Utilization Of Activated Carbon Cloth For Cigarette Smoke Filtration

Firdevs Mert[a*], Numan Hoda[b], Ayhan Topuz[c] and İsmail Tontul[d]

[a] Akdeniz University, Department of Chemistry, 07058, Antalya, TURKEY
[b] Akdeniz University, Department of Material Science and Engineering
[c] Akdeniz University, Department of Food Engineering
[d]Necmettin Erbakan University, Department of Food Engineering
(Corresponding Author's E-mail: firdevsmertt@gmail.com)

ABSTRACT

Utilization of activated carbon cloth (ACC) as cigarette filter for the removal efficiencies of cigarette smoke constituents was studied. Cigarette smoke contains thousands of chemicals which are hazardous to human health. When the cigarette burns, thousands of chemical substances are generated, and these are emitted to gas phase. Some of these chemicals have already proven to be carcinogenic. In this work, the removal of the chemicals in cigarette smoke was studied in dynamic phase using a new product of activated carbon cloth (GDSEL 651) by proposing a new strategy. The reduction of chemicals in cigarette smoke using cigarette filters that are built manually having non-filter, mono-layer and double-layer of ACC filter was monitored by GC-MS. The flow rate of cigarette smoke was 2.48 LPM. It was found that in all filters that were used the concentration of chemicals in the smoke decreased, some of them decreased to zero. As a result, activated carbon cloth has proven to filter harmful substances effectively in cigarette smoke before entering the body during smoking. Such filter media has the ability to remove many chemicals in the air and has potential for many other air purification applications.

Keywords: Cigarette filter, Activated carbon cloth, Adsorption, Cigarette smoke.

INTRODUCTION

Activated carbons are black solid substances having an extreme porosity (space) enclosed by carbon atoms. Because of that, they are powerful adsorbents that are used in the removal of hazardous contaminants existing in gas or liquid phases. These powerful adsorbents, used also among history, are the most common adsorbents in industry. Especially, behind using for the removal of hazardous compounds in drinking or waste water, they are used also for the removal of contaminants in air to increase indoor air quality (Ayranci & Hoda, 2004b, 2005; Cal et. al., 1996; Hoda et. al., 2006). Generally, they are used in powder, granulate and fiber/cloth forms. Although their common usage is granulate form, the fiber/cloth form has great attention because of having several advantages over granulated activated carbon (GAC) such as even distribution of micropores, higher value of surface area, higher dynamic adsorption capacity and adsorption rate and smaller critical bed depth. Besides providing ease in applications because of its elasticity and lightness (Ayranci & Hoda, 2005), ACC has exhibited outstanding performance in adsorbing odors, solvents, bacteria, virus and all of the contaminants that exist in air, gas, water and other liquids as indicated in many literatures (Ayranci & Hoda, 2004a, 2004b; Gómez et. al., 2007; Hoda et. al., 2006; Lin et. al, 2013).

Cigarette smoking is a dangerous and common practice in the society. Cigarette smoke is an extremely complex mixture formed by more than 4000 chemicals and approximately 150 of which have been identified as toxic and carcinogenic for human (Fowles & Dybing, 2003; Gao et. al., 2009; Hoffmann et. al. 1997). Therefore, techniques to remove undesired hazardous contaminants of cigarette smoke without losing essential taste have been searched to develop. One of the methods for this purpose is to use appropriate adsorbents such as activated carbon in cigarette filters (Cashmore & Case, 2006; Dey et. al., 2010; Peters et. al., 2007; Rodgman & Green, 2014).Utilization of powdered or granulated activated carbon is performed by dispersing among cellulose acetate fibers or placing in a cavity in the center of the filter (Mola et. al., 2008).

As for all adsorbates, the pore size, distribution and volume of activated carbon are extremely important for adsorption of cigarette smoke contaminants. Branton et al. (2009) compared four different activated carbons with different pore sizes for their absorption efficiency for cigarette smoke. They concluded that increase in micro-pore volume leads to an increase in the removal efficiency of cigarette smoke by adsorption (Branton et. al., 2009). In Mola et al.'s work same conclusions were reported as higher activity carbons resulted in increased retention of smoke constituents(Mola et. al., 2008).Besides effects of adsorbent properties, McCormack and Taylor (2010) have pointed out the weight of carbon per tip is the dominant factor affecting the retention of vapor phase compound rather than the distribution of carbon within the filter tip (Mccormack et. al., 2010).

In this work, the removal of harmful chemicals in cigarette smoke was studied in dynamic phase using a product of activated carbon cloth (GDSEL 651) by proposing a new strategy. The reduction of chemicals in cigarette smoke using cigarette filters that are built manually having single layer and double layers of activated carbon cloth is monitored by GC-MS.

MATERIAL AND METHODS

Material

ACC used in the present work was provided by Nume Kimya Ltd. Şti, Turkey, coded as GDSEL 651. It is produced from cellulose based fabric throughout carbonization and activation. The properties of ACC were given Table 1 which are derived from Hoda et al.'s work (2017) (Hoda et. al., n.d.). Also, the cigarettes used for produced smoke were an American brand and the physical properties were given in Table 2. The chemicals in cigarette smoke were detected by gas chromatography (Shimadzu QP2010-Plus).

Table 1. Physical properties of the ACC

BET surface area (m^2/g)	**Micropore area ($m^2.g^{-1}$)**	**Surface functional groups (meq/g)**				
		Total acidic groups	Total basic groups	Carboxylic groups	Lactonic groups	Phenolic groups
500,0	498,0	3,8	4,1	2,0	0,4	1,4

Table 2. Physical properties of the commercial cigarette used

Cigarette brand	Weight of tobacco per cigarette (mg/cigarette)	Filter length (mm)	Filter diameter (mm)	Cigarette length (mm)
Americanbrand	620	24	8	83

Preparation of cigarette samples

A schematic diagram of the housing for cigarette and ACC filters is shown in Fig. 1. Different layered ACC filter (mono, double) was used in smoking tests. ACC filters were cut to fit inner diameter of the housing and placed into it.

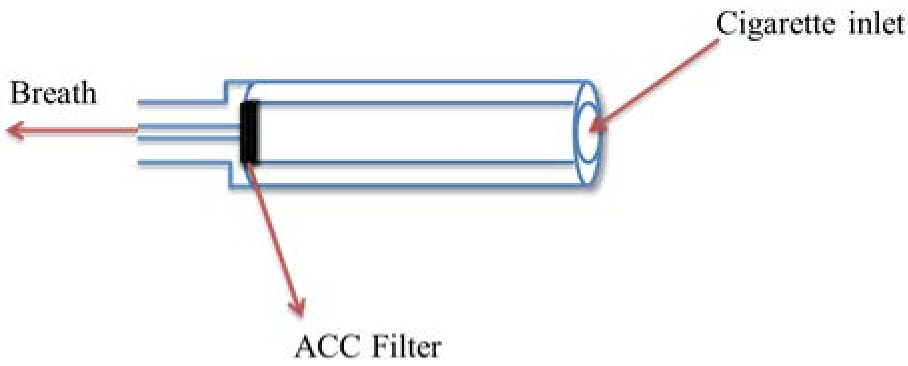

Fig.1. Schematic diagram of the housing for cigarette and filters

Smoking test

Smoking test system is given in Fig. 2. The system includes vacuum pump, flow rate meter, adapter and housing for cigarette. ACC filters were placed in a housing adapter in just front of cigarette as seen in Fig.2. The housing was connected to flow meter and vacuum pump respectively. The system was checked for any leakage. After burning the cigarette, vacuum pump run with adjusted rate of 2.48 LPM using flow meter. While the system was running, 2.5 mL of cigarette smoke was taken using a gas tight syringe from flow between flow meter and cigarette and it was injected into the inlet port of a gas chromatograph. For all experiments the cigarette smoke was intaken from flow just 1 min later running the pump. The detection of the cigarette smoke compounds was achieved by a GC–MS system (Shimadzu QP2010 Plus) equipped with a TRB-5MS (30 m × 0.25 mm × 0.25 µm) column. Elution of the cigarette smoke was performed under the following conditions: column temperature was programmed from 50 °C (held 0.5 min) to 280 °C at the rate of 5 °C/min and held for 0.5 min. The temperature of injection port and transfer line was 200 °C. Helium (%99.99) was used as carrier gas with a constant flow rate of 1.3 mL/min, and split ratio was 20. Also, MS conditions for both analyses were EI 70 eV, mass range 30–550 amu and scan rate 1111 s/scan. The experiments were repeated three times for all ACC filters with different layers and averaged.

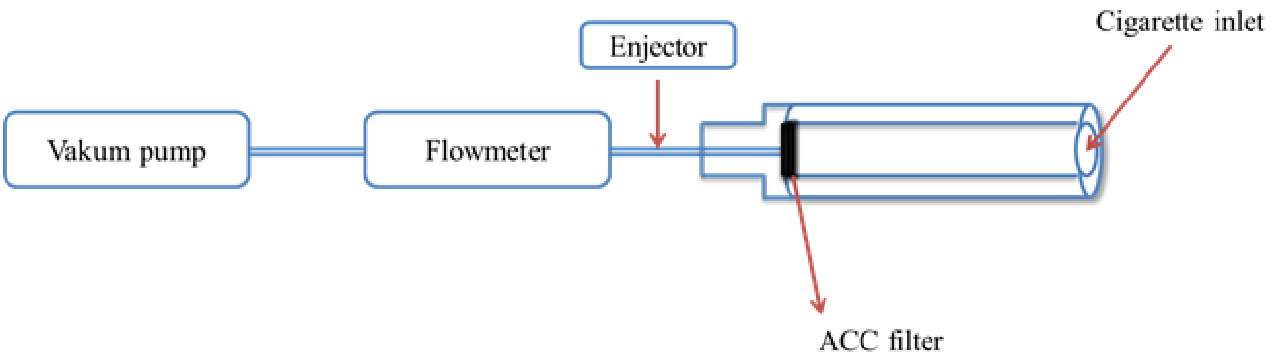

Fig.2. Schematic diagram of experimental apparatus

Table 3. Percent reductions of chemicals in cigarette smoke

Chemicals dedected	Percent reduction (%)	
	Mono layered ACC filter	**Double layered ACC filter**
Ethylidenecyclopropane	82	95
2-Butanone	75	74
1-hydroxy- 2-Propanone	76	68
3,3-Dimethyl-2-pentanone	51	76
N-Vinylpyridinium bromide	31	81
Pyrrole	63	91
1,3,5-Cycloheptatriene	12	86
Methylpyrazine	65	91
Phenol	36	100
N-Cyano-3-methylbut-2-enamine	61	100

2,2,3,4-Tetramethylpentane	45	100
3-Methyl-1,2-cyclopentanedione	100	100
Trans-1,2-bis(1-methylethenyl)cyclobutane	60	93
2,3-Dimethyl-2-cyclopenten-1-one	34	100
3-Methylphenol	53	100
2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one	49	100
2-Hydroxy- γ -butyrolactone	85	100
5-Hydroxymethyl- 2-furancarboxaldehyde	52	100
Hydroquinone	87	100
Nicotine	61	95
1-Methyl-4-(2-methyloxiranyl)-7-oxabicyclo(4.1.0)heptane	78	100
Vitamin E	100	100

RESULTS AND DISCUSSION

In this work, the removal of chemicals in cigarette smoke was studied in dynamic phase using ACC by proposing a new strategy. According to the results obtained by gas chromatography, the chemicals analyzed in the cigarettes smoke and the percentage of reduction with ACC filters are given in Table 3. Firstly, the system was run without using any ACC filter and cigarette smoke was analyzed for its detectable components. Only 20 chemicals could be detected by the condition used in GC-MS instrument.

The retention of each compound as percentage was calculated using unfiltered cigarette smoke as standard (control) by using equation (1);

$$\% \text{ Retention} = \frac{(\text{Control Cigarette GC Peak Area} - \text{Test Cigarette GC Peak Area})}{\text{Control Cigarette GC Peak Area}} \times 100 \quad (1)$$

When the results are examined, vitamin E and 3-methyl-1,2-cyclopentanedione were completely removed with just monolayered ACC filter. With doubled ACC layers, the retention of 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, phenol, 2,3-dimethyl-2-cyclopenten-1-one, 2-hydroxy-γ-butyrolactone, 5-hydroxymethyl- 2-furancarboxaldehyde, N-cyano-3-methylbut-2-enamine, 2,2,3,4-tetramethylpentane, 3-methylphenol and 1-methyl-4-(2-methyloxiranyl)-7-oxabicyclo (4.1.0) heptane have increased 100%.

Nicotine is one of the main components in the cigarette smoke which causes of addiction. Therefore, nicotine is a good model constituent for the retention of chemicals from cigarette smoke. In this work, the retention of nicotine by adsorption on ACC filters is shown in Fig. 3. The nicotine retention capacity increased as the number of ACC layers increased as expected. The double-layered-ACC filter reduced the nicotine by 95% in cigarette smoke.

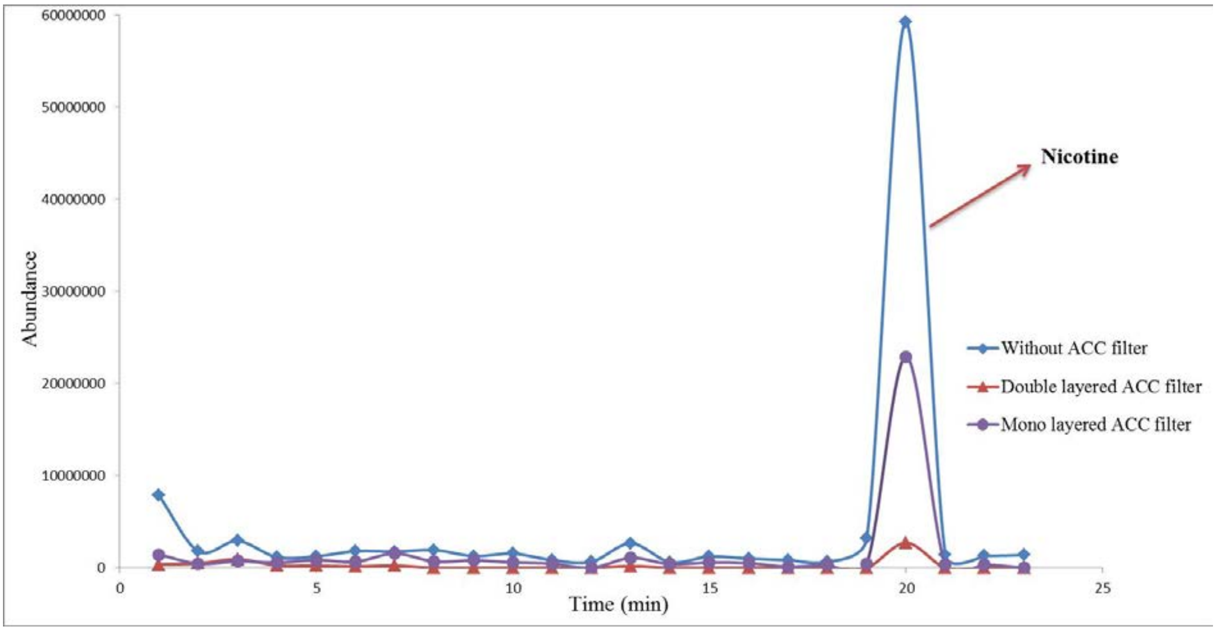

Fig.3. The results of nicotine in cigarette smoke by using GC-MS

CONCLUSIONS

The adsorption efficiency of ACC on the cigarette smoke in kinetic phase is examined for the possibility of cigarette filter using a new measurement technique proposed in this work. The results have showed that ACC can reduce or consume the chemicals existed in cigarette smoke if it is used as cigarette filter. When ACC used in cigarette filter, it can protect the health of non-smokers from hazards of chemicals in cigarette smoke as well as smokers' health. As well as using ACC as cigarette filter, it can be adopted to smoke filter for using industrial and household filtration to keep the environment more clean, healthy and comfortable.

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