [UH]	Color removal, [%]
1	5	1.926	1395.65	0.947	686.23	50.83
2	10	1.926	1395.65	0.932	675.36	51.60
3	15	1.926	1395.65	0.923	668.84	52.08
4	20	1.926	1395.65	0.913	661.59	52.60
5	30	1.926	1395.65	0.827	599.27	57.06
6	60	1.926	1395.65	0.817	592.02	57.58

The obtained results were indicated that increasing of contact time between the peat (MP) and real wastewater did not increase significantly the color removal after the first 5 min of adsorption, or wastewater discoloration degree, *i.e.* after an hour of contact between S/WW phases for adsorption development, the color removal increases with only 7%.

Phenol and color removal by adsorption onto tested adsorbents (PAC and MP), working with an adsorbent dose of 50 g/L, applied in the case of studied real wastewater containing a known added phenol amount (60 mg/20 mL of wastewater, *i.e.* 3,000 mg/L phenol) were high working with PAC, as shown in Table 7.

Table 7

Phenol and Color Removal from Real Wastewater by Adsorption onto PAC and MP

Adsorbent	Initial phenol amount, [mg]	Final phenol amount, [mg]	Phenol removal, [%]	Initial color, [UH]	Final color, [UH]	Color removal, [%]
PAC	60	0.235	99.61	1176.81	56.52	95.19
MP	60	46.7	22.71	1176.81	431.88	63.30

As mentioned in the scientific literature (Çeçen *et al*., 2003; Clark *et al*., 2000; Gupta *et al.*, 2009; Ionescu *et al*., 2013; Zaharia, 2015) adsorption onto PAC permits very good removals (even complete one) of some refractory organic compounds which represent pollutants in wastewaters, such as the case of phenol (*i.e.* 99.61% for real wastewater produced from wood fibrous plates manufacturing, in a wood furniture plant) and different toxic coloring species, globally expressed by wastewater color (*i.e.* 95.19% for the studied real wastewater).

In addition, MP can be used with good result as adsorptive material for removal of wastewater color, or discoloration purpose, but its performance in phenol removal still remains not corresponding.

4. Conclusions

1. Some preliminary laboratory experiments were performed for study the adsorption onto two types of coal-based adsorbents (activated charcoal and mezotrophic peat) applied for phenol and color removal from some synthetic and real wastewaters.

2. The experimental results were very good when powder activated charcoal (PAC) is used as adsorbent in both synthetic phenol solutions and real wastewaters containing phenols, *i.e.* removals higher than 95% for each studied wastewater. The PAC resistance in treatment process is not too good as powder, being difficult and relative high costly to separate from wastewaters after the adsorption process.

3. The granular activated coal (GAC) is used much easily, and can resist at different external pressure, or variation of wastewater flow and organics content in wastewater treatment process, having lower adsorption capacity than PAC and even MT, in some cases.

4. Some concrete values of phenol removals obtained after different experimental adsorption tests applied for synthetic and real wastewaters containing various phenol concentrations are recommending use of these types of adsorbent for solving some environmental-increasing pollution problems.

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ÎNDEPĂRTAREA FENOLULUI ŞI CULORII DIN APA UZATĂ FOLOSIND DOUĂ MATERIALE ADSORBANTE PE BAZĂ DE CĂRBUNE: TESTE PRELIMINARE DE LABORATOR ŞI PERFORMANȚE

(Rezumat)

Câteva rezultate preliminare la scară de laborator privind procesul de adsorbţie folosind diferite tipuri de cărbune, ca adsorbanţi cu carbon majoritar, adică cărbune activ pulbere (CAP) sau cărbune activ granular (CAG) şi turbă mezotrofă (TM), aplicate pentru îndepărtarea fenolului şi culorii din diferite ape uzate sintetice şi

reale conţinînd concentraţii mari de fenol sunt prezentate succint. Influenţa concentraţiei de fenol în procesele de adsorbţie aplicate pe ape uzate sintetice (*i.e.* soluţii apoase conţinând 10-3,000 mg/L fenol) şi ape uzate reale (*i.e.* ape uzate produse la fabricarea plăcilor fibroase din lemn, într-o fabrică de mobilă, care au adăugate concentraţii cunoscute de fenol de 3,000 mg/L) au fost studiate pentru obţinerea unei aprecieri de laborator privind cea mai bună performanţă în reţinerea fenolului şi decolorare. Cea mai mare eficienţă în îndepărtarea fenolului, lucrând cu o doză de 50 g/L CAP, a fost de 99,875% în cazul soluţiilor conţinând 100 mg/L fenol, 80,70% în cazul soluţiilor conţinând 278 mg/L fenol cu 50 g/L CAG şi 60,42% în cazul soluţiilor conţinând 2000 mg/L fenol cu 50 mg/L TM. Pentru apa uzată reală studiată conţinând adaos de 3,000 mg/L fenol, cea mai mare îndepărtare a fenolului a fost de 73,46% pentru culoare cu CAP şi 57,58% cu TM, după 60 min (50,83% după 10 min) şi de 95,19% fenol cu CAP şi 63,30% cu TM, după aceleaşi 60 min. Aceste date au fost utile în pregătirea experimentelor viitoare şi, de asemenea, în caracterizarea mecanismului de adsorbţie, optimizarea acestuia și următoarele aplicații industriale.