Journal of Scientific Research & Reports
12(3): 1-6, 2016; Article no.JSRR.28737
ISSN: 2320-0227

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Influence of Draw Resistance on Benz [a] Pyrene and Its Contribution to Cigarette Hazard Index

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2016/28737
Editor(s):
(1) Luigi Rodino, Professor of Mathematical Analysis, Dipartimento di Matematica, Università di Torino, Italy.
Reviewers:
(1) Rakesh Kumar Choure, Svits, Indore, MP, India.
(2) Chong Leong, Gan, Universiti Malaysia Perlis, Malaysia.
Complete Peer review History: http://www.sciencedomain.org/review-history/16729

Original Research Article

Received 2nd August 2016
Accepted 12th October 2016
Published 28th October 2016

ABSTRACT

Influence of cigarette draw resistance between 860-1130Pa on Benz [a] Pyrene in mainstream cigarette smoke was carried out, and contribution to cigarette hazard index was also studied. The experimental results showed that the contribution degree of is uniform, which is different from

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variation of HCN, CO, crotonaldehyde and NNK. 1000Pa is the critical draw resistance, below and above 1000Pa an obvious variation of Benz [a] Pyrene appears. Contribution to cigarette hazard index was also analyzed, which proves that it is feasible and convincing to study variation of Benz [a] Pyrene and other smoke harmful components.

Keywords: Benz [a] pyrene; draw resistance; mainstream cigarette smoke; harmful components; cigarette hazard index.

1. INTRODUCTION

In 1998, a modified Hoffmann list was widely recognized by the medical profession and the tobacco industry, causing a great impact in the world. Most countries concentrate more stringent restrictions on the release of Hoffmann in cigarette products, and consumers are increasingly concerned about the Hoffmann components. Now filtering function of the filter is mostly based on tar and nicotine, and there is little study on filtering efficiency on harmful ingredients such as tar and nicotine. At present, product design philosophy targeting on release amount of Hoffmann components (CO, NNK, NH_3, HCN, B[a]P, croton aldehyde and phenol) has been widely accepted. Hoffmann components (CO, NNK, AMMONIA, HCN, Benz [a] Pyrene, croton aldehyde and phenol) were applied by China's tobacco industry as a significant standard of the target products [1]. Chemical formula is C20H12, which is a ring of polycyclic aromatic hydrocarbons. Crystal is yellow solid. This substance is produced in an incomplete combustion state between 300 and 600℃. Benz [a] Pyrene existed in coal tar and coal tar can be found in the smoke produced by the burning of the motor vehicle exhaust (especially diesel engine), tobacco and wood, and grilled food.

Xie Jianping provided a characterization method of harmful ingredients including CO, NNK, ammonia, HCN, Benz [a] Pyrene, croton aldehyde and phenol. This method is widely applied in the design and evaluation of cigarettes [2]. Wei Yuling [3], Christophe L M [4], Zheng Qin [5], Liu Jianfu [6], Zhai Yujun [7] et al. investigated the effect of cigarette paper, tipping paper and other materials on the release of cigarette smoke components, Liu Xianjun [8], Li Qianjin [9], Yu Hongxiao [10,11], Du Yongmei [12] and Fu Qiujuan [13] carried out research on the harmful components and its release of mainstream smoke. Some scholars studied the effect of the design parameters of cigarette auxiliary materials such as the filter tip on harmful components of cigarette smoke [14-18], and some researchers focused on the effects of different pumping conditions on harmful gas emissions [19-24]. Draw resistance could influence the sensory quality of cigarettes, and Wu Zhiying [25], Sun Dongliang et al. [26] studied on the relationship between the physical indicators and draw resistance. However, the influence of the draw resistance on the harmful components of cigarette smoke, including Benz [a] Pyrene, has not been systematically reported.

2. EXPERIMENTAL

2.1 Test Materials and Instruments

Cigarette samples were provided by China Tobacco Yunnan Industrial Co., Ltd. The materials applied are all standard products (purity > 99%).

2.2 Collection, Treatment and Harmful Components Analysis of Flue Gas

According to national standard of China GB/T 23356-2009, GB/T21130-2007, YC/T253-2008, GB / T23228-2008, YC / T377-2010, YC / T255-2008, YC / T254-2008, harmful components of Benz [a] Pyrene, CO, HCN, NNK, ammonia, phenol and crotonaldehyde in the cigarette smoke were tested [27-33].

2.3 Instruments

Cigarette ignition device, a cigarette by mouth suction collection system; RM20H smoking machine (Borgwaldt KC company, Germany); Research N1 infrared thermal imaging instrument (Alpha company, USA); Agilent 1200 HPLC, Agilent 7890A gas chromatograph, Agilent7890-5975 gas chromatography mass spectrometry combined with analyzer (Agilent); IC3000 ion chromatograph (Dionex Corporation, USA); AA3 continuous flow analyzer (Bran Luebbe company, Germany); Gas Trace2000 phase chromatography -TEA610 type thermal energy analyzer (Thermo Finigan company, USA).

3. RESULTS AND DISCUSSION

3.1 Critical Draw Resistance and Its Influnces on Benz [a] Pyrene

Benz [a] Pyrene varies obviously with the variation of draw resistance. Draw resistance between 860-1130Pa was selected to analyze variation of Benz [a] Pyrene shown in Fig. 1. When the draw resistance is no more than 1000Pa, Benz [a] Pyrene fluctuates between 8.5-10.5 ng/cig, as the draw resistance continues to rise to above 1000Pa, variation of Benz [a] Pyrene is stable and the variation is between the range of 9.2-11.1 ng/cig.

1000 Pa can be viewed as the critical draw resistance of Benz [a] Pyrene. There is an obvious variation of Benz [a] Pyrene at the critical draw resistance. The critical draw resistance is significant to Benz [a] Pyrene, and in the cigarette design process, including punching location and filter selection, consideration on the influence of critical draw resistance is necessary. To further analyze influence of draw resistance variation, the concept of H value contribution of harmful smoke components was proposed [34].

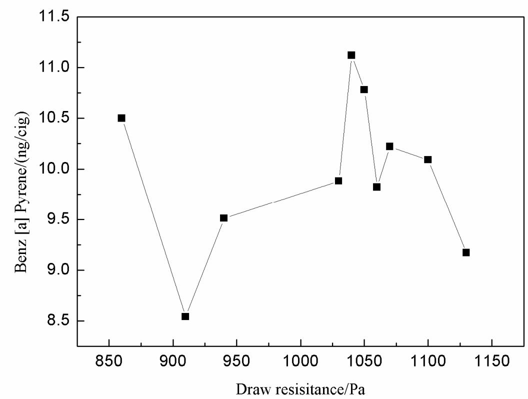

Fig. 1. Variation of Benz [a] Pyrene with different draw resistance

3.2 Calculation of H Value Contribution Degree

Xie Jianping put forward to calculate H value index [2].

$$H = \left(\frac{X_{CO}}{C_{CO}} + \frac{X_{HCN}}{C_{HCN}} + \frac{X_{NNK}}{C_{NNK}} + \frac{X_{\text{ammonia}}}{C_{\text{ammonia}}} + \frac{X_{\text{Benz [a] Pyrene}}}{C_{\text{Benz [a] Pyrene}}} + \frac{X_{\text{crotonaldehyde}}}{C_{\text{crotonaldehyde}}} + \frac{X_{\text{phenol}}}{C_{\text{phenol}}} \right) \times \frac{10}{7} \quad (1)$$

Where H is the hazard value index, X_{CO}, X_{HCN}, X_{NNK}, X_{NH_3}, $X_{\text{Benz [a] Pyrene}}$, $X_{\text{crotonaldehyde}}$ and X_{phenol} are the harmful components emission quality respectively, C_{CO}, C_{HCN}, C_{NNK}, C_{ammonia}, $C_{\text{Benz [a] Pyrene}}$, $C_{\text{crotonaldehyde}}$ and C_{phenol} are responding the calculation reference value from the national standard，and C_{CO} = 14.8, C_{HCN} =126.7, C_{NNK} = 4.7， C_{ammonia} = 7.8, $C_{\text{Benz [a] Pyrene}}$ = 8.2, $C_{\text{crotonaldehyde}}$ = 22.1, C_{phenol} = 19.4 respectively.

Authors proposed H value contribution degree, which is defined as follows [34],

$$\gamma_i = \frac{X_i}{H \cdot C_i} \times \frac{10}{7} \times 100\% \quad (2)$$

where γ_i is the H value contribution degree of harmful component type *i*.

$$\gamma_{\text{Benz [a] Pyrene}} = \frac{X_{\text{Benz [a] Pyrene}}}{H \cdot C_{\text{Benz [a] Pyrene}}} \times \frac{10}{7} \times 100\% \quad (3)$$

where $\gamma_{\text{Benz [a] Pyrene}}$ is the H value contribution degree of Benz [a] Pyrene.

$\gamma_{\text{Benz [a] Pyrene}}$ is influenced by 7 harmful smoke components, the greater the value, the greater influence of the harmful smoke on H value index is. Comparison of 7 types of smoke harmful components' contribution degree is shown in Fig. 2 [34].

H value contribution degree fluctuations of three harmful components of Benz [a] Pyrene, ammonia and phenol is basically similar. When the draw resistance is less than 1000Pa there is an obvious fluctuation of three kinds of harmful smoke components. When the draw resistance is higher than 1000Pa, H value contribution degree of Benz [a] Pyrene maintained at 13.3% - 16.7%. It can also be found that H value contribution degrees of Benz [a] Pyrene, ammonia and phenol are consistent, which is significantly lower than that of the NNK.

3.3 Linear Relationship among H Value Contributions of Benz [a] Pyrene, Ammonia and Phenol

Linear relation and fitting degree of Benz [a] Pyrene, ammonia and phenol were verified by Origin 8.0 software, which can be seen in Fig. 3.

There is a linear relationship among H value contribution degree of Benz [a] Pyrene, ammonia and phenol. Most of the data still satisfy linear distribution and fitting degree is greater than 0.65, which proves that linear relationship among Benz [a] Pyrene, ammonia and phenol H value contribution exists, as discussed in Section 3.2. The linearity between H value contribution degrees of these three types of harmful components and contribution degree of another group of HCN, CO, NNK and crotonaldehyde were also analyzed, and the analysis showed that the method of classifying Benz [a] Pyrene, ammonia and phenol according to the variation of H value contribution degree from

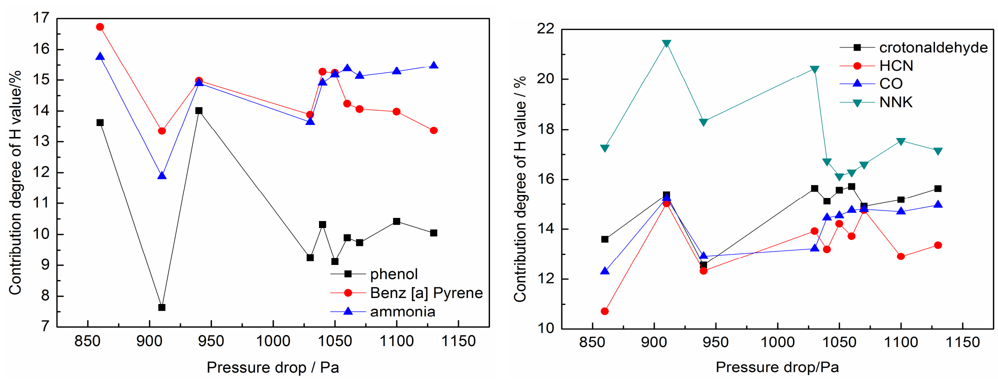

Fig. 2. Variation of H value contribution of 7 types of harmful flue gas components under different pressure drops [34]

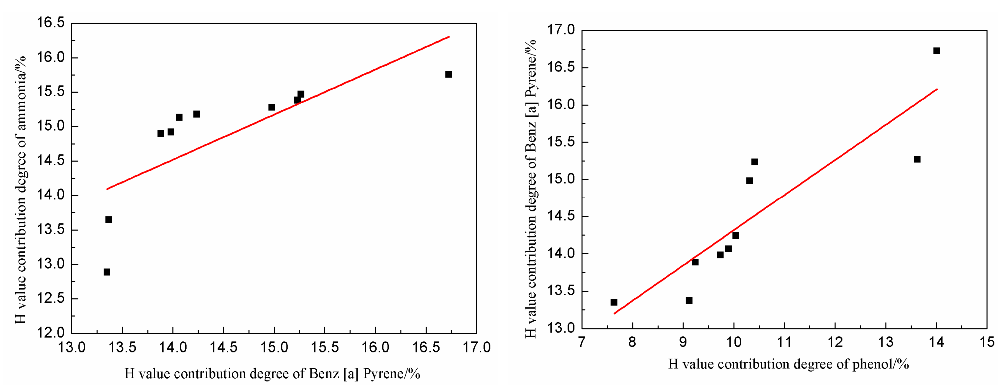

Fig. 3. Relationship among H value contributions of Benz [a] Pyrene, ammonia and phenol

another group is sound, and H value contribution is feasible when applied as a tool to analyze different harmful smoke components.

4. CONCLUSIONS

1. The concept of H value contribution degree reflects the contribution of the main harmful smoke components to H value, which is also an effective tool to measure and calculate the variation of Benz [a] Pyrene. Influnces of draw resistance on Benz [a] Pyrene and its contribution degree of cigarette hazard index are quite significant and efficient methods during the analysis process, which is useful for further analysis on relevant study on Benz [a] Pyrene.
2. 1000Pa is the critical draw resistance of Benz [a] Pyrene. When the draw resistance is less than the critical draw resistance1000Pa, fluctuation of Benz [a] Pyrene and its H value is greater, while the draw resistance is more than the critical draw resistance, the fluctuation tends to be less.
3. There is a linear relationship among H value contribution of Benz [a] Pyrene, ammonia and phenol is consistent, and. Analysis on H value contribution of the harmful smoke is feasible to investigate smoke variation.

ACKNOWLEDGEMENTS

The financial support of National Natural Science Foundation of China (Grant No.51404159), Science and Technology Project of Hebei Province (Grant No. 152177180) and Science and Technology Project of Qinhuangdao City (Grant No. 201502A037) are greatly acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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